Sex-Specific Predictors of Intra-articular Injuries Observed During Anterior Cruciate Ligament Reconstruction

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Background: Male patients tend to have more meniscal and chondral injuries at the time of anterior cruciate ligament (ACL) reconstruction than females. No studies have examined sex-specific predictors of meniscal and chondral lesions in ACL-injured patients.

Purpose: To identify sex-specific predictors of meniscal and chondral lesions, as well as meniscal tear management, in patients undergoing ACL reconstruction.

Study Design: Cohort study; Level of evidence, 3.

Methods: Data were collected prospectively from 689 patients (56.2% males) undergoing ACL reconstruction between 2005 and 2014. Predictors of meniscal tears, meniscal tear management, and chondral injuries were determined using multivariate logistic regression models stratified by sex. Predictors were age, body mass index (BMI; 25-29.99 and ≥30 vs ≤24.99 kg/m^2), mechanism (contact vs noncontact) and type (high-impact sports [basketball, football, soccer, and skiing] and other sports vs not sports-related) of injury, interval from injury to surgery (≤6 vs >6 weeks), and instability episodes (vs none). Odds ratios and 95% CIs were reported.

Results: Males had more lateral (46% vs 27.8%; $P < .0001$) and medial (40.2% vs 31.5%; $P = .01$) meniscal tears, as well as more lateral (72.1% vs 27.9%; $P < .0001$) and medial (61.4% vs 38.6%; $P = .01$) meniscectomies than females. For males, age predicted chondral injuries and medial meniscectomy; BMI ≥30 kg/m^2 predicted medial meniscal tears; high-impact and other sports predicted medial meniscal tears, medial meniscectomies, and medial meniscal repairs; injuries ≤6 weeks from surgery predicted lateral meniscal repairs; and instability episodes predicted medial meniscal tears, medial tears left in situ, medial meniscectomies, and medial meniscal repairs. For females, age predicted chondral injuries, BMI ≥30 kg/m^2 predicted lateral meniscectomies and repairs, and instability episodes predicted medial meniscectomies.

Conclusion: Sex differences were observed. For males, predictors included age, BMI, sports-related injuries, injuries ≤6 weeks from surgery, and instability episodes. For females, predictors included age, BMI, and instability episodes.

Keywords: sex; knee; ligament; ACL; meniscus; chondral

Meniscal tears (37%-45%) and chondral lesions (16%-46%) are prevalent among patients undergoing anterior cruciate ligament (ACL) reconstruction,[2,4,21,28] and comorbidity injury rates differ by sex.[11,23,26,27,29] The prevalence of meniscal tears has been shown to be higher among males than females.[23,27,29] Also, males tend to have more cartilage thinning in the posteromedial area of the femur 2 years after an acute ACL injury compared with females.[11] A large prospective study[26] of 15,783 patients found that males had 22% greater odds of full-thickness cartilage lesions at the time of ACL reconstruction compared with females ($P = .012$). Males tend to have greater body mass and participate in more high-level and contact sports than do females, which might contribute to greater force at the time of injury and subsequently more injuries in males.[3,22,26,31]

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There have not been any studies that have examined sex-specific predictors of intra-articular injuries in patients undergoing ACL reconstruction. This knowledge could be valuable in guiding treatment decisions for male and female patients. An ACL injury, coupled with an intra-articular injury/injuries, has been shown to be associated with negative clinical outcomes and later development of osteoarthritis.[6,24] Cox et al[6] found that chondral and meniscal lesions, as well as meniscal repairs, were associated with worse knee function and reduced activity levels 6 years after ACL reconstruction. Additionally, a systematic review of 31 studies found that the prevalence of knee osteoarthritis at least 10 years after ACL reconstruction was greater for patients with comorbid meniscal injuries (21%-48%) compared with those with isolated ACL injuries (0%-13%).[24] In this same review, the most common risk factors for developing knee osteoarthritis were meniscal injury and meniscectomy, and less commonly, chondral lesions.

The aims of this study were to examine sex-specific predictors of (1) intra-articular injuries and (2) meniscal tear management (ie, meniscus tear left in situ, meniscectomy performed, and meniscal repair performed) in patients undergoing ACL reconstruction. We hypothesized that predictors of intra-articular injuries and meniscal tear management would differ by sex.

MATERIALS AND METHODS

Sample Selection

Data were obtained from a prospective database of ACL reconstructions done at a single institution by 4 fellowship-trained orthopaedic surgeons. This study was approved by our institution's review board. A total of 869 consecutive ACL reconstructions were performed between January 2005 and April 2014. Nineteen patients had bilateral ACL tears during the study period, and 1 knee was randomly selected for study inclusion. There were 161 patients excluded because of previous knee surgery on the affected knee and grade 2 or 3 tears of the medial/lateral collateral ligaments or posterior cruciate ligament. After exclusions, 689 patients were included in the data analysis.

Data Collection

The surgeons used standard data forms to document risk factor data preoperatively and surgical findings immediately after surgery. Sex, date of injury, age at injury, body mass index (BMI), injured side, history of surgery, mechanism and type of injury, and number of instability episodes (subsequent to the initial injury) were documented preoperatively. In 2012, we began to collect more detailed information about instability episodes including whether a tear was felt during the episode, if new swelling developed after the episode and whether the episode occurred during sport or exercise. BMI was categorized as normal ($\leq$24.99 kg/m^2), overweight (25-29.99 kg/m^2), and obese ($\geq$30 kg/m^2).[32] Type of injury was categorized as high-impact sports–related (basketball, football, soccer, and skiing), other sports-related, and not sports-related or of unknown origin. Based on previous research, the interval from injury to surgery was categorized as $\leq$6 weeks and >6 weeks.[10,16] After surgery, the presence and location of meniscal and chondral injuries observed during arthroscopy were documented. The management of meniscal tears was also documented and categorized as left in situ, meniscectomy performed, and meniscal repair performed. Tears left in situ included stable longitudinal tears of the lateral meniscus posterior to the popliteal hiatus, as well as small (<1 cm), incomplete, and stable tears of the medial meniscus. Meniscal repairs were performed on technically repairable tears in the vascular zones (ie, red-red, red-white). All other tears were treated with partial resection.

Statistical Analysis

Descriptive statistics were calculated for sample characteristics and arthroscopic findings. Predictive models were built for the primary analysis and were stratified by sex. The outcome variables included lateral and medial meniscal tears (present or absent [referent]), chondral injuries (present or absent [referent]), and management of lateral and medial meniscal tears (tear absent [referent], left in situ, meniscectomized, and repaired). Predictor variables included age at injury (years), BMI (normal [referent], overweight, and obese), mechanism of injury (noncontact [referent] and contact), type of injury (high-impact sports–related, other sports-related, and not sports-related or of unknown origin [referent group]), time from ACL injury to surgery ($\leq$6 vs >6 weeks [referent group]), and number of instability episodes before surgery (0 episodes as the referent group). Multivariate logistic regression was used to examine predictors of binary outcomes (ie, meniscal tears and chondral injuries), and multivariate polytomous logistic regression was used to examine predictors of outcomes with more than 2 categories (ie, meniscal tear management). Regression models were run separately for males and females. Odds ratios (ORs) and 95% CIs are reported for each predictor and were adjusted for all other predictors in the model. Patients were dropped from the analysis if any of their predictor data were missing. Missing data are illustrated in Table 1. Statistical significance was considered $P < .05$, or if the null value (1.00) was absent from the CI. Statistical analyses were performed using SAS 9.3 (SAS Institute Inc).

RESULTS

Tables 1 and 2 illustrate sample characteristics and arthroscopic findings stratified by sex. Males were slightly older ($P = .01$), more likely to be overweight and obese ($P < .0001$), and more likely to be injured during a high-impact sport compared with females ($P < .0001$). Males had more lateral (46% vs 27.8%; $P < .0001$) and medial meniscal (40.2% vs 31.5%; $P = .01$) tears than did females. The frequency of chondral injuries did not significantly differ between males and females (12.5% vs

TABLE 1
Sample Characteristics Stratified by Sex (N = 689)[a]

	Males (n = 387)	Females (n = 302)	P Value
Age, y, mean ± SD	27.2 ± 11.3	26.1 ± 12.3	.01
Body mass index,[b] kg/m^2			<.0001
≤24.99	133 (37.4)	206 (71.0)	
25-29.99	157 (44.1)	59 (20.3)	
≥30	66 (18.5)	25 (8.6)	
Injured side[b]			.58
Right	196 (52)	150 (49.8)	
Left	181 (48)	151 (50.2)	
Mechanism of injury			.16
Contact	84 (21.7)	49 (16.2)	
Noncontact	268 (69.3)	228 (75.5)	
Unknown	35 (9.0)	25 (8.3)	
Type of injury[b]			<.0001
High-impact sports–related	208 (55.0)	112 (38.1)	
Other sports-related	122 (32.3)	145 (49.3)	
Not sports-related or unknown	48 (12.7)	37 (12.6)	
Weeks from injury to surgery,[b]			.18
≤6	258 (72.7)	189 (67.7)	
>6	97 (27.3)	90 (32.3)	
Instability episodes before surgery[b]			.64
0	138 (37.3)	109 (37.3)	
1	51 (13.8)	31 (10.6)	
2	39 (10.5)	25 (8.6)	
3	26 (7.0)	29 (9.9)	
4	11 (3.0)	14 (4.8)	
5	30 (8.1)	19 (6.5)	
6	7 (1.9)	5 (1.7)	
7	0 (0)	1 (0.3)	
8	2 (0.5)	3 (1.0)	
9	0 (0)	0 (0)	
10	6 (1.6)	5 (1.7)	
>10	60 (16.2)	50 (17.1)	
Felt tearing during episode[c]			.73
Yes	7 (13.7)	3 (9.1)	
No	44 (86.3)	30 (90.9)	
New swelling following the episode[c]			.92
Yes	16 (31.4)	10 (30.3)	
No	35 (68.6)	23 (69.7)	
Episode occurred during a sport or exercise[c]			.17
Yes	18 (35.3)	7 (21.2)	
No	33 (64.7)	26 (78.8)	

[a]Values are expressed as n (%) unless otherwise indicated.
[b]The total N does not add up to 689 because of missing data. For any single variable, <10% of data were missing.
[c]This question was added to the data collection form in 2012, and data were only available for patients who had surgery between 2012 and 2014.

10.6%; $P = .41$). The most common type of lateral and medial meniscal management was meniscectomy among males and females (Figures 1 and 2). When a meniscus tear was present, males also had more lateral (72.1% vs 27.9%; $P < .0001$) and medial (61.4% vs 38.6%; $P = .01$) meniscectomies than females.

TABLE 2
Arthroscopic Findings Stratified by Sex[a]

	Males (n = 391)	Females (n = 302)	P Value
Lateral meniscal tears, n	180	84	<.0001
Anterior horn	2 (1.11)	6 (7.1)	.15
Middle third	57 (31.7)	24 (28.6)	.01
Posterior horn	141 (78.3)	64 (76.2)	<.0001
Medial meniscal tears, n	157	95	.01
Anterior horn	7 (4.5)	5 (5.3)	.87
Middle third	61 (38.9)	48 (50.5)	.99
Posterior horn	149 (94.9)	85 (89.5)	.004
Chondral injuries, n	49	32	.41
Femur	31 (63.3)	23 (71.9)	.98
Patella	14 (28.6)	9 (28.1)	.63
Tibia	6 (12.2)	3 (9.4)	.30

[a]Values are given as n (%) unless otherwise indicated.

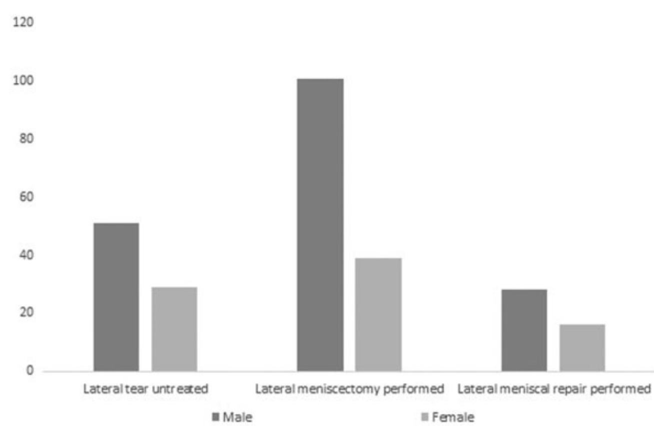

Figure 1. Management of lateral meniscal tears in males and females who underwent anterior cruciate ligament reconstruction ($P < .0001$).

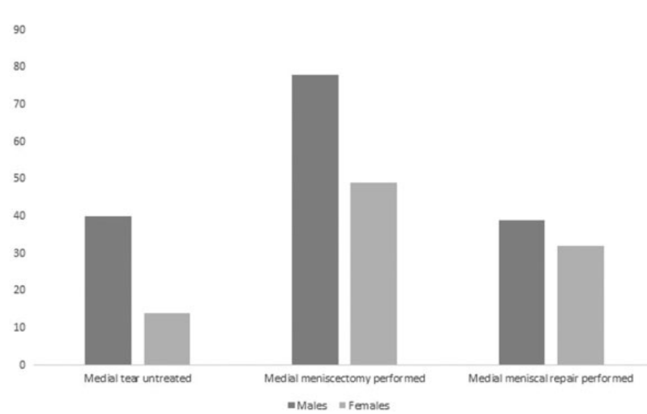

Figure 2. Management of medial meniscal tears in males and females who underwent anterior cruciate ligament reconstruction ($P = .01$).

Predictors of Intra-articular Injuries in Males

Logistic regression results for meniscal and chondral injuries, as well as meniscal management, in male patients are presented in Appendix Tables A1 to A3 and are summarized here.

Age at Injury. Increasing age predicted more chondral injuries (OR, 1.05; 95% CI, 1.02-1.09) and more medial meniscectomies (OR, 1.04; 95% CI, 1.01-1.08).

Body Mass Index. Obesity predicted fewer medial meniscal tears versus normal BMI (OR, 0.43; 95% CI, 0.19-0.98); however, BMI was not significantly associated with medial meniscal management.

Mechanism of Injury. Mechanism of injury (contact vs noncontact) was not a significant predictor of intra-articular injuries.

Type of Injury. Sports-related injuries predicted fewer medial meniscal tears (high-impact sports: OR, 0.26; 95% CI, 0.10-0.67; other sports: OR, 0.27; 95% CI, 0.11-0.70), medial meniscectomies (high-impact sports: OR, 0.23; 95% CI, 0.08-0.67; other sports: OR, 0.32; 95% CI, 0.11-0.92), and medial meniscal repairs (high-impact sports: OR, 0.19; 95% CI, 0.05-0.77; other sports: OR, 0.09; 95% CI, 0.02-0.44).

Interval From ACL Injury to Surgery. Anterior cruciate ligament injuries that occurred 6 weeks or less before surgery predicted more lateral meniscal repairs than ACL injuries that occurred more than 6 weeks before surgery (OR, 3.10; 95% CI, 1.09-8.77).

Number of Instability Episodes. Increased number of instability episodes predicted more medial meniscal tears (OR, 4.47; 95% CI, 1.75-11.40), meniscal tears left in situ (OR, 4.71; 95% CI, 1.35-16.39), meniscectomies (OR, 4.90; 95% CI, 1.05-22.93), and meniscal repairs (OR, 6.10; 95% CI, 1.57-23.66) versus no instability episodes.

Predictors of Intra-articular Injuries in Females

Logistic regression results for meniscal and chondral injuries, as well as meniscal management, in female patients are presented in Appendix Tables A4 to A6 and summarized here.

Age at Injury. Increasing age predicted chondral injuries (OR, 1.09; 95% CI, 1.05-1.14).

Body Mass Index. Obesity predicted lateral meniscectomies (OR, 4.26; 95% CI, 1.01-18.04) and lateral meniscal repairs (OR, 13.43; 95% CI, 1.04-174.14).

Mechanism of Injury. Mechanism of injury (contact vs noncontact) did not significantly predict intra-articular injuries.

Type of Injury. Type of injury (sports-related vs not sports-related or of unknown origin) did not significantly predict intra-articular injuries.

Interval From ACL Injury to Surgery. The interval from ACL injury to surgery ($\leq$6 vs >6 weeks) did not significantly predict intra-articular injuries.

Number of Instability Episodes. Increased number of instability episodes predicted more medial meniscectomies compared with no instability episodes (OR, 4.46; 95% CI, 1.40-14.18).

DISCUSSION

We hypothesized that predictors of intra-articular injuries and meniscal tear management would differ by sex, and this hypothesis was supported by our findings. We found that males had more meniscal injuries at the time of surgery and subsequently underwent more meniscal resections both medially and laterally. Predictors of associated intra-articular pathology highlight some sex differences in how meniscal and chondral injuries may accumulate, and among males included age, BMI, type of injury, interval from ACL injury to surgery, and number of instability episodes. Predictors among females included age, BMI, and number of instability episodes.

Several studies have examined predictors of intra-articular injuries in patients undergoing ACL reconstruction.[3,5,17,25] Although none of these studies has specifically examined sex-specific predictors, it seems relevant to do so given that males tend to have more meniscal and chondral injuries than females.[11,23,26,27,29] We found that men had significantly more lateral and medial meniscal tears than women, but not chondral injuries. Men tend to have more body mass than women, and a prospective study found that baseline BMI was a predictor of intra-articular injuries in patients undergoing ACL reconstruction.[3,18] It also seems plausible that increased BMI might contribute to increased force during injury, causing multiple injuries to the knee; however, this has not been directly studied.[26]

We found that increased age predicted intra-articular injuries in both males and females. Previous studies have shown increased age to be predictive of chondral injuries in patients undergoing ACL reconstruction.[5,17] The progression of cartilage damage usually occurs over several years and could explain the association with increased age, especially if changes in cartilage began prior to the ACL injury.[20] Our data, however, did not allow us to determine temporality of the ACL and chondral injuries. Increased age also predicted more medial meniscectomies in males, but not in females. This is likely due to the fact that males were slightly older and had more medial meniscus tears than females.

Body mass index has been shown to be associated with intra-articular injuries.[3,17] It is interesting to note the divergent effect of increasing BMI in males and females in our study, with higher BMI associated with fewer medial meniscal tears in males and more lateral meniscal resection and repairs in females. Our data alone cannot fully explain this observation; however, we can offer several speculative explanations. First, obesity was measured with BMI, which does not distinguish between fat and muscle mass.[14] Men may have had larger BMIs due to increased muscle mass, which might aid in protecting against intra-articular injuries.[7,18] Second, adipose tissue tends to be stored in the android region (upper body) for men and in the gynoid region (lower body) in females.[19] Gaida et al[13] found that among those with asymptomatic Achilles tendon pathology, males had more central fat and females had more peripheral fat compared with those without asymptomatic Achilles tendon pathology. Sex differences in body fat distribution might also exist for other lower extremity injuries such as ACL and intra-articular injuries; however, we did not measure fat mass and could not examine this further. Third, there may have been measurement error in our estimate of obesity because we used self-reported BMI, which has been shown to underestimate actual BMI in both men and women.[30] However, this same study also showed that adjusting self-reported BMI for age and sex provides a close approximation to actual BMI, and our analyses were adjusted for age and sex.

Mechanism of injury was not associated with intra-articular injuries in men and women in our study. This may be due to the fact that there were no statistically significant differences between the frequencies of contact and noncontact injuries for males compared with females. One study found that noncontact injuries were associated with medial meniscal tears in 54 patients undergoing ACL reconstruction ($P = .03$).[28] However, this was a univariate analysis and potential confounders were not adjusted for. We also found less pathology accumulating in males participating in high-impact sports when injured, possibly due to earlier diagnosis and more aggressive treatment of the initial ACL injury in these patients. Sports-related injuries were not predictive of intra-articular injuries in females.

A shortened interval from injury to surgery results in more lateral meniscal repairs in males but not in females, which could be due to males who undergo later surgery resuming higher levels of activity following the initial ACL tear, leading to further lateral meniscal injury and eventual irreparability. Time from injury to surgery was not associated with intra-articular injuries in females. A recent systematic review found 5 studies that showed increased risk of intra-articular injuries when ACL reconstruction was delayed, and 6 studies that found no association between timing of surgery and risk of intra-articular injuries.[1] Discrepant findings from this review might be due to smaller sample sizes, different definitions of early and delayed surgery, and shorter follow-up periods for the studies that found no association compared with studies that did find an association. Furthermore, none of these studies evaluated sex differences in the association between timing of surgery and intra-articular injuries. Delaying surgery is also a risk factor for worse clinical outcomes and future osteoarthritis.[9,12]

Finally, and as demonstrated elsewhere,[17] instability episodes are associated with more medial meniscal resection in both sexes. Injury to the ACL, one of the primary knee stabilizers, can lead to instability, which may in turn lead to intra-articular injuries.[8,17] Few studies have specifically examined sex differences in knee instability after ACL injuries. Hurd et al[15] found that females were more likely to be noncopers (ie, reported more instability episodes and restricted activity levels) than copers (ie, asymptomatic for at least 1 year) after a noncontact ACL injury ($P = .009$). Among males, there was no statistically significant difference in the rate of noncopers versus copers for contact ($P = .71$) and noncontact ($P = .25$) injuries. The authors attributed their findings to sex differences in neuromuscular characteristics, such as muscle activation strategies.[15] However, Hurd et al[15] did not examine sex differences in comorbid intra-articular injuries.

Strengths of this study include its prospective design, large sample size, and arthroscopic confirmation of ACL tears and intra-articular injuries. We also assessed numerous predictors including the number of instability episodes. Limitations of this study include self-reported BMI and number of instability episodes, which may have led to inaccuracies in reporting. Interviewer bias may have occurred since surgeons were aware of the patient's preliminary diagnosis at the time they queried the patient about their exposure status (ie, predictor variable). The generalizability of our results is limited only to patients who elect to undergo ACL reconstruction and does not apply to patients who choose nonoperative treatment. The temporality of injuries was unknown; it is possible that intra-articular injuries preceded the ACL injury. Analyses involving meniscal management may have been biased due to variation in surgeon preference. Finally, stratifying our data by several factors occasionally resulted in comparison groups with very small sample sizes.

This is one of the first studies to specifically assess sex-specific predictors of intra-articular injuries in patients undergoing ACL reconstruction. This knowledge might contribute to a better understanding of the development of these injuries and the appropriate course of treatment in males and females. Taken together, our findings may support earlier treatment of ACL tears in males to increase the likelihood of encountering repairable lateral meniscal tears, whereas females can be treated without concern that delaying surgery (in the absence of subsequent instability episodes) could result in more meniscal pathology. Examining modifiable predictors might aid in developing prevention strategies as well. We identified several modifiable predictors of intra-articular injuries: interval from ACL injury to surgery, number of instability episodes, and increased BMI. Deciding when to have surgery depends on a variety of factors, including symptom severity and patient preference. The presence and frequency of instability episodes after ACL injury can also be affected by numerous factors including activity avoidance, activity modification, neuromuscular rehabilitation, strength training, and wearing a brace. Weight loss in obese patients might reduce the risk of intra-articular pathology. Sex-specific predictors of intra-articular injuries, especially modifiable ones, should be examined further in future studies.

CONCLUSION

This prospective analysis of 689 patients undergoing ACL reconstruction demonstrated that predictors of comorbid intra-articular injuries differ by sex. Male predictors included age, BMI, type of injury, interval from ACL injury to surgery, and number of instability episodes. Female predictors included age, BMI, and number of instability episodes.

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APPENDIX

TABLE A1
Predictors of Intra-articular Injuries in Males Who Had an ACL Reconstruction[a]

	Lateral Meniscal Tears		Medial Meniscal Tears		Chondral Injuries	
Characteristic	Patients With Outcome, n	OR (95% CI)	Patients With Outcome, n	OR (95% CI)	Patients With Outcome, n	OR (95% CI)
Age at injury, y	144	1.00 (0.98-1.03)	121	1.02 (1.00-1.05)	33	1.05 (1.02-1.09)
BMI, kg/m^2						
Normal (≤24.99)	57	1.00 (referent)	45	1.00 (referent)	9	1.00 (referent)
Overweight (25-29.99)	58	0.76 (0.45-1.31)	60	1.15 (0.65-2.05)	13	1.03 (0.40-2.65)
Obese (≥30)	29	1.11 (0.55-2.21)	16	0.43 (0.19-0.98)	11	2.62 (0.92-7.45)
Mechanism of injury						
Noncontact	111	1.00 (referent)	98	1.00 (referent)	26	1.00 (referent)
Contact	33	0.96 (0.55-1.68)	23	0.73 (0.39-1.35)	7	1.10 (0.43-2.82)
Type of injury						
Not sports-related or unknown	16	1.00 (referent)	23	1.00 (referent)	7	1.00 (referent)
High-impact sports–related	87	1.41 (0.61-3.26)	59	0.26 (0.10-0.67)	16	1.32 (0.40-4.43)
Other sports-related	41	0.94 (0.40-2.19)	39	0.27 (0.11-0.70)	10	1.05 (0.31-3.54)
Interval from injury to surgery						
6 wk	45	1.00 (referent)	29	1.00 (referent)	7	1.00 (referent)
≤6 wk	99	1.23 (0.72-2.10)	92	0.88 (0.49-1.57)	26	0.76 (0.30-1.94)
Instability episodes before surgery						
0	55	1.00 (referent)	35	1.00 (referent)	12	1.00 (referent)
1	22	1.30 (0.62-2.72)	13	1.05 (0.46-2.41)	5	1.07 (0.33-3.45)
2	15	1.14 (0.51-2.56)	15	2.64 (1.14-6.14)	2	0.70 (0.14-3.54)
3	10	0.91 (0.35-2.38)	13	3.06 (1.12-8.38)	3	1.94 (0.46-8.16)
4	5	1.87 (0.42-8.34)	5	2.11 (0.48-9.26)	1	1.23 (0.13-11.98)
5	13	1.21 (0.51-2.90)	16	4.47 (1.75-11.40)	2	0.69 (0.14-3.46)
6-10[b]	4	0.72 (0.20-2.64)	6	3.12 (0.82-11.80)	0	NC
10	20	1.18 (0.54-2.58)	18	1.52 (0.65-3.56)	8	1.55 (0.50-4.77)

[a]Odds ratios adjusted were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.

TABLE A2
Predictors of Lateral Meniscal Management in Males Who Had an ACL Reconstruction[a]

		Lateral Meniscus Tear Left In Situ (n = 42)		Lateral Meniscectomy Performed (n = 80)		Lateral Meniscal Repair Performed (n = 21)	
Predictor	No Lateral Meniscus Tear (n = 156; Referent), n	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
Age at injury, y	156	42	0.96 (0.92-1.00)	80	1.03 (1.00-1.05)	21	0.96 (0.91-1.02)
BMI, kg/m^2							
Normal (≤24.99)	57	19	1.00 (referent)	32	1.00 (referent)	6	1.00 (referent)
Overweight (25-29.99)	74	18	0.95 (0.41-2.23)	30	0.63 (0.33-1.20)	10	1.60 (0.49-5.23)
Obese (≥30)	25	5	0.65 (0.20-2.17)	18	1.16 (0.52-2.59)	5	2.43 (0.60-9.90)
Mechanism of injury							
Noncontact	119	30	1.00 (referent)	62	1.00 (referent)	18	1.00 (referent)
Contact	37	12	1.49 (0.64-3.48)	18	0.95 (0.48-1.88)	3	0.39 (0.10-1.53)
Type of injury							
Not sports-related or unknown	19	5	1.00 (referent)	9	1.00 (referent)	2	1.00 (referent)
High impact sports–related	79	24	0.46 (0.13-1.69)	50	2.67 (0.94-7.57)	12	0.87 (0.14-5.41)
Other sports-related	58	13	0.42 (0.11-1.59)	21	1.28 (0.45-3.65)	7	1.05 (0.16-7.02)
Interval from injury to surgery							
6 wk	42	11	1.00 (referent)	22	1.00 (referent)	11	1.00 (referent)
≤6 wk	114	31	0.72 (0.31-1.65)	58	1.13 (0.59-2.19)	10	3.10 (1.09-8.77)
Instability episodes before surgery							
0	64	18	1.00 (referent)	26	1.00 (referent)	10	1.00 (referent)
1	19	8	1.34 (0.48-3.73)	10	1.30 (0.51-3.28)	4	1.54 (0.38-6.22)
2	16	5	0.84 (0.26-2.71)	8	1.46 (0.54-3.98)	2	0.84 (0.16-4.40)
3	12	1	0.21 (0.03-1.82)	9	2.01 (0.70-5.75)	0	NC
4	4	3	4.00 (0.69-23.16)	2	1.72 (0.27-11.14)	0	NC
5	13	4	0.94 (0.26-3.38)	6	1.20 (0.40-3.64)	3	2.17 (0.48-9.88)
6-10[b]	7	0	NC	3	1.22 (0.28-5.28)	1	1.67 (0.17-16.57)
10	21	3	0.24 (0.05-1.25)	16	2.39 (0.98-5.87)	1	0.44 (0.05-4.01)

[a]Odds ratios were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.

TABLE A3
Predictors of Medial Meniscal Management in Males Who Had an ACL Reconstruction[a]

		Medial Meniscus Tear Left In Situ n = 31		Medial Meniscectomy Performed n = 61		Medial Meniscal Repair Performed n = 29	
Predictor	No Medial Meniscus Tear (n = 179; Referent), n	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
Age at injury, y	179	31	0.98 (0.94-1.03)	61	1.04 (1.01-1.08)	29	1.02 (0.97-1.06)
BMI, kg/m^2							
Normal (≤24.99)	69	10	1.00 (referent)	22	1.00 (referent)	13	1.00 (referent)
Overweight (25-29.99)	72	16	1.93 (0.74-5.08)	30	1.04 (0.49-2.18)	14	0.85 (0.34-2.14)
Obese (≥30)	38	5	1.09 (0.31-3.85)	9	0.37 (0.13-1.05)	2	0.20 (0.04-1.05)
Mechanism of injury							
Noncontact	132	24	1.00 (referent)	50	1.00 (referent)	24	1.00 (referent)
Contact	47	7	0.77 (0.29-2.08)	11	0.71 (0.31-1.62)	5	0.65 (0.22-1.97)
Type of injury							
Not sports-related or unknown	12	2	1.00 (referent)	16	1.00 (referent)	5	1.00 (referent)
High-impact sports–related	107	18	0.53 (0.09-3.03)	22	0.23 (0.08-0.67)	19	0.19 (0.05-0.77)
Other sports-related	60	11	0.60 (0.10-3.52)	23	0.32 (0.11-0.92)	5	0.09 (0.02-0.44)
Interval from injury to surgery							
6 wk	58	7	1.00 (referent)	10	1.00 (referent)	12	1.00 (referent)
≤6 wk	121	24	0.63 (0.24-1.66)	51	0.63 (0.27-1.45)	17	1.93 (0.77-4.87)
Instability episodes before surgery							
0	84	10	1.00 (referent)	15	1.00 (referent)	10	1.00 (referent)
1	28	3	0.93 (0.23-3.77)	8	1.56 (0.55-4.44)	2	0.51 (0.10-2.74)
2	16	8	3.81 (1.27-11.47)	3	1.36 (0.34-5.53)	4	2.68 (0.69-10.39)
3	9	1	0.91 (0.10-8.16)	9	5.84 (1.80-18.92)	3	1.71 (0.30-9.79)
4	4	1	2.18 (0.22-22.11)	3	2.48 (0.38-16.28)	1	1.72 (0.17-17.47)
5	10	6	4.71 (1.35-16.39)	5	3.10 (0.86-11.13)	5	6.10 (1.57-23.66)
6-10[b]	5	0	NC	4	4.90 (1.05-22.93)	2	4.69 (0.71-30.96)
10	23	2	0.64 (0.12-3.41)	14	2.64 (0.95-7.31)	2	0.72 (0.12-4.18)

[a]Odds ratios were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.

TABLE A4
Predictors of Intra-articular Injuries in Females Who Had an ACL Reconstruction[a]

	Lateral Meniscal Tears		Medial Meniscal Tears		Chondral Injuries	
Characteristic	No. With Outcome	OR (95% CI)	No. With Outcome	OR (95% CI)	No. With Outcome	OR (95% CI)
Age at injury, y	68	0.98 (0.95-1.00)	74	1.00 (0.97-1.03)	26	1.09 (1.05-1.14)
BMI, kg/m^2						
Normal (≤24.99)	52	1.00 (referent)	51	1.00 (referent)	17	1.00 (referent)
Overweight (25-29.99)	9	0.54 (0.24-1.24)	14	0.75 (0.35-1.59)	5	0.54 (0.15-1.91)
Obese (≥30)	7	1.87 (0.60-5.80)	9	1.63 (0.55-4.80)	4	0.77 (0.16-3.66)
Mechanism of injury						
Noncontact	56	1.00 (referent)	67	1.00 (referent)	19	1.00 (referent)
Contact	12	1.05 (0.49-2.28)	7	0.43 (0.18-1.04)	7	3.01 (0.95-9.54)
Type of injury						
Not sports-related or unknown	8	1.00 (referent)	9	1.00 (referent)	7	1.00 (referent)
High-impact sports–related	27	0.86 (0.28-2.63)	30	1.34 (0.44-4.05)	3	0.37 (0.06-2.13)
Other sports-related	33	0.91 (0.33-2.53)	35	1.06 (0.39-2.89)	16	0.97 (0.29-3.33)
Interval from injury to surgery						
6 wk	25	1.00 (referent)	21	1.00 (referent)	8	1.00 (referent)
≤6 wk	43	1.22 (0.62-2.40)	53	0.85 (0.43-1.67)	18	1.14 (0.36-3.56)
Instability episodes before surgery						
0	30	1.00 (referent)	22	1.00 (referent)	9	1.00 (referent)
1	10	1.71 (0.66-4.40)	10	1.85 (0.70-4.90)	3	1.42 (0.29-6.92)
2	5	0.66 (0.22-2.01)	7	1.63 (0.58-4.63)	1	0.78 (0.08-7.31)
3	3	0.36 (0.10-1.36)	7	1.28 (0.45-3.62)	2	0.84 (0.14-5.01)
4	4	1.13 (0.29-4.32)	5	2.15 (0.59-7.91)	1	1.22 (0.12-12.73)
5	3	0.59 (0.15-2.32)	4	1.11 (0.31-3.91)	1	0.65 (0.07-6.50)
6-10[b]	3	0.94 (0.22-3.93)	3	1.15 (0.27-4.89)	2	1.11 (0.15-8.44)
10	10	0.83 (0.34-2.07)	16	2.14 (0.91-5.07)	7	2.27 (0.64-8.02)

[a]Odds ratios adjusted were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.

TABLE A5
Predictors of Lateral Meniscal Management in Females Who Had an ACL Reconstruction[a]

		Lateral Meniscus Tear Left In Situ (n = 25)		Lateral Meniscectomy Performed (n = 31)		Lateral Meniscal Repair Performed (n = 12)	
Predictor	No Lateral Meniscus Tear (n = 179; Referent), n	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
Age at injury, y	179	25	1.00 (0.96-1.04)	31	0.95 (0.91-1.00)	12	0.99 (0.93-1.06)
BMI, kg/m^2							
Normal (≤24.99)	122	20	1.00 (referent)	22	1.00 (referent)	10	1.00 (referent)
Overweight (25-29.99)	43	5	0.69 (0.23-2.08)	4	0.54 (0.16-1.78)	0	NC
Obese (≥30)	14	0	NC	5	4.26 (1.01-18.04)	2	13.43 (1.04-174.14)
Mechanism of injury							
Noncontact	150	17	1.00 (referent)	29	1.00 (referent)	10	1.00 (referent)
Contact	29	8	2.07 (0.79-5.45)	2	0.32 (0.07-1.47)	2	0.80 (0.15-4.27)
Type of injury							
Not sports-related or unknown	22	3	1.00 (referent)	4	1.00 (referent)	1	1.00 (referent)
High-impact sports–related	66	10	0.68 (0.14-3.36)	11	0.62 (0.13-3.02)	6	4.04 (0.20-81.72)
Other sports-related	91	12	0.69 (0.16-3.03)	16	0.81 (0.19-3.44)	5	2.17 (0.13-35.10)
Interval from injury to surgery							
6 wk	57	6	1.00 (referent)	12	1.00 (referent)	7	1.00 (referent)
≤6 wk	122	19	0.68 (0.24-1.99)	19	1.35 (0.53-3.45)	5	3.73 (0.80-17.33)
Instability episodes before surgery							
0	66	8	1.00 (referent)	14	1.00 (referent)	8	1.00 (referent)
1	17	2	1.03 (0.19-5.48)	6	2.56 (0.77-8.48)	2	2.23 (0.38-13.20)
2	17	3	1.54 (0.35-6.77)	2	0.56 (0.11-2.83)	0	NC
3	20	1	0.49 (0.06-4.33)	1	0.22 (0.03-1.94)	1	0.32 (0.03-3.39)
4	8	2	1.80 (0.30-10.87)	1	0.54 (0.05-5.43)	1	1.91 (0.16-23.50)
5	12	2	1.38 (0.25-7.72)	1	0.34 (0.04-3.23)	0	NC
6-10[b]	9	1	0.83 (0.08-8.39)	2	1.44 (0.24-8.61)	0	NC
10	30	6	1.64 (0.48-5.62)	4	0.61 (0.16-2.36)	0	NC

[a]Odds ratios were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.

TABLE A6
Predictors of Medial Meniscal Management in Females Who Had an ACL Reconstruction[a]

		Medial Meniscus Tear Left In Situ (n = 12)		Medial Meniscectomy Performed (n = 34)		Medial Meniscal Repair Performed (n = 28)	
Predictor	No Medial Meniscus Tear (n = 173; Referent), n	n	OR (95% CI)	n	OR (95% CI)	n	OR (95% CI)
Age at injury, y	173	12	0.94 (0.86-1.03)	34	1.04 (1.00-1.08)	28	0.96 (0.92-1.01)
BMI, kg/m^2							
Normal (≤24.99)	123	12	1.00 (referent)	18	1.00 (referent)	21	1.00 (referent)
Overweight (25-29.99)	38	0	NC	10	1.25 (0.47-3.32)	4	0.65 (0.19-2.18)
Obese (≥30)	12	0	NC	6	1.92 (0.46-7.94)	3	1.85 (0.37-9.34)
Mechanism of injury							
Noncontact	139	10	1.00 (referent)	30	1.00 (referent)	27	1.00 (referent)
Contact	34	2	0.70 (0.14-3.61)	4	0.60 (0.18-1.98)	1	0.15 (0.02-1.16)
Type of injury							
Not sports-related or unknown	21	1	1.00 (referent)	6	1.00 (referent)	2	1.00 (referent)
High-impact sports–related	63	7	0.74 (0.06-9.21)	10	1.21 (0.26-5.60)	13	1.46 (0.22-9.56)
Other sports-related	89	4	0.39 (0.03-5.08)	18	1.33 (0.36-4.92)	13	1.15 (0.19-6.90)
Interval from injury to surgery							
6 wk	61	6	1.00 (referent)	5	1.00 (referent)	10	1.00 (referent)
≤6 wk	112	6	1.44 (0.38-5.47)	29	0.33 (0.10-1.12)	18	1.47 (0.54-3.99)
Instability episodes before surgery							
0	74	6	1.00 (referent)	6	1.00 (referent)	10	1.00 (referent)
1	17	1	0.97 (0.10-9.39)	5	2.58 (0.59-11.34)	4	2.09 (0.54-8.19)
2	15	1	0.92 (0.10-8.67)	6	6.02 (1.52-23.84)	0	NC
3	16	2	2.70 (0.41-17.59)	1	0.50 (0.05-4.73)	4	2.06 (0.51-8.32)
4	7	0	NC	2	2.76 (0.43-17.64)	3	3.69 (0.68-19.92)
5	11	1	1.24 (0.10-14.89)	2	1.98 (0.34-11.67)	1	0.75 (0.08-6.95)
6-10[b]	9	0	NC	0	NC	3	4.26 (0.80-22.69)
10	24	1	0.95 (0.09-9.88)	12	4.46 (1.40-14.18)	3	1.20 (0.27-5.39)

[a]Odds ratios were adjusted for all other predictors in the table. BMI, body mass index; NC, not calculable.
[b]Six to 10 instability episodes occurred infrequently and thus were collapsed into a single category.