

Sex-Specific Outcomes After Anterior Cruciate Ligament Reconstruction

A Systematic Review and Meta-analysis

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Background: Despite the significant difference between men and women in incidence of anterior cruciate ligament (ACL) injuries, there is a paucity of consistent information on the influence of patient sex on outcomes after ACL reconstruction. A previous meta-analysis has demonstrated that female patients have worse outcomes with regard to laxity, revision rate, Lysholm score, and Tegner activity score and are less likely to return to sports (RTS).

Purpose: To conduct a systematic review and meta-analysis to evaluate and compare sex-specific outcomes after ACL reconstruction.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review was performed using PubMed, PubMed Central, Embase, OVID, and Cochrane databases per PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The following search terms were used: “anterior cruciate ligament reconstruction” OR “ACL reconstruction” OR “anterior cruciate ligament” OR “ACL” AND “gender” OR “sex” OR “male” OR “female” AND “outcome” AND “2015-Present” to gather all relevant articles between 2015 and 2020. A risk-of-bias assessment and quality assessment was conducted on included studies.

Results: Of 9594 studies initially identified, 20 studies with 35,935 male and 21,455 female patients were included for analysis. The 7 studies reporting International Knee Documentation Committee (IKDC) scores showed that male patients had statistically significantly higher postoperative scores (mean difference, 3.02 [95% CI, 1.19-4.84]; $P < .01$; $I^2 = 66\%$), and 7 studies that reported the rate of ACL revision showed there was no significant difference between male and female patients (odds ratio, 0.85 [95% CI, 0.45-1.60]; $P = .61$; $I^2 = 94\%$). The 7 studies that reported rates of rerupture showed that males were significantly more likely than females to have a graft rerupture (odds ratio, 1.35 [95% CI, 1.22-1.50]; $P < .01$; $I^2 = 0\%$). Male patients reported a higher RTS rate than did their female counterparts (59.82% compared with 42.89%); however, no formal statistical analysis could be done because of the variability in reporting techniques.

Conclusion: Male and female patients with ACL injuries demonstrated similar outcomes regarding their rates of revision; however, male patients were found to have statistically significantly higher postoperative IKDC scores but at the same time higher rerupture rates. Our findings suggest that sex-based differences in outcomes after ACL reconstruction vary based on which metric is used. These results must be considered when counseling patients with ACL injuries.

Keywords: ACL; knee; outcomes; sex; surgical repair

Anterior cruciate ligament (ACL) tears are a common knee-related injury, with approximately 120,000 ACL reconstructions (ACLRs) performed in the United States each year.^{21,60} The incidence of ACLR has increased from 32.9 per 100,000 person-years to 43.5 per 100,000 person-years over a recent 12-year span.⁹ Many different risk

factors, such as sex, age, and sport played, have been studied to determine their role in the incidence of ACL ruptures, but few studies have looked at the effect that these factors play on the outcomes of ACLR. Specifically, the incidence of ACL ruptures has been shown to be higher in patients who are female^{12,67}, younger⁶², and play sports with frequent cutting or landing maneuvers, such as basketball, ice hockey, field hockey, football, and volleyball.¹

In general, the literature demonstrates that ACLR results in optimal outcomes for patients, regardless of age

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or concomitant injuries.^{47,49,58} Many factors are considered when looking at the effectiveness of an ACLR, including, but not limited to, reoperative rate, rerupture rate, functional tests, objective tests, return-to-sports (RTS) rate, and the visual analog scale (VAS) pain scale. Many previous studies have evaluated the extent to which various risk factors (eg, age, athletic ability, graft, surgical technique, and rehabilitation program) play a role in the success of ACLR.[¶] However, little work has been done to examine the effect that patient sex has on outcomes after ACLR. A systematic review published in 2014, evaluating sex-based differences in ACLR outcomes, found that there were no significant differences between male and female patients in the 13 papers included in the review.⁵¹ In 2016, Tan et al⁶⁸ performed another systematic review and meta-analysis to evaluate outcomes of ACLR based on patient sex. The authors found that, postoperatively, female patients had inferior outcomes in instrumented laxity, revision rate, Lysholm score, Tegner activity score, and RTS. All other outcomes analyzed, including anterior drawer test, Lachman test, pivot-shift test, and single-leg hop tests, were comparable.

Despite these 2 systematic reviews, there is still a very limited understanding of the effect of patient sex on outcomes after ACLR. In this study, we aimed to update the study published by Tan et al⁶⁸ to include information regarding sex-specific ACLR outcomes between 2015 and 2020.

METHODS

Search Strategy and Study Selection

This study was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.⁶⁵ Two authors (A.C.M., D.J.F.) performed a manual study selection using the PubMed, PubMed Central, Cochrane, OVID, and Embase databases with discrepancies being resolved via discussion with a third author (M.L.V.). The following search terms were used: “anterior cruciate ligament reconstruction” OR “ACL reconstruction” OR “anterior cruciate ligament” OR “ACL” AND “gender” OR “sex” OR “male” OR “female” AND “outcome” AND “2015-Present.” These databases were

[¶]References 1–5, 7, 13, 18, 20, 24, 28, 33, 35, 36, 38, 57, 59, 62, 64, 69, 73.

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searched between January 2015 and March 2020. Titles and abstracts were screened to assess for removal per our eligibility criteria, and then the full text was reviewed for the remaining studies to further assess for eligibility using the criteria stated below. All included studies included distinct cohorts from separate research groups.

Eligibility Criteria

Studies that met the following criteria were included: published in the English language, used human participants, and evaluated for sex-specific outcomes of ACLR. Our initial search terms were applied to the aforementioned databases. All studies that resulted from the search were initially included. The abstracts of all studies were then screened, and studies were excluded if any of the following were present: non—English language publication, cadaveric study, nonhuman participants, and no evaluation for any of the sex-specific ACLR outcomes of interest. The methods of the remaining studies were reviewed, and if the study included injuries of concomitant cartilage procedure, multiligamentous injury, or a quadriceps/patellar tendon rupture, it was also excluded. Finally, only studies that separated their outcomes based on sex in an extractable manner were included in our final meta-analysis. For example, studies were excluded because they only reported which sex had better results, without any data, or the study was the only one that reported a specific outcome (eg, osteoarthritis rate), in which case we would not be able to perform statistical analysis.

Outcomes

Patient characteristics that were collected from the eligible studies included patient sex, age at time of injury, age at time of surgery, follow-up time, body mass index, treatment technique, ACL graft type used, and sport played. Outcomes for which we were screening in our papers to possibly conduct a meta-analysis included functional outcomes, retear rate, reoperative rate, contralateral injury rate, postoperative range of motion (flexion and extension), postoperative stability (Lachman test and pivot-shift test), rate of RTS, time required to RTS, VAS for pain, KT-1000 arthrometer side-to-side difference in laxity, Tegner score, International Knee Documentation Committee (IKDC) score, osteoarthritis rates, limb symmetry index score, and maximal voluntary isometric contraction torque. We were

able to identify at least 1 of these values separated by sex in 61 studies. If these outcomes were reported in >1 study in an extractable manner, then they were included in our analysis. Only outcomes of IKDC scores, revision rates, rerupture rates, RTS rates, and contralateral ACL injury rates were reported in >1 study to allow for analysis.

Quality Assessments

We used an assessment of bias table to address the levels of bias within each study included in our study. Studies were ranked as having a low risk, high risk, or unclear risk of bias in 7 different categories. These categories included 2 assessments for selection bias, 1 assessment for performance bias, 1 assessment for detection bias, 2 assessments for attrition bias, and 1 assessment for any other type of bias.

We also used a modified version of the Coleman Methodology Score to assess the quality of the studies included. Each study is given a score based on 10 evaluation standards. A score ≥ 85 is considered excellent, 70 to 84 is considered good, 50 to 69 is considered moderate, and < 50 is considered poor.

Statistical Analysis

Studies that reported postoperative IKDC scores, rerupture rates, and revision rates were included in the meta-analysis. For studies that reported a range instead of an SD for IKDC scores, the SD was estimated by using range divided by 4. Random-effects meta-analysis was utilized.²² The inverse variance method was used for continuous outcomes, and the Mantel-Haenszel method was used for binary outcomes. The mean difference, along with 95% CI, was calculated for IKDC scores. For the rerupture and revision rates, odds ratios (ORs) and 95% CIs were calculated. Heterogeneity was examined using the I^2 statistic. A high I^2 ($> 50\%$) indicated that the studies were inconsistent in what they found. Low I^2 indicated that the studies were consistent with each other. (Version 3.6.3; R Core Team) was used for all statistical analysis. $P < .05$ was considered significant.

RESULTS

A total of 9594 studies were identified in our initial search; of these, 9129 studies were removed per our study selection and eligibility criteria, leaving 465 studies for full-text review. After the full text was reviewed and assessed, 61 of the studies met all inclusion criteria; however, only 20 of these studies reported outcomes that were also reported in other studies included so that analysis could be performed (ie, 7 studies reported IKDC scores so that analysis could be performed, but only 1 study reported postoperative range of motion, which is why postoperative range of motion is not included in our analysis). Other outcomes for which only 1 study reported sex-based differences were postoperative tibial slope, flexion and extension angles, maximum torque, KT-1000

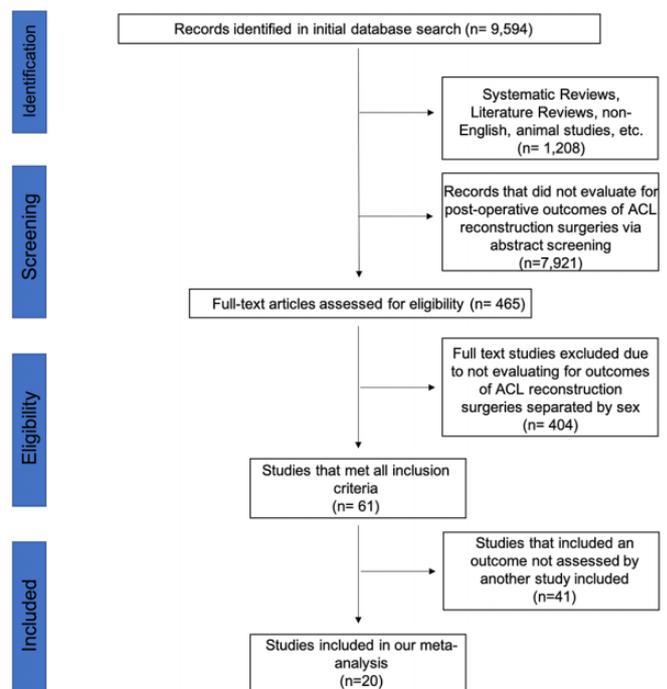


Figure 1. Flow diagram of study selection following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). ACLR, anterior cruciate ligament reconstruction.

arthrometer laxity, Tegner score, Lachman score, anterior drawer test, and limb symmetry index.

Of the 61 eligible studies, 20 (33%) reported data in their results in an extractable manner, separated by sex, and thus were included in the meta-analysis.[#] A total of 57,390 patients were included in these 20 studies (35,935 male, 21,455 female). Figure 1 denotes the study selection process.

Of the 20 studies included in the meta-analysis, 7 included IKDC scores,^{14,29-31,45,60,71} 6 included revision rates,^{6,16,40,55,63,75} 6 included rerupture rate,^{15,26,52,62,66,70} and 1 paper included both revision and rerupture rates.⁴³

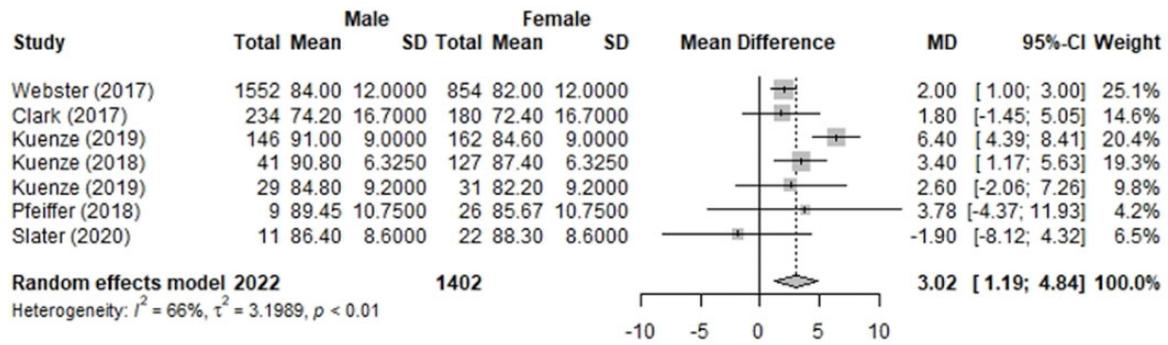
IKDC Scores

Postoperative IKDC scores were included in 7 studies that were used for statistical analysis.^{14,30-32,46,61,72} Within these studies, scores from 2022 male and 1402 female patients were included. Male patients reported a statistically significant higher postoperative IKDC score with a mean difference of 3.02 (95% CI, 1.19-4.84; $P < .01$; $I^2 = 66\%$). A forest plot showing the results and weight for the IKDC scores is shown in Figure 2, and the characteristics of the studies are listed in Table 1.

Revision Rates

The revision rates of ACLR in both male and female patients were included in 7 studies that were evaluated

[#]References 6, 14–16, 26, 30–32, 40, 44, 46, 52, 55, 61–63, 66, 70, 72, 75.



| IKDC Scores in Male and Female Patients | | | |
|---|------------------------------|--------------------------------|--------|
| Total Male Patients | Male IKDC Score, mean ± SD | Mean Score Difference (95% CI) | I^2 |
| 2022 | 83.56 ± 12.32 | 3.02 (1.19; 4.84) | 66.00% |
| Total Female Patients | Female IKDC Score, mean ± SD | | |
| 1402 | 81.73 ± 11.94 | | |

Figure 2. Forest plot of studies used in meta-analysis of International Knee Documentation Committee (IKDC) scores. MD, mean difference. First Kuenze 2019 is reference 31, second Kuenze 2019 is reference 30.

TABLE 1
Characteristics of Studies Used in IKDC Score Meta-analysis^a

| Study | LOE | Graft Used | Surgical Technique |
|-------------------------------|-----|---------------------------------------|--------------------|
| Webster (2017) ⁷² | 3 | Hamstring, patellar tendon, allograft | Single bundle |
| Clark (2017) ¹⁴ | 2 | Hamstring | NR |
| Kuenze (2019) ³⁰ | 4 | Patellar tendon, hamstring | NR |
| Kuenze (2018) ³² | 4 | Patellar tendon, hamstring, allograft | NR |
| Kuenze (2019) ³¹ | 4 | Patellar tendon, hamstring, allograft | NR |
| Pfeiffer (2018) ⁴⁶ | 4 | Patellar tendon autograft | NR |
| Slater (2020) ⁶¹ | 4 | Patellar tendon, hamstring, allograft | NR |

^aIKDC, International Knee Documentation Committee; LOE, level of evidence; NR, not reported.

quantitatively.^{6,16,23,40,55,63,75} Overall, data from 19,849 patients (14,543 male and 5,306 female) were included. The overall population had a total of 1283 revisions, which was 6.46% of the study population. There was a total of 811 revisions for male patients from this pool for an incidence rate of revision of 5.58%. For female patients, there was a total of 472 revisions from this pool for an incidence of revision of 8.90%. While male patients did have a lower incidence of revisions from this pool, the rate of revision in male patients as compared with their female counterparts was not statistically significant (OR, 0.85 [95% CI, 0.45-1.60]; $P = .61$; $I^2 = 94\%$). A forest plot of the results and weight for revision rates is shown in Figure 3, and the characteristics of the studies are listed in Table 2.

Rerupture Rate

The rerupture rates after ACLR were included in 7 studies that were evaluated quantitatively.^{15,26,44,52,62,66,70} A total of 34,117 patients were involved in our analysis (19,370 male and 14,747 female), and a total of 1642 reruptures occurred for an overall incidence of 4.81%. Of the male patients involved in this quantitative analysis, 1037 experienced an ACL rerupture, with an incidence of 5.35%.

Comparatively, 605 female patients experienced an ACL rerupture (incidence rate, 4.10%). Based on these results, male patients were significantly more likely to have a rerupture than were female patients, with an OR of 1.35 (95% CI, 1.22-1.50; $P < .01$; $I^2 = 0\%$). A forest plot showing each study's results and weight for the rerupture rates is shown in Figure 4, and the studies' characteristics are listed in Table 3.

RTS Rate

Reporting of RTS varied greatly depending on whether the rates were separated by patient sex and/or age. In general, average time to RTS varied from as short as 8.3 months to as long as 11.1 months.^{11,15,27,41,42} The average RTS rates for both male and female patients combined also varied greatly, with rates reported as low as 63.7% to as high as 96%.^{11,15,17,27,41,74}

The RTS rates by sex were reported by 8 of the included studies,^{10,17,27,29,50,56,71,74} with a total of 3632 patients (2541 male and 1091 female). No formal data analysis could be performed due to the difference in reporting of RTS among studies. The papers included did not consistently report their results based on age, which appears to have a

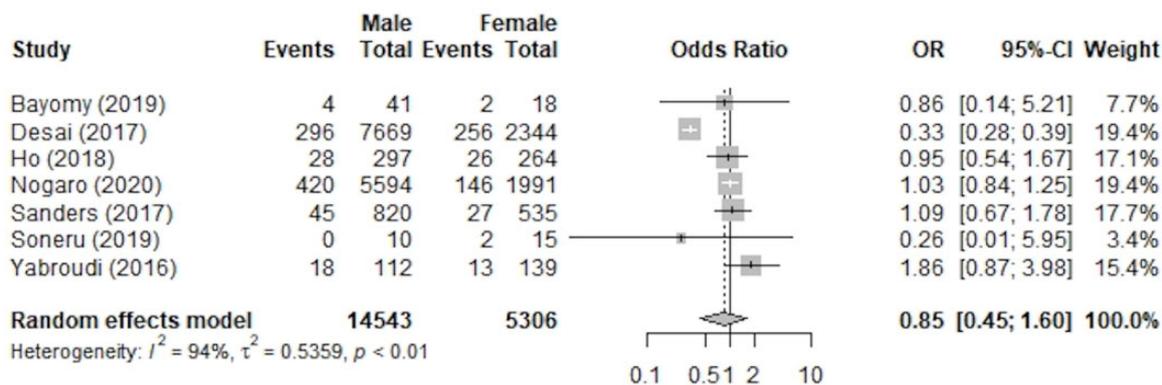


Figure 3. Forest plot of studies included in meta-analysis of revision rates. ACLR, anterior cruciate ligament reconstruction; OR, odds ratio.

TABLE 2
Studies Used in Rate of Revision Meta-analysis

| Study | Level of Study | Reported Graft Used | Surgical Technique |
|-------------------------------|------------------|--------------------------------------|------------------------------|
| Bayomy (2019) ⁶ | III-Case-Control | Autologous Hamstring Tendon | Transphyseal ACR |
| Desai (2017) ¹⁶ | III | Hamstring | Single bundle |
| Ho (2018) ²³ | III | Not Specified | Not Specified |
| Nogaro (2020) ⁴⁰ | III | Not Specified | Not Specified |
| Sanders (2017) ⁵⁵ | II | Patellar, Hamstring, Allograft | Not Specified |
| Soneru (2019) ⁶³ | II | Achilles tendon bone graft, patellar | Not Specified |
| Yabroudi (2016) ⁷⁵ | III-Case-Control | Autograft, Allograft, Mixed | Single Bundle, Double Bundle |

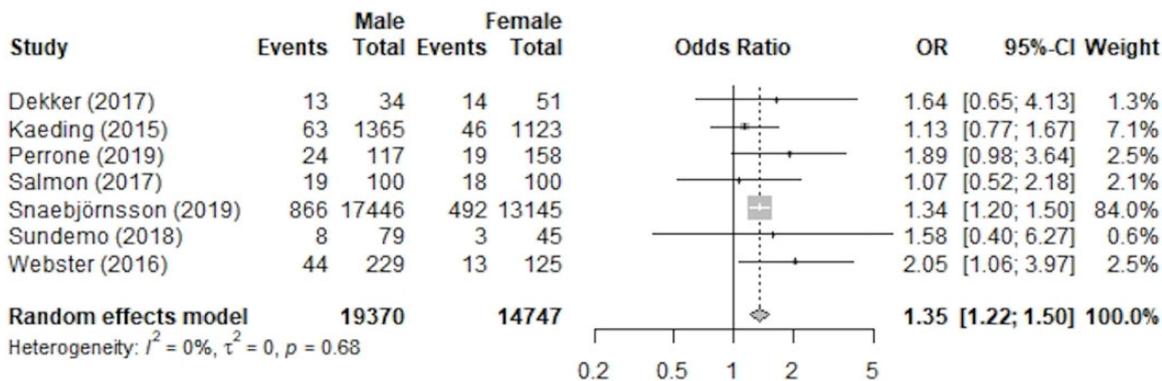


Figure 4. Forest plot of studies included in meta-analysis of rerupture rates. ACLR, anterior cruciate ligament reconstruction; OR, odds ratio.

significant effect on RTS rates.⁷¹ However, in the studies that reported rates of RTS, male patients had a higher RTS rate (59.82%) compared with their female counterparts (42.89%).

Contralateral Knee Injuries

The number of contralateral knee injuries were recorded in only 5 studies (n = 17,078 patients) of the 61 included in our quantitative analysis.^{40,44,52,66,70} There were 12,276 male patients, of whom 411 had a contralateral ACL injury

(incidence, 3.35%). There was a total of 4802 female patients, 197 of whom sustained a contralateral ACL injury (incidence, 4.10%). We were unable to perform a statistical analysis for these results given that 16,125 patients came from a single study.³⁹

Risk-of-Bias and Quality Assessments

There was a high risk of bias for the majority of papers included in our meta-analysis, as the majority of the included studies were cohort studies (Table 4). The quality

TABLE 3
Studies Used in Rate of Rupture Meta-analysis

| Study | Level of Evidence | Reported Graft Used | Surgical Technique |
|------------------------------------|-------------------|---|---|
| Dekker (2017) ¹⁵ | IV | Patellar, Hamstring, Hamstring autograft and allograft combined | Adult-Type Reconstruction, Vertical Transphyseal Reconstruction, Physeal Preserving |
| Kaeding (2015) ²⁶ | III | Patellar, Hamstring, Allograft | Not Listed |
| Perrone (2019) ⁴⁴ | IV | Hamstring | Arthroscopic |
| Salmon (2017) ⁵² | III | Hamstring | Arthroscopic |
| Snaebjörnsson (2019) ⁶² | II | Hamstring, Patellar | Not Listed |
| Sundemo (2018) ⁶⁶ | III | Hamstring, Patellar | Transtibial technique |
| Webster (2016) ⁷⁰ | III | Hamstring | Arthroscopic |

TABLE 4
Risk-of-Bias Assessment^a

| Lead Author (Year) | Random Sequence Generation (Selection Bias) | Allocation Concealment (Selection Bias) | Blinding of Participants and Personnel (Performance Bias) | Blinding of Outcome Assessment (Detection Bias) | Incomplete Outcome Data (Attrition Bias) | Selective Reporting (Attrition Bias) | Other Bias |
|------------------------------------|---|---|---|---|--|--------------------------------------|------------|
| Bayomy (2019) ⁶ | ● | ● | ● | ● | ● | ● | ● |
| Clark (2017) ¹⁴ | ● | ● | ● | ● | ● | ● | ● |
| Dekker (2017) ¹⁵ | ● | ● | ● | ● | ● | ● | ● |
| Desai (2017) ¹⁶ | ● | ● | ● | ● | ● | ● | ● |
| Kaeding (2015) ²⁶ | ● | ● | ● | ● | ● | ● | ● |
| Kuenze (2019) ³⁰ | ● | ● | ● | ● | ● | ● | ● |
| Kuenze (2019) ³¹ | ● | ● | ● | ● | ● | ● | ● |
| Kuenze (2018) ³² | ● | ● | ● | ● | ● | ● | ● |
| Nogaro (2020) ⁴⁰ | ● | ● | ● | ● | ● | ● | ● |
| Perrone (2019) ⁴⁴ | ● | ● | ● | ● | ● | ● | ● |
| Pfeiffer (2018) ⁴⁶ | ● | ● | ● | ● | ● | ● | ● |
| Salmon (2017) ⁵² | ● | ● | ● | ● | ● | ● | ● |
| Sanders (2017) ⁵⁵ | ● | ● | ● | ● | ● | ● | ● |
| Slater (2020) ⁶¹ | ● | ● | ● | ● | ● | ● | ● |
| Snaebjörnsson (2019) ⁶² | ● | ● | ● | ● | ● | ● | ● |
| Soneru (2019) ⁶³ | ● | ● | ● | ● | ● | ● | ● |
| Sundemo (2018) ⁶⁶ | ● | ● | ● | ● | ● | ● | ● |
| Webster (2016) ⁷⁰ | ● | ● | ● | ● | ● | ● | ● |
| Webster (2017) ⁷² | ● | ● | ● | ● | ● | ● | ● |
| Yabroudi (2016) ⁷⁵ | ● | ● | ● | ● | ● | ● | ● |

^aRed indicates a high risk of bias, green represents a low risk of bias, and yellow represents an unclear risk of bias in each category.

of the studies as assessed via the modified Coleman Methodology Score indicated that all of the included studies fell in the moderate and poor scoring categories (Table 5).

DISCUSSION

To our knowledge, this is the most recent and in-depth study on the effect of patient sex on outcomes after ACLR. We found that male patients reported higher levels of IKDC scores after ACLR but at the same time had a higher rate of rerupture. We found no difference in the rate of revision between male and female patients. We also found that male patients had a higher rate of RTS, but this was

influenced by age, making interpretation of the data difficult.

In this study, the differences based on sex were dependent upon the metric used, with no clear-cut, overall difference noted. This theme was found to be relatively consistent with previous papers that evaluated outcomes of ACLR. Tan et al⁶⁸ found that, in the majority of the measures included, men and women had statistically similar results. This included measures such as the anterior drawer test, Lachman test, pivot-shift test, single-leg hop test, quadriceps/hamstring testing, flexion/extension loss, and IKDC knee examination scores. However, they found that female patients had inferior outcomes in instrumented laxity (standardized mean difference [SMD], 0.24 [95% CI,

TABLE 5
Modified Coleman Methodology Scores^a

| Lead Author (Year) | Study Size | Mean Follow-up | No. of Different Versions (of Implant) Used | Type of Study | Description of Indications/ Diagnosis | Description of Surgical Technique | Survivorship Analysis | Outcome Criteria | Outcome Assessment | Subject Selection Process | Total Score |
|------------------------------------|------------|----------------|---|---------------|---------------------------------------|-----------------------------------|-----------------------|------------------|--------------------|---------------------------|-------------|
| Bayomy (2019) ⁶ | 7 | 4 | 10 | 0 | 5 | 5 | 0 | 7 | 5 | 5 | 48 |
| Clark (2017) ¹⁴ | 10 | 0 | 10 | 0 | 5 | 3 | 0 | 7 | 8 | 10 | 53 |
| Dekker (2017) ¹⁵ | 10 | 4 | 0 | 0 | 5 | 3 | 0 | 7 | 3 | 5 | 37 |
| Desai (2017) ¹⁶ | 10 | 7 | 0 | 0 | 5 | 3 | 0 | 5 | 4 | 0 | 34 |
| Kaeding (2015) ²⁶ | 10 | 4 | 0 | 0 | 5 | 0 | 0 | 5 | 4 | 5 | 33 |
| Kuenze (2019) ³⁰ | 10 | 4 | 0 | 0 | 5 | 0 | 0 | 7 | 5 | 5 | 36 |
| Kuenze (2019) ³¹ | 7 | 0 | 0 | 0 | 5 | 0 | 0 | 7 | 12 | 5 | 36 |
| Kuenze (2018) ³² | 10 | 4 | 0 | 0 | 5 | 0 | 0 | 5 | 8 | 5 | 37 |
| Nogaro (2020) ⁴⁰ | 10 | 10 | 0 | 0 | 5 | 0 | 0 | 5 | 4 | 5 | 39 |
| Perrone (2019) ⁴⁴ | 10 | 7 | 10 | 0 | 5 | 5 | 0 | 5 | 5 | 5 | 52 |
| Pfeiffer (2018) ⁴⁶ | 4 | 0 | 0 | 0 | 5 | 0 | 0 | 2 | 5 | 5 | 21 |
| Salmon (2017) ⁵² | 10 | 10 | 10 | 0 | 5 | 5 | 0 | 7 | 11 | 5 | 63 |
| Sanders (2017) ⁵⁵ | 10 | 10 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 5 | 40 |
| Slater (2020) ⁶¹ | 7 | 0 | 0 | 0 | 5 | 0 | 0 | 2 | 5 | 5 | 24 |
| Snaebjörnsson (2019) ⁶² | 10 | 4 | 0 | 10 | 5 | 0 | 0 | 7 | 9 | 5 | 50 |
| Soneru (2019) ⁶³ | 4 | 4 | 0 | 0 | 5 | 0 | 0 | 5 | 8 | 5 | 31 |
| Sundemo (2018) ⁶⁶ | 10 | 10 | 0 | 0 | 5 | 5 | 0 | 7 | 9 | 5 | 51 |
| Webster (2016) ⁷⁰ | 10 | 7 | 10 | 0 | 5 | 5 | 0 | 7 | 5 | 5 | 54 |
| Webster (2017) ⁷² | 10 | 7 | 10 | 0 | 5 | 0 | 0 | 5 | 5 | 5 | 47 |
| Yabroudi (2016) ⁷⁵ | 10 | 4 | 0 | 0 | 5 | 0 | 0 | 5 | 5 | 5 | 34 |

^aA score ≥ 85 points is considered excellent, 70-84 is considered good, 50-69 is considered moderate, and anything < 50 is considered poor.

0.11 to 0.37]), revision rate (relative risk, 1.15 [95%CI, -0.49 to -0.24]), Lysholm score (SMD, -0.33 [95% CI, -0.55 to -0.11]), Tegner Activity score (SMD, -0.37 [95% CI, -0.49 to -0.24]), and incidence of not returning to sport (relative risk, 1.12 [95% CI, 1.04 to 1.21]). The systematic review by Ryan et al⁵¹ looking at ACLR outcomes by sex found that both male and female patients had significantly similar graft rupture risk, contralateral ACL rupture risk, knee laxity, instrumented laxity, and patient-reported outcomes.

Of the 7 studies included in our analysis of IKDC scores, 3 reported no statistical difference, 1 reported that male patients had higher scores, 1 reported that female patients had higher scores, and 2 did not complete a statistical analysis on their results.^{14,30-32,46,61,72} A report published by the AOSSM Outcomes Task Force recommended that a minimal clinically significant difference is between 3.19 and 16.7.²⁵ Therefore, while our finding of male patients reporting higher IKDC scores than female patients is statistically significant, it would not be clinically significant based on the AOSSM criterion. The IKDC is still regarded as a trustworthy measure of quality of life postoperatively, and these results may still be a useful tool for clinicians when predicting outcomes and counseling patients after ACLR.

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Another significant finding of our study was that men and women did not differ significantly in the number of revision surgeries they underwent. Of the 7 studies included in our study, 5 found no statistical difference between sexes in regard to revisions, and the other 2 did not complete a statistical analysis on their results.^{6,16,40,44,55,63,75} This is similar to the results of a previous systematic review of Danish, Sweden, and Norwegian registries that found no significant difference in revision surgeries between male and female patients.^{16,19,34,45,48} Interestingly, a study that looked at the Kaiser Permanente registry, which included 17,682 patients, reported that male patients have a 38% increased risk for revision after ACLR (95% CI, 1.14-1.69).³⁷ It appears that there is no general consensus in the literature on the effect that sex plays on the rates of revision after ACLR. One potential explanation for this observation is that it appears that the type of sport played postoperatively may affect the incidence of revision.^{42,44,56} A study by Snaebjörnsson et al⁶² showed that soccer was the most common sport associated

with primary ACL injuries and recurrent injuries. It has also been reported that revision rates for soccer players are as high as 28.7%, which is in contrast to our overall revision rate for both sexes of 6.5%.⁵⁶ There may be other factors, in addition to type of sport played, such as age of patient, time to RTS, and rehabilitation protocol, that may act as covariables affecting revision rates.

The final finding of our meta-analysis that male patients had a higher rerupture rate than did female patients is similar to that of other studies that have reported that male patients are at a higher risk for graft injury than are female patients.⁸ Of the 7 studies included in our statistical analysis, 5 did not report a statistically significant difference in rerupture rates, 1 reported that rerupture rates were higher in male patients, and 1 study did not conduct a statistical analysis.^{15,26,44,52,62,66,70} Schilaty et al⁵⁷ also showed that risk for second ACL injuries differs by sex and age, reporting that they occur at a higher rate in female patients aged <25 years and a higher rate in male patients aged 26 to 45 years. Other studies that have looked at causes for graft ruptures have found that although female patients do have greater laxity post-ACLR, sex does not play a role in rerupture rates.^{44,53,54} As with revision surgery rates, comorbidities in addition to sex likely play a role in the risk for rerupture.

Unfortunately, due to the variable methods of reporting RTS rates by studies, we were unable to perform any formal statistical analyses. Reporting of RTS varied greatly, depending on whether the rates were separated by patient sex and/or age. The rate of RTS assessed by patient sex varied significantly, which may have been due to the large range in number of patients, as well as numbers of men and women, included in each study. Rates of RTS for male and female patients have been reported to be as low as 42.39% and 5.55%, respectively.¹⁰ However, Cheecharern¹⁰ included only 18 female and 92 male participants in their study, which may explain the low percentage. Excluding this study, the results of RTS rates were more consistent, with the lowest rates for male and female patients being 44.6% and 30.4%, respectively.^{50,71} Due to our inability to perform a statistical analysis, caution must be used when interpreting these results.

The differences in RTS rates between male and female patients may be affected by many confounding factors. There may be a significant difference in effect of age on RTS rates between male and female patients: in 2017, Webster reported that male patients younger than 35 years of age had a higher RTS rate than did female patients within the same age group.⁷² Conversely, men older than 35 years of age had a lower RTS rate than did women within the same age group. Unfortunately, the other studies did not separate RTS rates by both patient sex and age, making it difficult to compare the results, although highlighting an area for future research.

Another significant issue is the rate of contralateral ACL injuries after ACLR. We found that the rates of contralateral ACL injuries were similar between the sexes, with male patients having a rate of 3.35% and female patients having a rate of 4.10%. The reliability of these results is questionable, however, due to the fact that 96% of the male

and 91% of the female patients from the statistical analysis came from 1 study.³⁹ However, other studies have also documented that female patients experience a higher rate of contralateral ACL tears.^{39,43}

Limitations

There are several limitations to this study. As mentioned previously, there is a fairly large risk of bias in the studies included due to the majority being cohort studies. The assessment of quality using the Coleman score also shows that many studies were not of the highest research quality, again due to the nature of studies included. Randomized controlled trials present the highest quality studies, but they are not logical for the nature of our research. Another limitation is that some studies did not specifically state their inclusion criteria, which makes it difficult to evaluate whether or not they should be included. For example, if a study did not explicitly state whether they included or excluded patients with concomitant ligamentous injuries, that study was included. Finally, many studies reported their data in different ways and included some descriptive data that other studies did not. This makes it difficult to analyze the data on a larger scale. There were many data points that we would have liked to have analyzed but were unable to analyze due to lack of datapoints or the variance in reporting methods. This creates the risk of missing significant data about ACLR outcomes.

CONCLUSION

This study assessed the more recent literature to determine the effect of sex on outcomes of ACLRs. One of the primary concerns noted from this review was that only about one-third of studies that met initial inclusion criteria presented their data in an extractable format separated by sex. Given the differences in ACL injury incidence and intermediate and long-term outcomes of ACL injuries, it is crucial that future studies include assessment of data based on sex. Similar to the paper published by Tan et al,⁶⁸ we were not able to demonstrate a significant difference between sexes for the majority of the outcomes that we studied, potentially related to the paucity of data. Further studies are needed to evaluate the effect of patient sex, age, graft, and sport played on outcomes after ACLR to increase the breadth of knowledge in this area and to better counsel all patients on anticipated results.

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