Incidence and risk factors of joint stiffness after Anterior Cruciate Ligament reconstruction

Bin Wang†, Jun-Long Zhong†, Xiang-He Xu, Jie Shang, Nan Lin and Hua-Ding Lu*

Abstract

Background: Joint stiffness is a common complication after anterior cruciate ligament (ACL) reconstruction, which seriously affects the efficacy of the operation and patient satisfaction. After ACL reconstruction, the identification of joint stiffness’ risk factors can help its prevention. This meta-analysis was conducted to evaluate joint stiffness’ risk factors and incidence after ACL reconstruction and provide guidance on its prevention.

Methods: PubMed, Embase, and Cochrane Library were searched to obtain relevant studies. The odds ratios (ORs) with 95% confidence intervals (CIs) for all potential risk factors were analyzed using fixed or random-effects meta-analysis in RevMan 5.2.

Results: In total, there were 37 studies and 113,740 patients that were included in this study. After ACL reconstruction, joint stiffness’ incidence negatively correlated with the studies publication time ($R = -0.62, P = 0.0094$). After ACL reconstruction, the joint stiffness overall pooled incidence was 3% (95% CI, 3-4%). Gender (OR, 0.51; 95% CI, 0.38-0.68; $P < 0.00001$) was identified as a risk factor. Potential risk factors, such as trauma to surgery time interval, graft type, and concomitant surgery with meniscus injury, have no significant correlation with joint stiffness after ACL reconstruction.

Conclusion: This study indicated that joint stiffness’ incidence after ACL reconstruction is 3% and that gender is a risk factor for joint stiffness after ACL reconstruction.

Keywords: Joint stiffness, Anterior cruciate ligament reconstruction, Meta-analysis, Incidence, Risk factors

Background

Anterior cruciate ligament (ACL) injuries account for a large proportion of knee injuries and have a significant impact on knee joint stability [1]. With the development of sports’ medicine, arthroscopic ACL reconstruction has proven to be a safe and effective surgical method [2, 3]. Nonetheless, knee stiffness, a common postoperative complication, severely restricts patients from returning to their original exercise level [4]. Knee postoperative stiffness manifests as an insufficient range of motion, which can be caused by poor graft position, cyclops lesions, and arthrofibrosis [5–7]. Previous studies reported that after ACL reconstruction, the incidence of joint stiffness was between 4 and 38% [8]. Due to the effect of joint stiffness on efficacy and patient satisfaction following ACL reconstruction, the identification and minimization of risk factors’ occurrence, are essential. Sanders et al. [9] reported that female joint stiffness’ incidence was significantly higher than that in men; however in another report, it was shown that womanhood is not a risk factor for joint stiffness [10]. Controversies also exist with regard to the
time interval from trauma to surgery, the type of graft and concomitant surgery with meniscus injury [11–15]. Therefore, we conducted this meta-analysis to investigate joint stiffness risk factors and incidence after ACL reconstruction and provide guidance on the joint stiffness’ prevention to improve ACL reconstruction efficacy and post-operative patients’ satisfaction.

**Methods**

**Search strategy**

The systematic review and meta-analysis methods used in this study followed the recommendations of Moher et al [16]. Using the databases of Cochrane Library, PubMed, and Embase, a systematic literature search was performed for studies on joint stiffness in patients after ACL reconstruction on February 18, 2019. The retrieval strategy used the following terms in the title and abstract: (“anterior cruciate ligament” OR “ACL”) AND (“reconstruction” OR “treatment” OR “surgery” OR “repair”) AND (“stiffness” OR “range of motion deficits” OR “ROM deficits” OR “arthrofibrosis”).

**Eligibility criteria**

Studies that met the following inclusion criteria were included in our meta-analysis:

1) The studies should be randomized or non-randomized controlled studies or observational studies.
2) The studies should contain sufficient information on joint stiffness risk factors and incidence after ACL reconstruction.
3) The object of the study must be human participants.
4) The language of the article must be English or Chinese.

Studies that met the following exclusion criteria were removed from our meta-analysis:

1) Conference abstracts, letters, editorials, case reports, and reviews.
2) Joint stiffness was not present in the clinical results of all study participants.

![Fig. 1 Preferred reporting items for systematic meta-analyses (PRISMA) flow diagram of the study selection process](image-url)
3) Insufficient control information in the study which limits complete extraction.

**Data extraction**
The following information was independently extracted by the two authors (WB and ZJL) using a standardized Excel table: (1) The baseline characteristics of the included literature comprised representative authors, publication time, nationality, study type, study period, number of included patients, time and number of patients who were followed up, and number of patients with joint stiffness and joint stiffness

| Patients, n | Followed up | Time of follow-up | Total number of stiffness, n | Incidence of stiffness (%) |
|-------------|-------------|-------------------|-----------------------------|---------------------------|
| Included    | Followed up | Time of follow-up | Total number of stiffness, n | Incidence of stiffness (%) |
| 64          | 32          | 5 years           | 23                          | 71                        |
| 959         | 959         | 9 months          | 42                          | 4                         |
| 106         | 87          | 18 months         | 13                          | 15                        |
| 194         | 194         | Minimum 12 months | 38                          | 19.6                      |
| 57          | 57          | Minimum 33 months | 8                           | 14                        |
| 191         | 188         | Average 16 months (3-60 months) | 22                         | 11.7                      |
| 37          | 37          | Minimum 6 weeks   | 1                           | 2.7                       |
| 162         | 105         | Average 40 months (24-76 months) | 2                          | 1.9                       |
| 31          | 31          | 52 weeks          | 2                           | 6.5                       |
| 19          | 19          | Minimum 2 years   | 1                           | 5.3                       |
| 49          | 49          | Minimum 6 months  | 3                           | 6.1                       |
| 133         | 120         | Average 54.4 months (24-104 months) | 1                          | 0.8                       |
| 100         | 100         | Minimum 12 months | 12                          | 12                        |
| 1016        | 933         | Average 6.3 years (1.6-14.2 years) | 77                         | 8.3                       |
| 40          | 40          | Average 24.3 months (21-28 months) | 15                         | 37.5                      |
| 75          | 66          | Average 22 months (16-29 months) | 5                          | 7.6                       |
| 980         | 920         | Minimum 2 years   | 40                          | 4.3                       |
| 14522       | 14522       | Average 1.9 years | 95                          | 0.7                       |
| 103         | 103         | Average 21 months (6-66 months) | 2                          | 1.9                       |
| 59244       | 59244       | Minimum 3 months  | 955                         | 1.6                       |
| 13358       | 13358       | Minimum 3 months  | 298                         | 2.2                       |
| 1841        | 1355        | Average 10.3 years | 23                         | 1.7                       |
| 1205        | 1112        | 2 years           | 16                          | 1.4                       |
| 26          | 26          | Minimum 12 months | 6                           | 23                        |
| 969         | 969         | Minimum 45 days   | 1                           | 0.1                       |
| 102         | 73          | Minimum 3 months  | 6                           | 8.2                       |
| 1121        | 1121        | Minimum 3 months  | 20                          | 1.8                       |
| 2558        | 2424        | Average 56.7 months (7.6-124 months) | 108                        | 4.5                       |
| 59          | 57          | Minimum 3 months  | 14                          | 2.46                      |
| 27          | 27          | 2 years           | 4                           | 14.8                      |
| 127         | 127         | Average 10.1 months | 19                         | 15                        |
| 9766        | 9766        | Average 9.2 weeks | 111                         | 1.14                      |
| 424         | 424         | 37 months         | 38                          | 9                         |
| 358         | 358         | Minimum 3.5 months | 10                          | 2.8                       |
| 958         | 811         | 24 months         | 72                          | 8.8                       |
| 200         | 166         | 6 months          | 8                           | 5                         |
| 2559        | 2559        | 3 months          | 6                           | 0.23                      |
incidence; (2) Related risk factors mentioned in three or more studies.

Quality assessment
We evaluated the quality of included studies using the Newcastle-Ottawa quality assessment scale [17]. Studies with a quality of more than five stars were included in future analyses.

Statistical analysis
Joint stiffness incidence after ACL reconstruction was determined using inverse variance in statistical methods and risk difference in effect, measured with 95%

| Study                  | Selection | Comparability | Exposure/outcome | Total |
|------------------------|-----------|---------------|------------------|-------|
| Feagin et al. [18]     | 3         | 2             | 3                | 8     |
| Fisher et al. [19]     | 2         | 2             | 3                | 7     |
| Wasilewski et al. [20] | 2         | 2             | 3                | 7     |
| Dandy et al. [21]      | 2         | 2             | 3                | 7     |
| Wachtl et al. [22]     | 2         | 2             | 3                | 7     |
| Cosgarea et al. [23]   | 3         | 2             | 3                | 8     |
| Kao et al. [24]        | 2         | 2             | 3                | 7     |
| Orfaly et al. [25]     | 3         | 2             | 2                | 7     |
| Meighan et al. [26]    | 3         | 2             | 3                | 8     |
| Millett et al. [27]    | 2         | 2             | 3                | 7     |
| Nicholas et al. [28]   | 2         | 2             | 3                | 7     |
| Prodromos et al. [29]  | 3         | 2             | 3                | 8     |
| Robertson et al. [8]   | 3         | 2             | 3                | 8     |
| Nwachukwu et al. [6]   | 3         | 2             | 3                | 8     |
| Demiraga et al. [30]   | 3         | 2             | 3                | 8     |
| Kiekara et al. [31]    | 3         | 2             | 3                | 8     |
| Hettrich et al. [32]   | 3         | 2             | 3                | 8     |
| Csintalan et al. [33]  | 3         | 2             | 3                | 8     |
| Cruz et al. [34]       | 3         | 2             | 3                | 8     |
| Werner et al. [35]     | 3         | 2             | 3                | 8     |
| Cancienne et al. [36]  | 3         | 2             | 3                | 8     |
| Sanders et al. [9]     | 3         | 2             | 2                | 7     |
| Ding et al. [37]       | 3         | 2             | 3                | 8     |
| Meister et al. [38]    | 2         | 2             | 3                | 7     |
| Bordes et al. [39]     | 3         | 2             | 2                | 7     |
| Runner et al. [40]     | 3         | 2             | 3                | 8     |
| Su et al. [41]         | 3         | 2             | 3                | 8     |
| Huleatt et al. [12]    | 3         | 2             | 3                | 8     |
| Osti et al. [42]       | 3         | 2             | 3                | 8     |
| Westermann et al. [43] | 3         | 2             | 3                | 8     |
| Patel et al. [44]      | 3         | 2             | 3                | 8     |
| Cruz et al. [45]       | 3         | 2             | 2                | 7     |
| Offerhaus et al. [46]  | 3         | 2             | 3                | 8     |
| Panisset et al. [47]   | 2         | 2             | 3                | 7     |
| Romain et al., 2019    | 3         | 2             | 3                | 8     |
| Rushdi et al. [15]     | 3         | 2             | 3                | 8     |
| Grassi et al. [48]     | 3         | 2             | 3                | 8     |
confidence intervals (CIs). The binary variables of potential risk factors were performed using Mantel-Haenszel in statistical methods and odds ratio in effect, measured with 95% CIs. To identify the heterogeneity of the included studies, we performed a chi-square test and calculation of $I^2$ statistics. We considered $I^2 \leq 50\%$ and/or $P \geq 0.1$ to be an insignificant heterogeneity. In the above heterogeneous outcome, we applied the fixed effect model in the analytic model for statistical processing. On the contrary, we used the random effect model. The above statistical analyses were performed using the Review Manager 5.2. The R software was used to fit the correlation between incidence and the studies' publication time using Spearman analysis. $P < 0.05$ was considered statistically significant.

Results
Study selection and characteristics
Using the pre-designed search strategy, we identified a total of 1749 records from three databases. After removing duplicate results, 1005 potential results were screened for the follow-up study and via intensive reading of the article title and abstract; we further identified 168 studies to be included in the follow-up research process. Next, we downloaded and carefully screened the full text of the selected articles. As a result, 131 articles were excluded due to insufficient data.

Fig. 2 Correlation between the incidence of joint stiffness after ACL reconstruction and the studies publication time
identification. Finally, 37 studies were included in this meta-analysis and a detailed screening process was recorded in a flow diagram (Fig. 1). The included studies’ baseline characteristics were detailed in Table 1.

Quality assessment of the studies
According to the Newcastle-Ottawa quality assessment scale, we have quantified the quality of the included studies, and the results’ details are presented in Table 2. The quality of the included studies was acceptable as there were 24 studies with eight stars and 13 articles with seven stars.

Incidence
In total, there were 37 studies and 113,740 patients that were included in this study. The results showed that 2117 patients encountered joint stiffness after ACL reconstruction and the reported incidence rates by various institutes ranged from 0.1 to 71%, showing large fluctuations. After ACL reconstruction, the joint stiffness’ incidence negatively correlated with the studies’ publication time ($R = -0.62, p = 0.0094$) (Fig. 2). After ACL reconstruction, the overall pooled incidence of joint stiffness was 3% (95% CI, 2-4%) (Fig. 3).

---

### Table 1: Baseline Characteristics of the Included Studies

| Study or Subgroup       | Risk Difference | SE   | Weight | Risk Difference IV, Random, 95% CI | Risk Difference IV, Random, 95% CI |
|-------------------------|-----------------|------|--------|-----------------------------------|-----------------------------------|
| Alberto, et al. 2020    | 0.0023          | 0.00094696 | 6.2%   | 0.00 [0.00, 0.00]                  |                                   |
| Arndt, et al. 2019      | 0.0114          | 0.00107425 | 6.2%   | 0.01 [0.01, 0.01]                  |                                   |
| Boroo, et al. 2017      | 0.0011          | 0.00101536 | 6.2%   | 0.002 [0.00, 0.00]                 |                                   |
| Cancienne, et al. 2015  | 0.0224          | 0.00126814 | 6.1%   | 0.02 [0.02, 0.02]                  |                                   |
| Christoph, et al. 2019  | 0.098           | 0.03189822 | 2.3%   | 0.09 [0.06, 0.12]                  |                                   |
| Cosgarea, et al. 1995   | 0.1171          | 0.02344198 | 1.1%   | 0.12 [0.07, 0.16]                  |                                   |
| Cruz, et al. 2015       | 0.0119          | 0.00134251 | 2.4%   | 0.02 [-0.01, 0.05]                 |                                   |
| Cusmaan, et al. 2013    | 0.0073          | 0.00069085 | 6.2%   | 0.01 [0.01, 0.01]                  |                                   |
| Dmycki, et al. 1994     | 0.1968          | 0.02365068 | 8.6%   | 0.20 [0.14, 0.25]                  |                                   |
| Dymad, et al. 2011      | 0.3753          | 0.07604650 | 0.1%   | 0.38 [0.22, 0.53]                  |                                   |
| Drag, et al. 2017       | 0.0145          | 0.00352533 | 5.6%   | 0.01 [0.01, 0.02]                  |                                   |
| Feiyn, et al. 1976      | 0.714           | 0.00621456 | 0.1%   | 0.71 [0.55, 0.87]                  |                                   |
| Fisher, et al. 1993     | 0.0436          | 0.00632785 | 4.6%   | 0.04 [0.03, 0.05]                  |                                   |
| Heitrich, et al. 2013    | 0.834           | 0.0066688 | 4.5%   | 0.04 [0.03, 0.06]                  |                                   |
| Hurst, et al. 2018      | 0.0443          | 0.00421568 | 5.4%   | 0.04 [0.04, 0.05]                  |                                   |
| Kao, et al. 1995        | 0.0271          | 0.02694633 | 0.9%   | 0.01 [0.03, 0.08]                  |                                   |
| Klekara, et al. 2012    | 0.0762          | 0.03261901 | 0.6%   | 0.08 [0.01, 0.14]                  |                                   |
| Martin, et al. 2017     | 0.233           | 0.06275204 | 0.1%   | 0.23 [0.07, 0.39]                  |                                   |
| Meisner, et al. 2003    | 0.065           | 0.04427746 | 3.3%   | 0.07 [0.02, 0.15]                  |                                   |
| Michael, et al. 2018    | 0.2461          | 0.05704476 | 0.2%   | 0.25 [0.13, 0.36]                  |                                   |
| Millet, et al. 2004     | 0.053           | 0.0139638  | 0.3%   | 0.05 [-0.05, 0.15]                 |                                   |
| Nichol, et al. 2004     | 0.061           | 0.02349004 | 0.6%   | 0.06 [0.01, 0.13]                  |                                   |
| Nwachukwu, et al. 2011  | 0.083           | 0.00990198 | 3.7%   | 0.08 [0.07, 0.10]                  |                                   |
| Orbo, et al. 1996       | 0.019           | 0.01332345 | 2.5%   | 0.02 [0.01, 0.05]                  |                                   |
| Pasinasai, et al. 2019  | 0.028           | 0.00871908 | 3.8%   | 0.03 [0.01, 0.05]                  |                                   |
| Patel, et al. 2015      | 0.15            | 0.03168496 | 0.6%   | 0.15 [0.09, 0.21]                  |                                   |
| Proctor, et al. 2005    | 0.008           | 0.00813224 | 4.0%   | 0.01 [0.01, 0.02]                  |                                   |
| Rowden, et al. 2008     | 0.123           | 0.03043615 | 0.6%   | 0.12 [0.08, 0.18]                  |                                   |
| Romain, et al. 2019     | 0.088           | 0.00994783 | 3.4%   | 0.09 [0.07, 0.11]                  |                                   |
| Runner, et al. 2018     | 0.082           | 0.03211156 | 0.6%   | 0.08 [0.02, 0.14]                  |                                   |
| Rushd, et al. 2019      | 0.053           | 0.01915081 | 1.8%   | 0.05 [0.02, 0.08]                  |                                   |
| Sanders, et al. 2015    | 0.017           | 0.00351182 | 5.6%   | 0.02 [0.01, 0.02]                  |                                   |
| Su, et al. 2018         | 0.018           | 0.00398297 | 5.5%   | 0.02 [0.01, 0.03]                  |                                   |
| Wessucki, et al. 1994   | 0.144           | 0.04556956 | 0.3%   | 0.14 [0.05, 0.23]                  |                                   |
| Wessucki, et al. 1993   | 0.154           | 0.03828458 | 0.5%   | 0.15 [0.07, 0.23]                  |                                   |
| Werner, et al. 2015     | 0.016           | 0.00051951 | 6.2%   | 0.02 [0.01, 0.02]                  |                                   |
| Westermann, et al. 2018 | 0.148           | 0.06833562 | 0.2%   | 0.15 [0.01, 0.28]                  |                                   |

Total (95% CI)           | 100.0%          | 0.03 [0.03, 0.04] |                                   |                                   |

---

**Fig. 3** Joint stiffness’ pooled incidence after ACL reconstruction. IV, inverse variance; CI, confidence interval

---

**Fig. 4** Forest plot of joint stiffness between male and female groups after ACL reconstruction. M-H, Mantel-Haenszel; CI, confidence interval
Risk factors for joint stiffness after ACL reconstruction

Gender
A total of 5 studies and 3811 patients were included in this study group, and the results showed that gender is a risk factor for joint stiffness after ACL reconstruction (OR, 0.51; 95% CI, 0.38-0.68; \(p\) < 0.00001) (Fig. 4).

Time interval from trauma to surgery
A total of 5 studies and 1404 patients were included in this study group, and the results showed that there is no significant correlation between the time interval from trauma to surgery and joint stiffness after ACL reconstruction (OR, 2.56; 95% CI, 0.76-8.63; \(p\) = 0.13) (Fig. 5).

Graft type
A total of 5 studies and 3308 patients were included in this study group, and the results showed that there is no significant correlation between the type of graft and joint stiffness after ACL reconstruction (OR, 0.92; 95% CI, 0.52-1.64; \(p\) = 0.77) (Fig. 6).

Concomitant surgery with meniscus injury
A total of 6 studies and 61,723 patients were included in this study group, and the results showed that there is no significant correlation between concomitant surgery with meniscus injury and joint stiffness after ACL reconstruction (OR, 0.73; 95% CI, 0.52-1.03; \(p\) = 0.07) (Fig. 7).

Discussion
In this study, we found that the incidence of joint stiffness after ACL reconstruction varies from 0.1 to 71% with a relatively large fluctuation amplitude [6, 8, 9, 14, 15, 18–49]. After statistical analysis, we observed that the incidence was negatively related to the study publication time. Retrospectively, we found that ACL knowledge and research began in the mid-nineteenth century, and it was not until the early twentieth century that there was a proposal for ACL reconstruction [50]. With the advances in ACL anatomy and biomechanical research, the improvement of ACL injury diagnosis, the development of ACL surgery technology, and the concept of rehabilitation, the postoperative complications of ACL reconstruction, including joint stiffness, were significantly reduced and the curative effect significantly improved [51, 52]. However, once joint stiffness occurs, it can have a significant impact on patients’ quality of life and may require secondary surgery [53]. To avoid joint stiffness, particular attention to the related risk factors is required to pay attention.

The pooled results indicated that gender was a risk factor for joint stiffness after ACL reconstruction. When ignoring other related risk factors, the incidence of joint stiffness was significantly higher in women than that in men. Previous studies have reported that the female athletes’ risk of ACL injury is 2 to 6 times higher than that in male athletes [54]. The structural difference between male and female athletes can be used as an anatomical factor to explain the above phenomenon [55]. It was also shown that ACL injury occurs more frequently in women pre-
ovulation stage, which is related to the effects of estrogen, progesterone, testosterone, and relaxin on women’s ligaments [56, 57]. Park et al. reported that knee joint laxity and stiffness’ change is related to ovulation hormone levels [58]. Given that women are a common risk factor for ACL injury and postoperative joint stiffness, more attention should be paid to this factor by fully evaluating the patient’s hormone levels, choosing the appropriate timing of surgery and improving the efficacy of surgery.

Our pooled results showed that the time interval from trauma to surgery has no significant correlation with joint stiffness after ACL reconstruction. Our results were consistent with previous reports that indicated early ACL reconstruction surgery, within 3 weeks or even 1 week after trauma, does not increase the risk of postoperative joint stiffness [11, 13]. The most commonly used autografts for ACL reconstruction are the hamstring and the bone-patellar tendon-bone [59]. Despite their advantages and disadvantages, failure rates are low and there is no difference in graft fracture [60, 61]. Our results showed that there was no significant correlation between these two autografts and joint stiffness; therefore, both types of grafts can be used for ACL reconstruction, and the choice depends on the patient individual specificity. According to the literature, meniscal injury is associated with 40% to 60% of patients with ACL injury [62]. Meniscus plays very important roles in knee joints stability, stress transmission, proprioception, and joints’ lubrication and nutrition [63]. Many scholars have shown that the outcomes of ACL reconstruction alone, or in combination with a meniscal operation, are similar [64]. Our analysis also showed that simultaneous meniscus related surgery did not increase the risk of joint stiffness. Due to the important functions of the meniscus, we should select the appropriate treatment method according to the condition of the meniscal injury and its complete treatment.

Some limitations existed in this meta-analysis. First, most of the included studies were retrospective, which may have affected the results’ credibility. Second, there is a clinical heterogeneity that cannot be eliminated through subgroup analysis, which may be caused by differences in patients’ standards, included in each study, and the surgeons’ surgical techniques. In addition, there were some potential risk factors, such as age, weight, rehabilitation training, and preoperative activity limitation, which were not included in our analysis due to insufficient data. Despite these limitations, we believe that this study deepens our understanding of joint stiffness and provides guidance for preventing joint stiffness after ACL reconstruction. In the future, further studies will be needed to investigate the risk factors of joint stiffness after ACL reconstruction.

**Conclusion**

This study indicated that the incidence of joint stiffness after ACL reconstruction is 3%. Gender is a risk factor for joint stiffness after ACL reconstruction.

**Abbreviations**

ACL: Anterior cruciate ligament; OR: Odds ratios; CI: Confidence intervals

**Acknowledgements**

All contributors are authors.

**Authors’ contributions**

WB and LHD contributed in study concept construction. WB and ZJL contributed in data collection, analysis and interpretation, and manuscript writing. XXH, SJ, and LN made substantial contributions to the interpretation of data and provided final approval of the version published.

**Funding**

This work was supported by grants from the National Natural Science Foundation of China (grant number 81772384).

**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**

No formal ethical approval and consent to participate are required due to no collection of primary data.

**Consent for publication**

No consent for publication is required due to no personal data included.

**Competing interests**

The authors declare that they have no competing interests.
39. Borders P, Laboute E, Bertolotti A, Dalmay JF, Puig P, Trouve P, Verhaegue E, Joseph PA, Dehail P, De Seze M. No beneficial effect of bracing after anterior cruciate ligament reconstruction in a cohort of 969 athletes followed in rehabilitation. Annals of physical and rehabilitation medicine (no pagination). 2017. 2017;Date of Publication: April 18.
40. Runner RP, Boden SA, Godfrey WS, Premkumar A, Samady H, Gottschall MB, Xerogeanes JW. Quadriceps strength deficits after a femoral nerve block versus adductor canal block for anterior cruciate ligament reconstruction: a prospective, single-blinded, randomized trial. Orthop J Sports Med. 2018;6.
41. Su AW, Storey EP, Lin SC, Forst B, Lawrence JT, Ganley TJ, Wells L. Association of the graft size and arthrofibrosis in young patients after primary anterior cruciate ligament reconstruction. J Am Acad Orthop Surg. 2018;26:483–49.
42. Osti M, El Attal R, Doskar W, Höck P, Smekal V. High complication rate following dynamic intraligamentary stabilization for primary repair of the anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc. 2019;27(1):29–36.
43. Westermann RW, Spindler KP, Huston LJ, Wolf BR. Outcomes of grade III medial collateral ligament injuries treated concurrently with anterior cruciate ligament reconstruction: a multicenter study. Arthroscopy. 2019;35:1466–72.
44. Patel AR, Sarkisova N, Smith R, Gupta K, VandenBerg CD. Socioeconomic status impacts outcomes following pediatric anterior cruciate ligament reconstruction. Medicine. 2019;98:e15361.
45. Cruz AI, Fabricant PD, McGraw M, Rozell JC, Ganley TJ, Wells L. All-epiphyseal ACL reconstruction in children: review of safety and early complications. J Pediatr Orthop. 2017;37:204–9.
46. Offerhaus C, Balke M, Hente J, Gehling M, Bendl S, Hoher J. Vancomycin pre-soaking of the graft reduces postoperative infection rate without increasing risk of graft failure and arthrofibrosis in ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2019;27(9):3014–21.
47. Panisset JC, Gonzalez JF, de Lavigne C, Ode Q, Dejour D, Ehlinger M, Fayard JM, Lustig S. ACL reconstruction in over-50 year-olds: a comparative study between prospective series of over-50 year-old and under-40-year-old patients. Orthop Traumatol Surg Res. 2019;105:5259–565.
48. Grassi A, Costa GG, Cialdella S, Lo Presti M, Nerli MP, Zaffagnini S. The 90-day readmission rate after single-bundle ACL reconstruction plus LET: analysis of 2,559 consecutive cases from a single institution. J Knee Surg. 2020.
49. Hulett J, Gottschall M, Fraser K, Boden A, Dalwadi P, Xerogeanes J, Hammond K. Risk factors for manipulation under anesthesia and/or lysis of adhesions following anterior cruciate ligament reconstruction. Arthroscopy. 2018;34:e8–9.
50. Schindler OS. Surgery for anterior cruciate ligament deficiency: a historical perspective. Knee Surg Sports Traumatol Arthrosc. 2012;20:5–47.
51. Myer GD, Paterno MV, Ford KR, Quatman CE, Hewett TE. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. J Orthop Sports Phys Ther. 2006;36:385–402.
52. Chambat P, Guier C, Sonnery-Cottet B, Fayard JM, Thaunat M. The evolution of ACL reconstruction over the last fifty years. Int Orthop. 2013;37:181–6.
53. Salzler MJ, Lin A, Miller CD, Herold S, Ingarg JJ, Hamer CD. Complications after arthroscopic knee surgery. Am J Sports Med. 2014;42:992–6.
54. Phodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. Arthroscopy. 2007;23:1320–5.e6.
55. Huston LJ, Greenfield ML, Wojtys EM. Anterior cruciate ligament injuries in the female athlete. Potential risk factors. Clin Orthop Relat Res. 2000:50–63.
56. Slaeterbeck JR, Fuzie SF, Smith MP, Clark RJ, Xu K, Starch DW, Hardy DM. The menstrual cycle, sex hormones, and anterior cruciate ligament injury. J Athl Train. 2002;37:275–8.
57. Wentorf FA, Sudoku K, Moses C, Arentz EA, Carlson CS. The effects of estrogen on material and mechanical properties of the intra- extra-articular knee structures. Am J Sports Med. 2006;34:1948–52.
58. Park SK, Stefanyszyn DJ, Loitz-Ramage B, Hart DA, Ronsky JL. Changing hormone levels during the menstrual cycle affect knee laxity and stiffness in healthy female subjects. Am J Sports Med. 2009;37:588–98.
59. Albor LR, Chan PH, Funahashi TT, Wynn R, Maleis GS, Inacio MC. Surgical technique trends in primary ACL reconstruction from 2007 to 2014. J Bone Joint Surg Am. 2016;98:1079–89.
60. Xie X, Liu X, Chen Z, Yu Y, Peng S, Li Q. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. Knee. 2015;22:100–10.