Nonsurgical or Surgical Treatment of ACL Injuries: Knee Function, Sports Participation, and Knee Reinjury

The Delaware-Oslo ACL Cohort Study

Hege Grindem, PT, PhD, Ingrid Eitzen, PT, PhD, Lars Engebretsen, MD, PhD,
Lynn Snyder-Mackler, PT, ScD, SCS, ATC, FAPTA, and May Arna Risberg, PT, PhD

Investigation performed at the Norwegian Research Center for Active Rehabilitation, Department of Sports Medicine, Norwegian School of Sport Sciences, and the Department of Orthopaedics, Oslo University Hospital, Oslo, Norway

Background: While there are many opinions about the expected knee function, sports participation, and risk of knee reinjury following nonsurgical treatment of injuries of the anterior cruciate ligament (ACL), there is a lack of knowledge about the clinical course following nonsurgical treatment compared with that after surgical treatment.

Methods: This prospective cohort study included 143 patients with an ACL injury. Isokinetic knee extension and flexion strength and patient-reported knee function as recorded on the International Knee Documentation Committee (IKDC) 2000 form were collected at baseline, six weeks, and two years. Sports participation was reported monthly for two years with use of an online activity survey. Knee reinjuries were reported at the follow-up evaluations and in a monthly online survey. Repeated analysis of variance (ANOVA), generalized estimating equation (GEE) models, and Cox regression analysis were used to analyze group differences in functional outcomes, sports participation, and knee reinjuries, respectively.

Results: The surgically treated patients (n = 100) were significantly younger, more likely to participate in level-I sports, and less likely to participate in level-II sports prior to injury than the nonsurgically treated patients (n = 43). There were no significant group-by-time effects on functional outcome. The crude analysis showed that surgically treated patients were more likely to sustain a knee reinjury and to participate in level-I sports in the second year of the follow-up period. After propensity score adjustment, these differences were nonsignificant; however, the nonsurgically treated patients were significantly more likely to participate in level-II sports during the first year of the follow-up period and in level-III sports over the two years. After two years, 30% of all patients had an extensor strength deficit, 31% had a flexor strength deficit, 20% had patient-reported knee function below the normal range, and 20% had experienced knee reinjury.

Conclusions: There were few differences between the clinical courses following nonsurgical and surgical treatment of ACL injury in this prospective cohort study. Regardless of treatment course, a considerable number of patients did not fully recover following the ACL injury, and future work should focus on improving the outcomes for these patients.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

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A commentary by Donald C. Fithian, MD, is linked to the online version of this article at jbjs.org.

Injuries to the anterior cruciate ligament (ACL) are common in sports, and they may lead to reduced knee function and sports participation as well as the early onset of knee osteoarthritis[1]. A wish to return to pivoting sports remains the most important indication for ACL reconstruction, and it has been argued that surgery improves the ability to return to sports as well as reduces the risk of knee reinjury[2-4]. However, there is a lack of evidence that the outcomes of surgical treatment are better than those of nonsurgical treatment with respect to knee function, sports participation, or the early onset of knee osteoarthritis[5-8].

Nonsurgical and surgical treatment courses differ not only with regard to whether or not patients undergo ACL reconstruction but also with regard to rehabilitation and recommendations for future sports participation[7]. Clinicians often must counsel patients for whom either surgical or nonsurgical treatment is a reasonable alternative. In order to guide treatment decisions, knowledge about the clinical course following both treatment options is important. Studies on the outcomes after treatment as it is practiced provide knowledge on the expected outcomes in different patient groups, and a prospective design enables documentation of why patients choose the treatment that they choose. However, nonsurgically and surgically treated patient populations may differ in age and preinjury activity level[9,10], two factors that also affect outcome[11,12]. While there have been several previous observational studies of outcomes following nonsurgical and surgical treatment of a torn ACL[10,13-17], the presence of both measured and unmeasured differences between patient groups makes it difficult to conclude whether the outcome is caused by the treatment or by preexisting differences between patient groups. Although seldom utilized, statistical balancing of measured confounders reduces this bias.

The aim of this prospective cohort study was to evaluate knee function, sports participation, and knee reinjuries over two years in a group of patients who chose either nonsurgical or surgical treatment for an ACL injury. To provide information on how the outcome was affected by known baseline differences between the patient groups, we report both unadjusted and adjusted estimates.

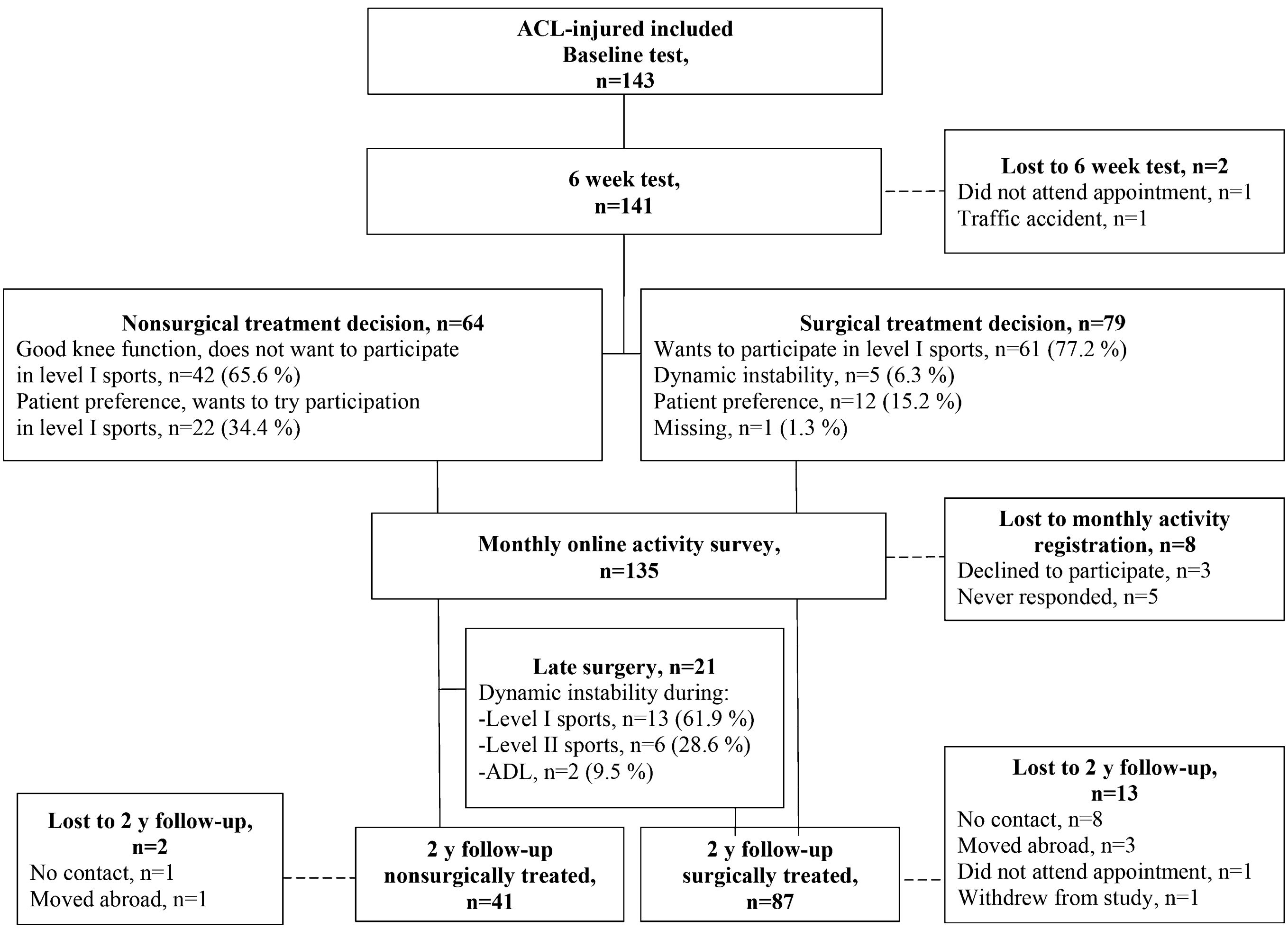

Fig. 1

Flowchart of patient participation in the study. ADL = activities of daily living. One nonsurgically treated and four surgically treated patients did not perform strength testing at the two-year follow-up evaluation because of recently sustained injuries.

TABLE I Sports Recorded in the Monthly Online Activity Survey Classified According to Activity Level

Sport	Activity Level
Handball, soccer, basketball, floorball	I
Volleyball, martial arts, gymnastics, ice hockey, tennis/squash, alpine/telemark skiing, snowboarding, dancing/aerobics	II
Cross-country skiing, running, cycling, swimming, strength training	III

Materials and Methods

Subjects

During the years 2007 to 2011, 143 consecutive patients were included in this prospective cohort study (Fig. 1). All patients were recruited from the Norwegian Sports Medicine Clinic (NIMI) and had sustained an ACL rupture within the previous three months. The diagnosis was confirmed with magnetic resonance imaging (MRI) and a side-to-side difference of ≥3 mm measured with a KT-1000 arthrometer (MEDmetric, San Diego, California). Other inclusion criteria were an age of thirteen to sixty years and participation in level-I or II sports[18] twice a week or more (Table I). Patients were excluded if they had a current or previous injury to the contralateral leg or if the MRI showed another grade-III ligament injury, fracture, or full-thickness articular cartilage damage. Patients with a meniscal tear were excluded only if they had pain or effusion during or following plyometric activities.

All patients signed an informed-consent form prior to inclusion in the study. The study was approved by the regional ethical committee for South-Eastern Norway. The study was registered in ClinicalTrials.gov (NCT02115451).

Treatment Algorithm

Before inclusion, the patients underwent rehabilitation to resolve initial impairments. Immediately after inclusion, all underwent five weeks of rehabilitation following the protocol that we described previously[19]. During these weeks, patients received information about nonsurgical and surgical treatment. After this period, they chose the type of treatment and the main reason for their choice was recorded prospectively. Nonsurgically treated patients underwent continued rehabilitation as needed, typically for two to three additional months. Surgically treated patients underwent ACL reconstruction with bone-patellar tendon-bone autograft, single-bundle hamstring autograft, or double-bundle hamstring autograft. The postoperative rehabilitation consisted mainly of strength training, neuromuscular training, and plyometrics and lasted for six to twelve months[18].

All patients were advised not to return to level-I or II sports (Table I) until the limb symmetry indexes were ≥90% for hamstring and quadriceps strength as well as for four hop tests[7]. In addition, surgically treated patients were recommended to avoid level-II sports for the first six postoperative months and level-I sports for the first nine postoperative months. Nonsurgically treated patients were advised not to participate in any level-I sports forever.

Data Collection

Testing was performed at baseline, after completion of the five-week rehabilitation program (six-week test), and two years later (nonsurgically treated patients) or two years postoperatively (surgically treated patients). After the patient performed a standardized warm-up on a stationary bicycle, the isokinetic concentric muscle strength of the knee extensors and knee flexors was measured at 60°/sec with a

TABLE II Descriptive Characteristics of Nonsurgically and Surgically Treated Patients

	Nonsurgical (N = 43)	Surgical (N = 100)	P Value
Preinjury participation *(yes/no [% yes])*			
Level I	19/24 (44)	80/20 (80)	<0.001
Level II	30/13 (70)	51/49 (51)	0.038
Sex *(F/M [% F])*	24/19 (56)	56/44 (56)	0.984
Age* *(yr)*	30.2 ± 8.8	24.0 ± 7.2	<0.001
Height* *(cm)*	175.6 ± 8.9	173.8 ± 9.0	0.278
Weight* *(kg)*	72.7 ± 11.7	72.6 ± 14.5	0.974
BMI* *(kg/m²)*	23.5 ± 2.6	23.9 ± 3.3	0.479
Concomitant injuries† *(no. [%])*			
Medial meniscus	10 (23)	25 (25)	0.842
Lateral meniscus	6 (14)	22 (22)	0.266
Medial cartilage	3 (7)	3 (3)	0.365
Lateral cartilage	4 (9.3)	10 (10)	1.000
Medial collateral ligament (grades I-II)	12 (27.9)	28 (28)	0.991
Lateral collateral ligament (grades I-II)	4 (9)	1 (1)	0.029
Popliteus	0 (0)	2 (2)	1.000
No concomitant meniscal, cartilage, ligament, or muscle injury	18 (42)	44 (44)	0.813
Time from injury to baseline test* *(mo)*	2.1 ± 0.5	2.0 ± 0.6	0.615
Time from injury to 6-week test* *(mo)*	3.3 ± 0.6	3.2 ± 0.7	0.695

*The values are given as the mean and standard deviation. †Diagnosed with MRI at inclusion.

TABLE III Functional Outcomes of Nonsurgically and Surgically Treated Patients from Baseline to the Two-Year Follow-up Evaluation

	Baseline*		6 Wk*		2 Yr*	
	Nonsurgical	Surgical	Nonsurgical	Surgical	Nonsurgical	Surgical
IKDC-2000 score	72.8 ± 11.3	69.8 ± 11.5	80.4 ± 10.4	77.8 ± 11.2	89.2 ± 11.3	88.9 ± 12.1
Knee extension strength						
Uninvolved *(Nm)*	186.8 ± 46.3	193.6 ± 52.3	195.1 ± 49.6	204.4 ± 52.5	198.4 ± 55.4	213.1 ± 55.3
Involved *(Nm)*	167.1 ± 43.0	171.7 ± 48.1	180.8 ± 45.4	190.0 ± 49.3	190.3 ± 51.1	200.9 ± 55.5
Limb symmetry *(%)*	90.0 ± 10.9	89.0 ± 10.5	93.2 ± 8.0	93.5 ± 10.6	96.4 ± 9.8	99.2 ± 15.2
Knee flexion strength						
Uninvolved *(Nm)*	95.4 ± 29.1	95.9 ± 26.1	101.2 ± 29.1	104.4 ± 26.3	104.5 ± 31.9	108.6 ± 29.2
Involved *(Nm)*	88.8 ± 26.2	91.3 ± 25.8	98.3 ± 26.8	101.8 ± 26.9	102.6 ± 29.0	102.6 ± 29.3
Limb symmetry *(%)*	94.9 ± 15.2	95.7 ± 12.4	97.9 ± 10.8	97.7 ± 10.6	99.2 ± 15.2	94.7 ± 11.5

*The values are given as the mean and standard deviation and represent the patients for whom data were available at the time of follow-up. IKDC-2000 scores were available for forty-one nonsurgically treated patients and eighty-six surgically treated patients (one patient did not return for the six-week assessment). Knee extension and flexion strength data were available for forty nonsurgically treated patients and eighty-one surgically treated patients (two patients did not return for the six-week assessment).

Biodex 6000 dynamometer (Biodex Medical Systems, Shirley, New York). Four trial repetitions were performed with submaximal effort, followed by a one-minute rest, and then five test repetitions were recorded. The uninjured leg was always tested first. For assessment of patient-reported knee function, the patients completed the International Knee Documentation Committee (IKDC) 2000 form, which is a valid, reliable, and responsive measure of knee function in patients with knee injuries[20,21].

An online survey (QuestBack version 9.6; QuestBack AS, Oslo, Norway) was used to record monthly sports participation in the period between the six-week test and the two-year follow-up for nonsurgically treated patients, and between the surgery and the two-year follow-up for surgically treated patients[22]. The online activity survey posed the question: "Which of the following sports have you participated in during the last four weeks?" followed by the sports listed in Table I. Patients were also asked how many times they had, on average, participated in those sports. This response was categorized as zero or once per week, two or three times per week, four or five times per week, or more than five times per week. The online activity survey is highly reliable and provides a valid representation of sports participation in this patient group[22].

Patients reported whether or not they had experienced reinjury in the index or contralateral knee at the follow-up evaluations and on the monthly online survey. Patients who reported knee reinjury underwent clinical examination by a physical therapist or orthopaedic surgeon. According to the standard practice at our institution, the diagnosis was verified with use of MRI and/or during surgery when clinically indicated.

Data Management and Statistical Analysis

Muscle strength was reported as the limb symmetry index for peak torque: (peak torque of involved leg)/(peak torque of uninvolved leg) × 100. The number of patients with a limb symmetry index of <90% and an IKDC-2000 score below the age and sex-specific 15th percentile for uninjured individuals[11] was also reported. Participation in level-I, II, and III sports was defined as participation in at least one sport at the respective level.

Group differences in nominal variables were analyzed with the chi-square or Fisher exact test. Independent t tests were used to analyze differences in normally distributed continuous variables, and the Mann-Whitney U test was utilized when variables were not normally distributed.

Knee-function change over time and group differences in the change over time were analyzed with a repeated-measures analysis of variance (ANOVA). The a priori sample-size estimation showed that thirty-three patients were needed in each group to detect a small group-by-time effect on the IKDC-2000 scores (Cohen's f = 0.2, between-measures correlation = 0.6). The standardized response mean from baseline to the two-year follow-up evaluation was reported for all functional outcomes, and was calculated on the basis of the mean change from baseline to the two-year follow-up evaluation divided by the standard deviation (SD) of the change[23]. Standardized response mean values of 0.2, 0.5, and 0.8 were regarded as small, moderate, and large changes, respectively[24].

To analyze group differences in level-I, II, and III sports participation and in weekly frequency of sports participation, generalized estimating equation (GEE) models were fitted, with adjustment for dependence between months with a first-order autoregressive correlation structure. The logit link and binomial variance functions were used for participation in level-I, II and III sports, whereas the identity link and Gaussian variance functions were used in the analysis of frequency of sports participation. Robust standard error estimates were used in all analyses. The analyses of participation in level-I and II sports were stratified by the first and second year of the follow-up period because of significant group-by-time interactions.

Cox regression analysis with robust estimation of standard errors was used to assess group differences in the risk of knee reinjury. Significance was tested with the Wald test.

To account for potentially important baseline differences between surgically and nonsurgically treated patients, propensity score covariate-adjusted analyses were performed for all outcomes. The propensity score was estimated with use of logic regression and provides a single metric of a patient's probability of being surgically treated, based on the following independent variables: preinjury participation in level-I sports, preinjury participation in level-II sports, age, sex, body mass index (BMI), and concomitant injuries as reported in Table II. The analysis of reinjuries was not adjusted for postinjury sports participation because postinjury sports participation is likely to be affected by treatment. The mean propensity scores (and SD) of the nonsurgically and surgically treated patients were 0.54 ± 0.26 and 0.77 ± 0.16, respectively, with an area under the curve of 0.76 (95% confidence interval [CI]: 0.67 to 0.85). Sensitivity analyses were performed by comparing results from the full data set with results after trimming non-overlapping regions of the propensity score (87.5% of the data retained). Findings were consistent and led to similar conclusions.

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TABLE III (*continued*)

	Standardized Response Mean from Baseline to 2 Yr		P Value	
Time P Value	Nonsurgical	Surgical	Group × Time	Propensity-Score-Adjusted Group × Time
<0.001	1.06	1.21	0.650	0.261
<0.001	0.49	0.59	0.472	0.788
<0.001	0.84	0.86	0.676	0.906
<0.001	0.43	0.46	0.664	0.448
<0.001	0.55	0.73	0.408	0.638
<0.001	0.80	0.60	0.413	0.689
0.257	0.21	−0.08	0.165	0.924

Results

Of the 143 included patients, forty-three (30%) remained nonsurgically treated and 100 (70%) underwent ACL reconstruction (Fig. 1). Seventy-nine patients made a primary decision to undergo ACL reconstruction, and twenty-one decided later to undergo surgery after initially opting for nonsurgical treatment. Descriptive characteristics and outcomes for these two groups of patients (primary and later decision) can be found in the Appendix.

The nonsurgically treated group was significantly older than the surgically treated group ($p < 0.001$), less likely to participate in level-I sports prior to injury ($p < 0.001$), and more likely to participate in level-II sports prior to injury ($p = 0.038$) (Table II). The two-year follow-up was performed 24.5 ± 0.7 months after the six-week test for nonsurgically treated patients and 24.4 ± 0.6 months after surgery for the surgically treated patients ($p = 0.493$).

At the time of ACL reconstruction, thirty-two patients (32%) had concomitant surgery on one meniscus (twenty-eight patients) or both menisci (four patients). The medial meniscus was repaired in fifteen patients (15%) and partially resected in five (5%). The lateral meniscus was repaired in one patient (1%) and partially resected in fifteen (15%). No surgical procedures related to the index injury were performed in the nonsurgically treated group.

Knee Function

There were no significant group differences in baseline IKDC-2000 scores or knee extension and flexion strength (all $p \geq 0.16$), and no significant group-by-time effects were found (Table III). Both groups showed large standardized response mean values for the IKDC-2000 scores and moderate-to-large standardized response mean values for extension and flexion strength of the involved leg. At the two-year follow-up evaluation, seven nonsurgically treated patients (17%) and nineteen surgically treated patients (22%) had IKDC-2000 scores below the normative 15th percentile. Nine nonsurgically treated patients (23%) and twenty-eight surgically treated patients (34%) had a knee-extension limb symmetry index of <90%, and nine nonsurgically treated patients (23%) and twenty-nine surgically

TABLE IV Comparison of Monthly Sports Participation Between Nonsurgically and Surgically Treated Patients Over Two Postoperative Years*

	Crude Odds Ratio† (95% CI), P Value	Propensity-Score-Adjusted Odds Ratio† (95% CI), P Value
Participation in level-I sports		
1st year of follow-up	1.45 (0.76-2.76), 0.265	0.73 (0.38-1.41), 0.350
2nd year of follow-up	2.78 (1.40-5.52), 0.004	1.30 (0.61-2.78), 0.497
Participation in level-II sports		
1st year of follow-up	0.23 (0.14-0.38), <0.001	0.28 (0.16-0.49), <0.001
2nd year of follow-up	0.65 (0.37-1.14), 0.131	0.88 (0.47-1.34), 0.689
Participation in level-III sports	0.47 (0.21-1.05), 0.065	0.41 (0.18-0.94), 0.034

*Sports participation was recorded from the six-week test to the two-year test in the nonsurgical group and from the ACL reconstruction to the two-year test in the surgical group. †An odds ratio of >1 indicates a higher number of patients treated with ACL reconstruction participating in sports.

TABLE V Knee Reinjuries in Nonsurgically and Surgically Treated Patients*

	Nonsurgical (N = 43)	Surgical (N = 100)
Index knee *(no. [%])*		
ACL rerupture	0	8 (8)
Medial meniscus	2 (5)	9 (9)
Lateral meniscus	2 (5)	4 (4)
Medial cartilage	1 (2)	2 (2)
Lateral cartilage	1 (2)	2 (2)
Patellofemoral cartilage		3 (3)
Medial collateral ligament		1 (1)
Patellar subluxation		1 (1)
Contralateral knee *(no. [%])*		
ACL rupture	1 (2)	2 (2)
Lateral meniscus	0 (0)	1 (1)
Medial collateral ligament	0 (0)	1 (1)

*Knee reinjuries were recorded from the six-week test to the two-year test in the nonsurgical group and from the ACL reconstruction to the two-year test in the surgical group. Of the forty-one injuries, five (12%) were exclusively diagnosed clinically; fifteen (37%) were diagnosed by clinical examination and MRI; thirteen (32%) were diagnosed by clinical examination and arthroscopy; and eight (20%) were diagnosed by clinical examination, MRI, and arthroscopy. The seven injuries in the nonsurgical group were all diagnosed by clinical examination and arthroscopy.

treated patients (35%) had a knee-flexion limb symmetry index of <90%.

Sports Participation

The overall response rate for the online activity survey was 87%. In total, 2820 observations from 135 patients were included in the analyses. The follow-up period was from the six-week test to the two-year follow-up evaluation for the nonsurgically treated patients and from the surgery to the two-year follow-up evaluation for the surgically treated patients.

Consistent with the differences in preinjury sports participation, nonsurgically and surgically treated patients had different sports-activity profiles after the injury (Fig. 2). The crude (unadjusted) analysis showed that a significantly higher number of surgically treated patients participated in level-I sports in the second year of the follow-up period ($p = 0.004$); however, there was no significant difference after propensity-score adjustment (Table IV). The adjusted analyses showed that a significantly higher number of nonsurgically treated patients participated in level-III sports over the two years ($p = 0.034$) and in level-II sports in the first year of the follow-up period ($p < 0.001$). In every month of the two-year follow-up period, the median frequency of sports participation was two to three times per week in both groups, and it did not differ significantly between the groups (adjusted β [95% CI]: 0.20 [−0.01 to 0.41], $p = 0.060$).

Knee Reinjuries

Four nonsurgically treated patients (9%) reported a total of seven knee reinjuries (Table V). Twenty-four surgically treated patients (24%) reported a total of thirty-four knee reinjuries in the period from the surgery to the two-year follow-up evaluation. Nonsurgically treated patients sustained 8.0 (95% CI: 2.1 to 13.9) knee reinjuries per 100 patient-years in the period from the six-week test to the two-year follow-up evaluation, and the surgically treated patients sustained 16.8 (95% CI: 11.1 to 22.4) reinjuries per 100 patient-years in the period from the surgery to the two-year follow-up evaluation. While surgically treated patients had a significantly higher crude risk of knee reinjury (hazard ratio [95% CI]: 2.89 [1.02 to 8.13], $p = 0.045$), there was no significant difference between the groups after propensity-score adjustment (adjusted hazard ratio [95% CI]: 1.87 [0.52 to 6.78], $p = 0.340$).

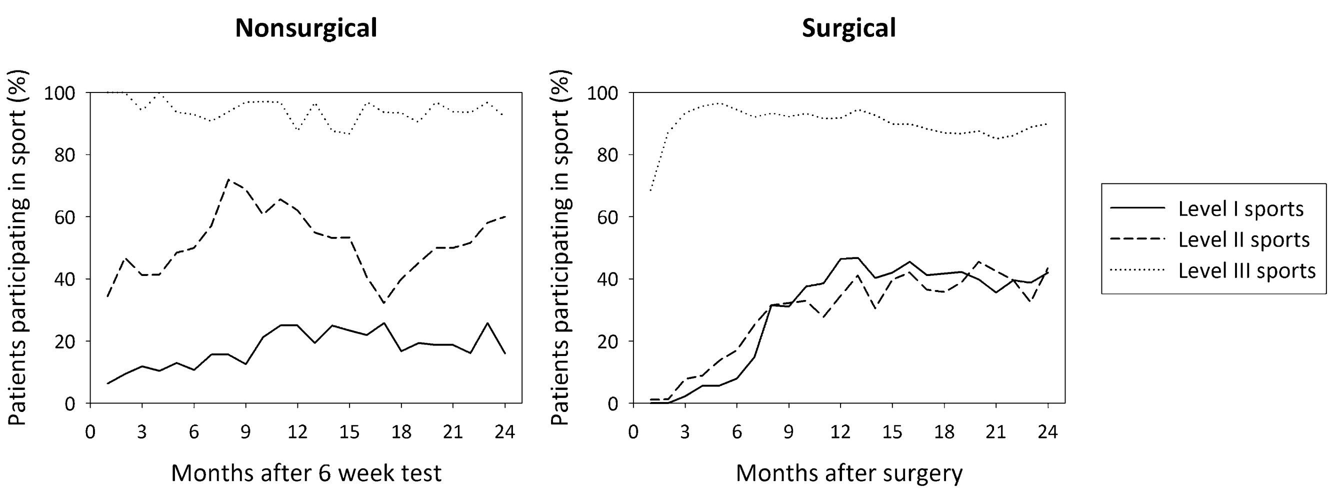

Fig. 2

Percentages of nonsurgically (n = 37) and surgically treated (n = 98) patients participating in level-I, II, and III sports over two years (unadjusted data representing all patients, regardless of preinjury participation in respective level of sport).

Discussion

Knowledge of the clinical courses following nonsurgical and surgical treatment of ACL injuries is needed to provide patients with evidence-based recommendations for treatment. Our prospective cohort study suggests that there are few differences in the clinical course between patients who choose nonsurgical treatment and those who choose surgical treatment. However, surgically treated patients were more active in level-I sports in the second postoperative year and had a higher crude risk of knee reinjury. These findings were not significant in the adjusted analyses, suggesting that the higher participation in level-I sports and reinjury risk were attributed to surgically treated patients being younger and more active in level-I sports prior to injury rather than to the treatment course. After propensity-score adjustment, the only significant differences found were that nonsurgically treated patients were more likely to participate in level-II sports in the first year of the follow-up period and in level-III sports over two years. The first finding can be explained by surgically treated patients having reduced knee function and activity restrictions early after ACL reconstruction, and the difference in level-III sports participation was likely not important as >85% of the surgically treated patients also participated in these sports from the second to the twenty-fourth postoperative month (Fig. 2).

No significant differences were detected over time in patient-reported knee function or muscle strength between our nonsurgically and surgically treated patients. These results are in line with the findings in previous studies by Frobell et al.[5,6], Ageberg et al.[25], Daniel et al.[13], Meuffels et al.[8], and Myklebust et al.[16]. Consequently, current evidence does not suggest that patients who choose nonsurgical treatment should expect inferior knee function compared with those who choose ACL reconstruction. However, it is likely that some patients will benefit from surgery while others will not. Although previous studies have provided evidence of a differential response to ACL injury[26,27], there is no evidence-based algorithm that accurately identifies nonsurgically treated patients who will be able to participate in level-I sports over the long-term[28]. For this reason, all of our patients were advised to undergo ACL reconstruction if they intended to participate in level-I sports. Still, 34% of the patients who chose a nonsurgical approach intended to resume level-I sports when they made the treatment choice (Fig. 1). As shown previously[7], there was a large degree of noncompliance with the recommended activity restrictions (Fig. 2). Thirty-four percent of the surgically treated patients participated in level-I sports and 18% participated in level-II sports earlier than recommended, while 56% of the nonsurgically treated patients at some point participated in level-I sports despite the recommendations to avoid them.

In terms of graft choice and meniscal procedures performed at the time of ACL reconstruction, the surgically treated patients in this study were similar to patients included in the Scandinavian ACL registries[29]. Although we did not find significant differences in surgical procedures performed at the time of ACL reconstruction between patients who underwent ACL reconstruction as a primary intervention and those who did so as a result of a later decision (see Appendix), studies with larger samples have shown that the prevalence of meniscal tears increases with a longer time from the injury to the ACL reconstruction[30,31]. However, the comparison period for sports participation and reinjury risk was from the surgery to two years postoperatively, regardless of the timing of the surgery. The four injuries that occurred between the ACL injury and the surgery in the surgically treated group (see Appendix) therefore did not increase the reported reinjury rate in surgically treated patients.

As the current study was not powered to assess differences between patients who made a primary decision and those who made a late decision to undergo ACL reconstruction, the inferences that can be drawn from these results are limited. Patients who made a late decision to undergo ACL reconstruction did so because of episodes of dynamic instability, mainly during level-I-sports activity (Fig. 1). After surgery, a significantly lower number of these patients participated in level-I sports compared with those who chose surgery as a primary decision, and only two patients who made a late decision to undergo surgery reported knee reinjuries. Fear of reinjury is a more frequent reason for ceasing sports participation than knee problems[32]. As there were no significant differences in functional outcomes, it is plausible to suggest that the patients in our study who made a late decision to undergo surgery avoided level-I sports to protect their knees from additional injury rather than because of a decreased ability to participate in sports.

While this study provides information on the clinical course following treatment of ACL injuries, the observational design prohibits solid conclusions about differences in treatment efficacy. Although we provided propensity-score-adjusted results to reduce the inherent selection bias of the design, unmeasured confounding factors were not accounted for and the patient sample was too small for stratification. Our results may not apply to patients who undergo other surgical or rehabilitation interventions, or to institutions with different criteria for treatment selection. A knee reinjury was recorded only if the patient reported one. Thus, future studies including follow-up MRIs of all patients are needed to evaluate the total extent of structural changes in these patient groups. Additionally, we did not assess the relationship between postinjury sports participation and knee reinjuries in this study; it should be an area of focus in future studies. Although the average functional outcome of both treatments was good, one-fifth of all patients experienced knee reinjury and one-third of patients who initially chose nonsurgical treatment later underwent ACL reconstruction. Studies examining patients characteristics that can predict the success and failure of both treatments are therefore needed. Finally, continued follow-up is necessary to evaluate longer-term sports participation, reinjury risk, and development of knee osteoarthritis.

In conclusion, this prospective cohort study suggests that there are few differences in the two-year clinical course between patients who choose nonsurgical treatment of an ACL injury and those who choose surgical treatment. While surgically treated patients had a significantly higher crude risk of knee reinjury, there was no significant difference in the risk after propensity-score adjustment. Patients in both groups showed large improvements in patient-reported knee function; however, at two years, one-fifth of the patients reported knee reinjuries and one-third exhibited muscle strength deficits.

Appendix

eA Tables showing descriptive patients characteristics, surgical data, functional outcomes, monthly sports participation, and knee reinjuries according to whether the decision to undergo ACL reconstruction was primary or late are available with the online version of this article as a data supplement at jbjs.org. ■

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Hege Grindem, PT, PhD
May Arna Risberg, PT, PhD
Norwegian Research Center for Active Rehabilitation,
Department of Sports Medicine,
Norwegian School of Sport Sciences,
P.O. Box 4014, Ullevål Stadion,
0806 Oslo, Norway.
E-mail address for H. Grindem: hege.grindem@nih.no

Ingrid Eitzen, PT, PhD
Norwegian Research Center for Active Rehabilitation,
Department of Orthopaedics,
Oslo University Hospital,
Kirkeveien 166,
0407 Oslo, Norway

Lars Engebretsen, MD, PhD
Department of Orthopaedics,
Oslo University Hospital,
Kirkeveien 166, 0407 Oslo, Norway

Lynn Snyder-Mackler, PT, ScD, SCS, ATC, FAPTA
Department of Physical Therapy,
College of Health Sciences,
University of Delaware,
540 Sourth College Avenue,
Newark, DE 19713

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VINCENT EGGERDING, MD[1] • **DUNCAN E. MEUFFELS**, MD, PhD[1] • **SITA M.A. BIERMA-ZEINSTRA**, PhD[1,2]
JAN A. VERHAAR, MD, PhD[1] • **MAX REIJMAN**, PhD[1]

Factors Related to the Need for Surgical Reconstruction After Anterior Cruciate Ligament Rupture: A Systematic Review of the Literature

Anterior cruciate ligament (ACL) rupture is a common injury, with an estimated incidence of 4 new cases per 10 000 people yearly.[27] Anterior cruciate ligament rupture has a high impact not only on the personal life of the individual, who must undertake a long recovery period, but also on society, owing to loss of productivity and medical costs.[3,9,16]

STUDY DESIGN: Systematic literature review.

OBJECTIVES: To summarize and evaluate research on factors predictive of progression to surgery after nonoperative treatment for an anterior cruciate ligament (ACL) rupture.

BACKGROUND: Anterior cruciate ligament rupture is a common injury among young, active individuals. Surgical reconstruction is often required for patients who do not regain satisfactory knee function following nonsurgical rehabilitation. Knowledge of factors that predict the need for surgical reconstruction of the ACL would be helpful to guide the decision-making process in this population.

METHODS: A search was performed for studies predicting the need for surgery after nonoperative treatment for ACL rupture in the Embase, MEDLINE (OvidSP), Web of Science, CINAHL, Cochrane Central Register of Controlled Trials, PubMed, and Google Scholar digital databases from inception to October 2013. Two reviewers independently selected the studies and performed a quality assessment. Best-evidence synthesis was used to summarize the evidence of factors predicting the need for surgical reconstruction after nonoperative treatment for an ACL rupture.

RESULTS: Seven studies were included, 3 of which were of high quality. Based on these studies, neither sex (strong evidence) nor the severity of knee joint laxity (moderate evidence) can predict whether, soon after ACL injury, a patient will need ACL reconstruction following nonoperative treatment. All other factors identified in this review either had conflicting or only minimal evidence as to their level of association with the need for surgical reconstruction. Noteworthy is that 1 high-quality study reported that the spherical shape of the femoral condyle was predictive of the need for ACL reconstruction.

CONCLUSION: Sex and knee joint laxity tests do not predict the need for ACL reconstruction soon after an ACL rupture. Independent validation in future research will be necessary to establish whether knee shape is a predictive factor.

LEVEL OF EVIDENCE: Prognosis, level 1a–.
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KEY WORDS: *ACL, predictors, prognosis, surgery*

In past decades, many studies of various treatment options post–ACL rupture have been published.[12,21,22] Nonoperative management of ACL ruptures has been shown to result in good clinical outcomes in the short, medium, and long term.[2,4,15,24] For example, a recently published randomized controlled trial by Frobell and colleagues[15] indicated that clinical outcomes 5 years postinjury in patients successfully treated nonoperatively were comparable to outcomes in those treated with surgical reconstruction. The study found no increased risk of osteoarthritis or meniscal surgery and no significant difference in patient function, activity level, quality of life, pain, symptoms, and general health between surgical and nonsurgical treatment of an ACL tear.

These data suggest that a large portion of individuals will reach a good level of function without reconstruction of the ACL. However, a significant proportion of patients who are not satisfied with their knee function, either because they are unable to reach a desired sports activity level or because of recurrent giving-way episodes, will opt to undergo ACL reconstruction. Unfortunately, ACL reconstruction is not always successful, as indicated by Ardern et al,[1] who, based on their review of the literature, reported

[1]Department of Orthopaedics, Erasmus University Medical Center, Rotterdam, the Netherlands. [2]Department of General Practice, Erasmus University Medical Center, Rotterdam, the Netherlands. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article. Address correspondence to Dr Vincent Eggerding, Department of Orthopaedics, Erasmus University Medical Center, PO Box 2040, 3000 CA Rotterdam, the Netherlands. E-mail: v.eggerding@erasmusmc.nl

that only 63% of individuals return to sports after ACL reconstruction.

The 2012 ACL injury guidelines[25] from the Dutch Orthopaedic Association recommend that symptomatic instability of the knee after ACL injury that is not reduced after an intense physiotherapeutic exercise program or after adjustment in activity level is a good indication for surgical reconstruction. However, a potential risk of failed nonoperative treatment post–ACL rupture is the possibility of recurrent giving-way episodes, which may lead to secondary injuries to the meniscus and cartilage.[14,18,30] It should be noted that secondary injuries may also occur after surgical ACL reconstruction.[15]

The clinical decision to manage ACL rupture operatively or nonoperatively is usually based on the patient's preinjury activity level, fear of not being able to return to a previous level of sport ability, clinical knee instability test outcomes, age, and individual preference.[6,19,23,31] However, the predictive value of these factors to select the most appropriate management strategy post–ACL rupture is unclear. Identifying prognostic factors that could be used soon after the ACL injury to determine which individuals would be unlikely to succeed with nonoperative treatment could be useful in determining the need for surgical reconstruction of the ACL.

The purpose of this systematic review was to summarize the literature on prognostic factors identifying which patients require surgical reconstruction post–ACL rupture.

METHODS

Study Selection

A systematic search for relevant articles was performed in the Embase, MEDLINE (OvidSP), Web of Science, CINAHL, Cochrane Central Register of Controlled Trials, PubMed, and Google Scholar digital databases from inception to October 2013. The primary search phrases were *anterior cruciate ligament*, *rupture*, and *nonoperative*. A full overview of the search criteria can be found in the **APPENDIX**.

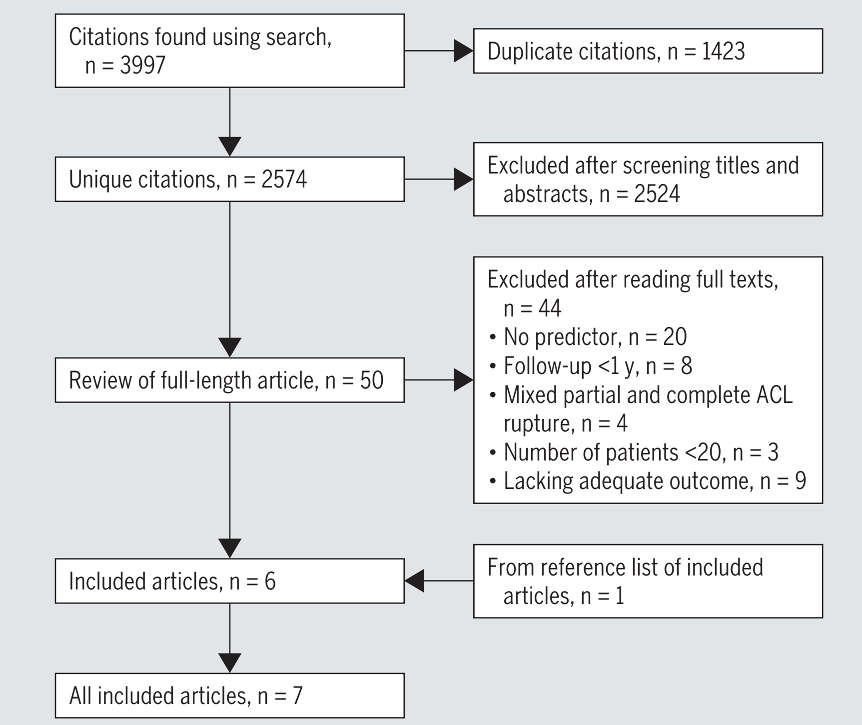

FIGURE. Flow chart of articles included in the literature review. Abbreviation: ACL, anterior cruciate ligament.

The articles were assessed for eligibility by 2 reviewers (V.E. and M.R.) independently, using the inclusion criteria listed below. Additionally, the reference lists of the selected articles were manually searched to identify any additional articles of potential interest.

To be included, studies had to meet all of the following criteria: (1) to report the statistical association between a patient-related factor and requirement for ACL reconstruction after nonoperative treatment of a complete, primary ACL rupture; (2) to verify a complete ACL rupture arthroscopically (gold standard test) or by a combination of physical examination and magnetic resonance imaging; (3) to be written in English, German, Italian, Spanish, French, or Dutch; (4) to be a randomized controlled trial, prospective, retrospective, or case-control study (not a systematic review or meta-analysis); (5) to have a follow-up period of at least 12 months; and (6) to have a sample size of at least 20 participants. Disagreement on inclusion was resolved by discussion or a final decision by a third reviewer (J.V.) if necessary.

Quality Assessment

The methodological quality of the included articles was evaluated with a quality assessment form that consisted of 11 items relevant to prognostic studies, such as the validity and reliability of determinants, selected outcome measures, and the statistical analysis. This form was composed in advance, based on existing quality assessment tools.[5,7,29]

Two reviewers (V.E. and M.R.) independently performed the quality assessment of the selected articles. Disagreement was resolved by discussion or a final decision by a third reviewer (J.V.) if necessary.

Studies were considered to be of high quality when all of the following items were scored as adequate: data were collected prospectively, consecutive patients were included, outcome and predictive

TABLE 1 CHARACTERISTICS OF THE INCLUDED STUDIES

	Eitzen et al[8]	Fithian et al[10]	Fridén et al[13]	Grindem et al[17]	Kostogiannis et al[20]	Moksnes et al[26]	Neuman et al[28]
Sample, n	145	146	99	69	94	102	94
Age, y*	25.9 (14-47)	41.5 ± 12.4	25 (14-40)	27.9 ± 7.3	25.1 (14-43)	27.2 ± 8.6	26 ± 8.0
Female, %	52	55	41	46	41	45	42
Follow-up, y*	1.2	6.6 (3-10)	5 (3-6)	1.1 ± 0.1	15 (12-20)	1.1 ± 0.2	15.7 ± 1.4
Predictors	Age, sex, knee laxity, questionnaires, hop tests, medial collateral ligament injury, quadriceps strength index, activity level	Combination of predictors	Body weight, height, age, femoral condyle shape	Activity level, sports frequency, laxity, meniscal/cartilage injury, questionnaires, hop tests, sex	Age, sex, activity level, knee laxity	Combination of tests	Knee laxity
Time between trauma and baseline measurement, d	59.8	<28	Unknown	74 (mean)	<10	82 (mean)	<10
Reason for surgery	Unknown	Unknown	Giving way An unacceptable activity level	Unknown	Patient's lack of acceptance of knee disability	Combination of factors	Frequent giving way Unacceptable function or activity level
Preinjury activity level	66% Hefti level I 34% Hefti level II	Tegner 6 (median)	Recreational sports or competed on a low to moderate level	54% Hefti level I 46% Hefti level II	Tegner 7 (median; range, 3-9)	68% Hefti level I 32% Hefti level II	Tegner <7, 41% Tegner ≥7, 59%

Values are mean, mean (range), or mean ± SD.

factors were measured objectively, aims of the study were clearly stated, and a description of inclusion and exclusion criteria was provided.

Data Extraction

The main characteristics of the studies, outcome measures, and factors predicting outcome and their relationship with the outcome measures were extracted by 1 reviewer (V.E.).

Best-Evidence Synthesis

Because the measures and follow-up times of the included studies were considered heterogeneous, the data were not statistically pooled. Instead, a best-evidence synthesis was used to outline the evidence available on factors predicting the outcome of nonoperative treatment after ACL rupture, and the following ranking of evidence was formulated in accordance with the method of van Tulder et al[32]:

1. Strong evidence: 2 or more studies with high-quality results and generally consistent findings in all studies (75% or more of the studies reported consistent findings)
2. Moderate evidence: 1 high-quality study and 2 or more low-quality studies and generally consistent findings in all studies (75% or more of the studies reported consistent findings)
3. Limited evidence: 1 high-quality study or low-quality studies and generally consistent findings (75% or more of the studies reported consistent findings)
4. Conflicting evidence: conflicting findings (less than 75% of the studies reported consistent findings)
5. No evidence: no studies could be found

RESULTS

Search

The database search produced a total of 3997 articles, of which 50 (1.3%) were found to be appropriate after screening the title and abstract. Of these 50 articles, 44 were subsequently excluded after reading the full text because they did not meet the inclusion and exclusion criteria, leaving 6 articles[8,13,17,20,26,28] to be included in the systematic review. Manual search of the reference lists of these 6 articles identified 1 extra article[10] (**FIGURE**). Disagreement on inclusion/exclusion was resolved by discussion between the 2 assessors in all cases.

Included Studies

TABLE 1 gives an overview of the 7 studies retained for this review, consisting of 5 prospective cohort studies,[8,13,20,26,28] 1 matched control study,[17] and 1 prospective nonrandomized trial.[10] All studies were published between 1993 and 2012 and solely included patients with a primary ACL rupture. The number of patients in the studies varied from 69 to 146, with a mean follow-up ranging from 1.1 to 15.7 years. The mean age of the included patients varied from 25 to 42 years. The studies were heterogeneous with regard to preinjury activity level (**TABLE 1**).

Quality Assessment

Three (43%) of the 7 included articles fulfilled the criteria for high-quality studies.[13,20,26] An overview of the quality assessment is provided in **TABLE 2**. Disagreement was resolved by discussion between the 2 assessors in all cases.

Factors Examined

Factors associated with eventual ACL reconstruction after nonoperative treatment are provided in **TABLE 3**.

Patient Characteristics

In 4 studies,[8,13,20,26] the influence of patient characteristics on an eventual reconstruction after nonoperative treatment for ACL rupture was investigated. We found strong evidence that sex does not influence the risk of a reconstruction after nonoperative treatment for an ACL rupture. Limited evidence was found that height and weight do not influence the likelihood of a reconstruction.

Conflicting evidence was found for the influence of age: the study by Eitzen et al[8] reported that patients who progressed to reconstruction were significantly younger, whereas 2 other high-quality studies[13,20] found that age had no significant influence.

TABLE 2 QUALITY ASSESSMENT OF THE STUDIES INCLUDED IN THE REVIEW*

Quality/Study	Question† 1	2	3‡	4	5	6	7	8	9	10	11
High quality§											
Kostogiannis et al[20]	1	1	1	1	1	0	1	1	1	0	0
Moksnes et al[26]	1	1	1	1	1	1	1	0	1	0	0
Fridén et al[13]	1	1	1	1	1	0	0	1	1	0	0
Low quality‡											
Grindem et al[17]	1	0	0	1	1	1	1	1	1	0	1
Neuman et al[28]	1	1	0	1	1	0	1	1	1	0	1
Eitzen et al[8]	0	1	1	1	1	1	1	0	0	0	0
Fithian et al[11]	0	1	1	1	1	1	1	1	0	0	0

**0 is inadequate, 1 is adequate.*
†(1) Inclusion of consecutive patients? Did the authors state: "consecutive patients" or "all patients during period from ... to...." or "all patients fulfilling the inclusion criteria"? (2) Prospective collection of data? Did the authors state: "prospective" or "follow-up"? (3) Unbiased assessment of the study outcome and determinants/predictor? To be judged as adequate, the following 2 items had to be positive: (1) outcome and determinants had to be measured independently; and (2) both for cases and for controls, the outcome and determinants had to be assessed in the same manner. (4) A clearly stated aim? Did the authors have a "study question" or "primary aim" or "objective"? The question addressed should be precise and relevant in the light of available literature. To be scored adequate, the aim of the study should be coherent with the introduction section of the paper. (5) A description of inclusion and exclusion criteria? Did the authors report the inclusion and exclusion criteria? (6) Was the inclusion process transparent? Did the authors report how many eligible patients agreed to participate? (7) Were the determinants used accurate (valid and reliable)? For studies in which the determinant measures are shown to be valid and reliable as part of the study, an adequate score is provided. For studies that refer to other work that demonstrates the determinant measures are accurate, an adequate score is provided. (8) Follow-up period? Judged adequate if the follow-up period was considered sufficiently long to allow the assessment of the main outcome (minimum of 1 year). (9) Loss at follow-up? Judged adequate if the following 2 aspects were met: (1) losses of patients at follow-up were reported, and (2) the loss at follow-up was less than 20%. (10) Calculation of the sample size? Is there any information about the sample-size calculation? (11) Adequate statistical analyses? To be judged as adequate, the following 3 aspects had to be met: (1) there must be a description of the relationship between the predictor and outcome or a description of the comparison (with information about the statistical significance); (2) there must be adjustment for the following confounders: age and gender (if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses, the question should be answered inadequate); and (3) variance (eg, SD, confidence interval) of the reported outcomes was reported.
‡Questions 1-3 were necessary for high quality.

Physical Examination

Relationships between clinical tests and an eventual reconstruction after nonoperative treatment for an ACL rupture were evaluated in 4 studies (1 high-quality study[20] and 3 low-quality studies[8,17,28]). There is moderate evidence that tests for knee joint laxity (1 high-quality study[20] and 3 low-quality studies[8,17,28]), such as the pivot shift, Lachman test, and the KT1000 arthrometer (MEDmetric Corporation, San Diego, CA), do not predict an eventual reconstruction after nonoperative treatment. One high-quality study[20] reported that concurrent injury to the medial collateral ligament is not predictive of later reconstruction. Also, limited evidence was found that the presence of an injury to the meniscus or cartilage at the time of initial physical examination has no influence on the need for eventual reconstruction after nonoperative treatment.

There was limited evidence from 1 low-quality study[8] that quadriceps strength deficit is not a significant predictor of a failed nonoperative treatment. Finally, 1 low-quality study[8] reported that 4 different hop tests independently do not significantly predict whether a patient will eventually need ACL reconstruction.

Activity Level

Conflicting evidence was found for the influence of the preinjury activity level on the likelihood of requiring surgical ACL reconstruction. The study by Eitzen et al[8] determined that there were significantly more high-level athletes in the group of patients requiring an eventual ACL reconstruction. On the other hand, Kostogiannis et al[20] did not find a difference in preinjury activity level between patients who eventually went through to surgery and those who did not.

Other Factors

There is limited evidence from 1 high-quality study[13] that a more spherical shape of the femoral condyle, as measured from a lateral knee radiograph,

TABLE 3 Factors Associated With Eventual Reconstruction of the ACL After Nonoperative Treatment*

Determinant	Positive Association†	Negative Association‡	No Association§	Best-Evidence Synthesis
Patient characteristics				
Age		8	**13,20**	Conflicting evidence
Body weight			**13**	Limited evidence for no association
Height			**13**	Limited evidence for no association
Sex (female)			8,**13,26**	Strong evidence for no association
Physical examination				
Laxity			8,17,**20**,28	Moderate evidence for no association
Quadriceps strength index			8	Limited evidence for no association
Hop tests			8,17	Limited evidence for no association
Meniscal/cartilage/MCL damage			8,17	Limited evidence for no association
Activity level				
Preinjury activity level	8		**20**	Conflicting evidence
Other factors				
Spherical shape of the femoral condyle	**13**			Limited evidence for a positive association
Predictive model A‖			**26**	Limited evidence for no association
Predictive model B¶			10	Limited evidence for no association
Predictive model C#	8			Limited evidence for a positive association

Abbreviation: MCL, medial collateral ligament.
**Numbers refer to the studies from the References section that were included in the review. Studies in bold are considered to be of high quality.*
†An increase in the determinant leads to an increased likelihood of patients eventually needing reconstruction surgery.
‡An increase in the determinant leads to a decreased likelihood of patients eventually needing reconstruction surgery.
§No correlation was found between determinant and the eventual need for reconstruction surgery.
‖Consisted of 6-meter timed hop test, Knee Outcome Survey activities of daily living subscale, global rating of knee function assessed by a visual analog scale, and number of episodes of giving way.
¶Consisted of sports hours per year and the difference in anterior/posterior laxity between the injured and noninjured knees, assessed with the KT1000 arthrometer.
#Consisted of patients' age, activity level, giving-way episodes, Knee Outcome Survey activities of daily living subscale, International Knee Documentation Committee Subjective Knee Form 2000 score, 6-meter timed hop test, and quadriceps strength index.

predicted patients who needed surgical reconstruction of the ACL.

Three studies (1 of high quality[26] and 2 of low quality[8,10]) investigated whether the need for surgical reconstruction after nonoperative treatment could be predicted by a combination of patient characteristics, scores on self-report questionnaires, and physical examination findings. Eitzen et al[8] found that a combination of baseline characteristics could significantly distinguish between those patients who needed ACL reconstruction and those who did not ($P<.001$). The best predictive model for ACL reconstruction incorporated younger age, higher preinjury activity level, multiple giving-way episodes, lower score on the Knee Outcome Survey activities of daily living subscale (KOS-ADL), lower score on the International Knee Documentation Committee Subjective Knee Form 2000, lower limb symmetry index on the 6-meter timed hop test, and a lower quadriceps strength index. The other 2 studies[10,26] found no correlation between their model and an eventual ACL reconstruction.

In 2 other studies,[10,26] no predictive value was found for either the algorithm developed by Fitzgerald et al[11] (1 high-quality study) or the surgical risk factor criteria[10] (1 low-quality study) on the need for later ACL reconstruction. The algorithm developed by Fitzgerald et al[11] classifies patients as potential copers if they meet all the following criteria: (1) hop test index of 80% or greater for the timed 6-meter hop test, (2) KOS-ADL score of 80% or greater, (3) global rating of knee function of 60 or greater, and (4) no more than 1 episode of giving way since the injury. The surgical risk factor criteria[10] label individuals as high, medium, or low risk of late surgery based on preinjury hours of sports participation, arthrometer measurements, and patient age.

DISCUSSION

In this systematic review, we summarized the available literature on factors predicting which patients may need reconstructive surgery after nonoperative treatment for an ACL rupture. Strong[8,13,26] and moderate[8,17,20,28] evidence showed that sex and the amount of knee joint laxity on primary physical examination, respectively, cannot predict whether a patient will progress to surgery after nonoperative treatment for an ACL rupture. The latter is especially noteworthy because laxity is often used in clinical decision making to opt for reconstruction.[10]

Among the selected studies, there was limited evidence for only 1 factor that was able to predict patients who would progress to surgery after nonoperative treatment: the spherical shape of the femoral condyle, as described in a high-quality study by Fridén et al.[13] It is remarkable that this relationship has not been researched more extensively, as the shape of the femoral condyle is easily determined in clinical practice by measuring the condyle height and depth on radiographs and calculating a quotient. A potential explanation is that a more rounded condyle may promote greater displacement between the articular surfaces. However, a predictive association shown in a single study is not sufficient to influence clinical practice and, consequently, independent validation is necessary.

Three studies examined whether a combination of factors could predict the need for ACL reconstruction. In the first study, Moksnes et al[26] did not find the combination of a functional test (6-meter timed hop test), a self-report questionnaire (KOS-ADL), the subjective rating of the knee function using a visual analog scale, and clinical instability (number of giving-way episodes) predictive of requiring ACL reconstruction. In a separate study, Fithian et al[10] determined that a combination of the amount of hours in sports participation per year and the amount of knee joint laxity did not predict the need for ACL reconstruction. Finally, Eitzen et al[8] found a model that could predict 43% of the variance in whether or not patients would require ACL reconstruction. The model consisted of younger age, higher activity level, more episodes of giving way, a lower KOS-ADL score, lower score on the International Knee Documentation Committee Subjective Knee Form 2000, lower limb symmetry index on the 6-meter timed hop test, and a lower quadriceps strength index.

The current study, to our knowledge, is the first to systematically review the literature on factors that may be associated with the need for surgical reconstruction after nonoperative treatment for an ACL rupture. Progression to surgery may be easily identified as an outcome measure, but it is not as objective as the results of some of the validated questionnaires, and may be subject to bias. Both patient and surgeon might make the decision for a reconstruction based on previous experiences or outcome of similar individual cases. In the studies included in the present review, the criteria for surgery were not reported and might not be similar. Also, because of the unclear indications for surgery, the question remains whether factors predictive for surgery are really patient-bound factors that increase the need for surgery or whether they reflect dogmatic theories in clinical practice.

A limitation of this review is the limited number of applicable studies. Despite extensive search, only 7 studies met the criteria for inclusion, of which only 3 were classified as high-quality studies.

It is also noteworthy that 6 of the 7 studies were performed by 2 research groups: 3 from a research group based in Oslo, Norway and 3 from a research group based in Lund, Sweden. These 6 studies differed in sample population, predictors, and outcome measures; therefore, all were included in this review.

It was not possible to pool the results of the studies included in this review because of the heterogeneity of prognostic factors and the different time points used in measuring the prognostic factors. Instead, a best-evidence synthesis, which involves classification into high- and low-quality studies, was used. Such subdivision of studies is somewhat arbitrary, but to make this process as transparent as possible, the quality assessment is shown in **TABLE 2**.

This review included a comprehensive search for published studies on factors potentially associated with the need for reconstruction surgery after nonoperative treatment for ACL rupture, and the limited number of studies identified highlights the paucity of evidence. While a large proportion of patients (49%-85% after 5-year follow-up)[13,15] after an ACL rupture seem to cope well with nonoperative treatment, based on the current evidence, we were not able to predict at an individual level whether a patient would require reconstruction surgery after nonoperative treatment. Therefore, rehabilitation should be considered the primary treatment after ACL rupture.

CONCLUSION

THIS REVIEW HIGHLIGHTS THAT THE evidence available on factors predicting the need for ACL reconstruction after nonoperative treatment for an ACL rupture is scarce. However, based on the limited literature available, this review found strong evidence that sex and moderate evidence that knee joint laxity are not good predictors. All other factors identified in this review either had conflicting or minimal evidence as to their level of association with the need for surgical reconstruction. One high-quality study reported that the shape of the femoral condyle may be associated with an eventual reconstruction after nonoperative treatment.

Well-designed prospective studies of patients with an ACL rupture are needed to identify factors predicting who is less likely to benefit from nonsurgical management post–ACL rupture and who should therefore be treated surgically. Also, to make the pooling of data possible in the future, greater standardization is required in the assessment of baseline features and treatment outcomes after an ACL rupture. Based on the lack of clear predictors for failure of nonoperative treatment after an ACL rupture, we advise clinicians to be reserved in advising patients directly to opt for operative treatment. ◉

KEY POINTS

FINDINGS: There is strong evidence that sex and moderate evidence that knee joint laxity are not good predictors of the need for reconstruction of the ACL after nonoperative treatment. All other factors identified in this review had either conflicting or minimal evidence as to their level of association with the need for surgical reconstruction.

IMPLICATIONS: At this moment, we are not able to predict on an individual level the need for an eventual reconstruction after ACL rupture based on patient-related factors.

CAUTION: The evidence available on factors predicting the need for ACL reconstruction after nonoperative treatment for an ACL rupture is scarce.

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APPENDIX

LITERATURE SEARCH

Embase

('anterior cruciate ligament'/de OR 'anterior cruciate ligament rupture'/de OR 'anterior cruciate ligament injury'/de OR 'knee cruciate ligament'/de OR (('anterior cruciate ligament' OR 'anterior cruciate ligaments' OR ACL) NEAR/3 (injur* OR rupture* OR tear* OR damage* OR deficien* OR insufficien*)):ab,ti) AND (('conservative treatment'/exp OR (conservative OR nonoperat* OR nonsurg* OR ((without OR non) NEXT/3 (reconstruct* OR operat* OR surg*)) OR ((treat* OR primar* OR first) NEAR/3 (activit* OR rehabilit*))):ab,ti) OR ((Physiotherapy/exp OR rehabilitation/exp OR (rehabilitat* OR physiotherap* OR 'physical therapy'):ab,ti) NOT (surgery/exp or surgery:lnk OR (reconstruct* OR surg* OR operat*):ab,ti))) AND ('prediction and forecasting'/exp OR 'prospective study'/de OR 'follow up'/de OR 'treatment failure'/de OR (predict* OR forecast* OR prospect* OR (follow* NEXT/1 up*) OR fail*):ab,ti) NOT ([animals]/lim NOT [humans]/lim)

MEDLINE (OvidSP)

("anterior cruciate ligament"/ OR ((anterior cruciate ligament* OR ACL) ADJ3 (injur* OR rupture* OR tear* OR damage* OR deficien* OR insufficien*)).ab,ti.) AND (((conservative OR nonoperat* OR nonsurg* OR ((without OR non) ADJ3 (reconstruct* OR operat* OR surg*)) OR ((treat* OR primar* OR first) ADJ3 (activit* OR rehabilit*))).ab,ti.) OR ((exp "Physical Therapy Modalities"/ OR exp rehabilitation/ OR rehabilitation.xs. OR (rehabilitat* OR physiotherap* OR "physical therapy").ab,ti.) NOT (exp "Surgical Procedures, Operative"/ OR surgery.xs. OR (reconstruct* OR surg* OR operat*).ab,ti.))) AND (exp "Prognosis"/ OR "prospective studies"/ OR "Follow-Up Studies"/ OR (predict* OR forecast* OR prognos* OR progress* OR prospect* OR (follow* ADJ up*) OR fail*).ab,ti.) NOT (exp animals/ NOT humans/)

Cochrane Central Register

((('anterior cruciate ligament' OR 'anterior cruciate ligaments' OR ACL) NEAR/3 (injur* OR rupture* OR tear* OR damage* OR deficien* OR insufficien*)):ab,ti) AND (((conservative OR nonoperat* OR nonsurg* OR ((without OR non) NEAR/3 (reconstruct* OR operat* OR surg*))):ab,ti) OR (((rehabilitat* OR physiotherap* OR 'physical therapy'):ab,ti) NOT ((reconstruct* OR surg* OR operat*):ab,ti))) AND ((predict* OR forecast* OR prognos* OR progress* OR prospect* OR (follow* NEAR/1 up*) OR fail*):ab,ti)

Web of Science

TS=(((("anterior cruciate ligament" OR "anterior cruciate ligaments" OR ACL) NEAR/3 (injur* OR rupture* OR tear* OR damage* OR deficien* OR insufficien*))) AND (((conservative OR nonoperat* OR nonsurg* OR ((without OR non) NEAR/3 (reconstruct* OR operat* OR surg*)))) OR (((rehabilitat* OR physiotherap* OR "physical therapy")) NOT ((reconstruct* OR surg* OR operat*)))) AND ((predict* OR forecast* OR prognos* OR progress* OR prospect* OR (follow* NEAR/1 up) OR fail*)))

CINAHL

(MH "anterior cruciate ligament"+ OR ((anterior cruciate ligament* OR ACL) N3 (injur* OR rupture* OR tear* OR damage* OR deficien* OR insufficien*))) AND (((conservative OR nonoperat* OR nonsurg* OR ((without OR non) N3 (reconstruct* OR operat* OR surg*)))) OR ((MH "Physical Therapy"+ OR MH rehabilitation+ OR (rehabilitat* OR physiotherap* OR "physical therapy")) NOT (MH "Surgery, Operative"+ OR (reconstruct* OR surg* OR operat*)))) AND (MH "Prognosis"+ OR "prospective studies"+ OR (predict* OR forecast* OR prognos* OR progress* OR prospect* OR "follow up*" OR fail*)) NOT (MH animals+ NOT MH humans+)

PubMed Publisher

(((anterior cruciate ligament*[tiab] OR ACL[tiab]) AND (injur*[tiab] OR rupture*[tiab] OR tear*[tiab] OR damage*[tiab] OR deficien*[tiab] OR insufficien*[tiab]))) AND (((conservative OR nonoperat*[tiab] OR nonsurg*[tiab] OR ((without OR non) AND (reconstruct*[tiab] OR operation*[tiab] OR operative*[tiab] OR surger*[tiab] OR surgic*[tiab])))) OR (((rehabilitat*[tiab] OR physiotherap*[tiab] OR physical therapy)) NOT ((reconstruct*[tiab] OR surger*[tiab] OR surgic*[tiab] OR operation*[tiab] OR operative*[tiab])))) AND ((predict*[tiab] OR forecast*[tiab] OR prognos*[tiab] OR progress*[tiab] OR prospect*[tiab] OR follow up*[tiab] OR fail*[tiab])) AND publisher[sb]

Google Scholar

ACL (conservative|nonoperative|nonsurgical|"(without|non) (reconstruction|operation|surgery)"|"without ACL reconstruction") (prediction|forecasting|prospective|"follow up"|failure)