Non-operative treatment of anterior cruciate ligament injuries: two-thirds avoid surgery at 2-year follow-up in a nationwide cohort

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ABSTRACT

Objective To describe the nationwide population of anterior cruciate ligament (ACL) injured patients initially managed non-operatively, quantify the proportion undergoing delayed ACL reconstruction (ACLR) and describe both intraoperative findings and patient-reported outcomes.

Methods Primary ACL injuries treated non-operatively were prospectively registered in the Norwegian Knee Ligament Register (2017–2023). We collected baseline characteristics, injury details, surgical details if delayed ACLR was performed and patient-reported outcomes (Knee injury and Osteoarthritis Outcome Score, KOOS). Treatment survival was analysed with Kaplan-Meier curves, and factors associated with ACLR were assessed with Cox regression.

Results Of 485 patients included (mean age at injury (SD) 35 (12), 25%<25 years), 93% (n=452) were physically active in sports preinjury. At 2 years, 63% remained non-operatively treated. Of the delayed ACLR patients (n=178), 56% underwent concurrent meniscal repair, and 18% partial resection. Instability was the main reason for ACLR (85%). Patients younger than 25 years, those active in pivoting sports preinjury and those with meniscal injuries at baseline were more likely to undergo delayed ACLR (HR (95% CI) 1.95 (1.2 to 3.2), 1.54 (1.1 to 2.2) and 1.63 (1.2 to 2.2), respectively. Both non-operative and delayed ACLR patients showed moderate impairment on KOOS Sport/Recreation and Quality of Life subscales at 2-year follow-up (mean scores 69.8 vs 61.0 and 68.6 vs 63.4), with no statistically significant between-group differences.

Conclusion In this active population of ACL injured patients treated non-operatively, two-thirds remained non-operatively treated at 2 years. Younger patients, those engaged in pivoting sports preinjury and those with baseline meniscal injuries had higher risks of undergoing delayed ACLR. KOOS scores were similar between non-operative and delayed ACLR patients.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Both operative and non-operative treatment are common and accepted options after anterior cruciate ligament (ACL) injury, yet randomised controlled trials show that approximately 50% of patients eventually undergo reconstruction after initial non-operative treatment.
⇒ Evidence on characteristics and outcomes of non-operatively treated patients in real-world settings is lacking, leaving informed shared decision-making and clear treatment recommendations a challenge.

WHAT THIS STUDY ADDS

⇒ This is the first large-scale prospective cohort in a national registry to include and report detailed data on non-operatively treated ACL injuries in a generally active adult population.
⇒ At 2 years, two-thirds of selected patients remained non-operatively treated. Young patients (<25 years), those engaged in pivoting sports pre-injury, and those with additional meniscal injuries at baseline were more likely to undergo delayed ACL reconstruction (ACLR), primarily due to knee instability. This indicates that patient injury characteristics are important in guiding management.
⇒ Patient-reported outcomes revealed no difference between non-operatively treated and delayed ACLR patients. The findings suggest that non-operative treatment with an option of delayed ACLR is a viable treatment option for selected ACL-injured patients.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICES OR POLICY

⇒ Non-operative treatment outcomes should be included in patient information when discussing treatment options for ACL injury.
⇒ Clinicians should be aware of the injury characteristics most likely to require ACLR.

INTRODUCTION

Anterior cruciate ligament (ACL) injury significantly impairs knee function and quality of life (QoL), regardless of treatment.[1 2] The choice between operative and non-operative treatment remains a fundamental challenge and depends on a total evaluation including patient age, activity profile, associated injuries, personal preferences and local treatment practices. Non-operative treatment is not well-defined and research is sparse, despite an estimated 50% of Norwegian patients being managed non-operatively.[3 4] Although a nationwide study from Denmark revealed no difference in age,[5] other cohort studies have shown that patients undergoing non-operative treatment are older and less active compared with the average

ACLR patient.[6] Randomised controlled trials (RCTs) show comparable outcomes following both treatment options, though half of non-operatively treated patients eventually undergo ACL reconstruction (ACLR).[7–10] While some cohort studies suggest delayed ACLR may increase the risk of meniscal and cartilage injuries,[11–15] evidence beyond the few RCTs is based on small prospective cohorts or retrospective studies prone to bias.[16 17]

The knowledge gap regarding non-operative treatment for ACL injuries limits our understanding of its associated risks and outcomes and hampers clinicians' ability to identify which patients will benefit from non-operative management. Since neither treatment option achieves optimal outcomes for all patients, more information about non-operative management is needed to support evidence-based treatment recommendations and informed shared decision-making.

National knee ligament registers provide extensive ACLR data. There has been a longstanding call to include non-operatively treated patients in such registries to better understand their outcomes, predictors for treatment success and reasons for delayed ACLR.[18 19] In 2017, the Norwegian Knee Ligament Register (NKLR) expanded to allow for inclusion of ACL injured patients opting for non-operative treatment. In this paper, our primary aim was to describe baseline characteristics and patient-reported outcomes among patients initially managed without surgery within the NKLR. Our secondary aims were to (1) determine the 2-year proportion of delayed ACLR and describe associated meniscal injuries, (2) compare characteristics and outcomes between non-operative patients and those who later underwent ACLR and (3) examine whether sex, age, activity level and meniscal injury were associated with conversion to surgery.

METHODS

Study design

This prospective cohort study was planned before the first non-operated patient was included in NKLR, adhering to the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines for cohort studies.[20]

Setting

The NKLR has recorded ACLRs in Norway from 2004, covering nearly 90% of all ACLRs nationwide through surgeon-reported data.[21] Patient-reported outcomes are collected using the Knee injury and Osteoarthritis Outcome Score (KOOS) at baseline and 2, 5 and 10 years after ACLR.[22–24] In 2017, a new electronic 'ACL injury' form was created to allow for inclusion of non-ACLR patients, mirroring the 'ACLR form' but replacing surgical details with preinjury activity level and detailed MRI findings of concomitant injuries. An electronic version of KOOS was also integrated, replacing mail-based forms with complete digital collection of both surgeon-reported and patient-reported data. These updates enabled orthopaedic surgeons and specialised trained physiotherapists to voluntarily register non-operatively treated ACL injured patients. By linking records to the patient's unique national identification number, any subsequent ACLR is tracked. Registration of ACL injuries was voluntary, unlike the mandatory registration of ACLRs, thus limiting coverage to registered cases. KOOS was administered following established routines for ACLR patients, where response rates typically reach 60%.[21] Due to a system error affecting the digital KOOS distribution between 2017 and 2020, some non-ACLR patients did not receive the 2-year questionnaire.

Participants

Patients with a clinically and radiologically confirmed primary ACL injury to the index knee, registered in the NKLR between 1 June 2017 and 31 December 2023, were assessed for eligibility. We included patients registered within 12 months postinjury. Non-operative treatment was defined as not undergoing ACLR within 3 months of injury and included only patients intending to pursue non-operative management. We excluded paediatric patients, posterior cruciate ligament injuries, those initially

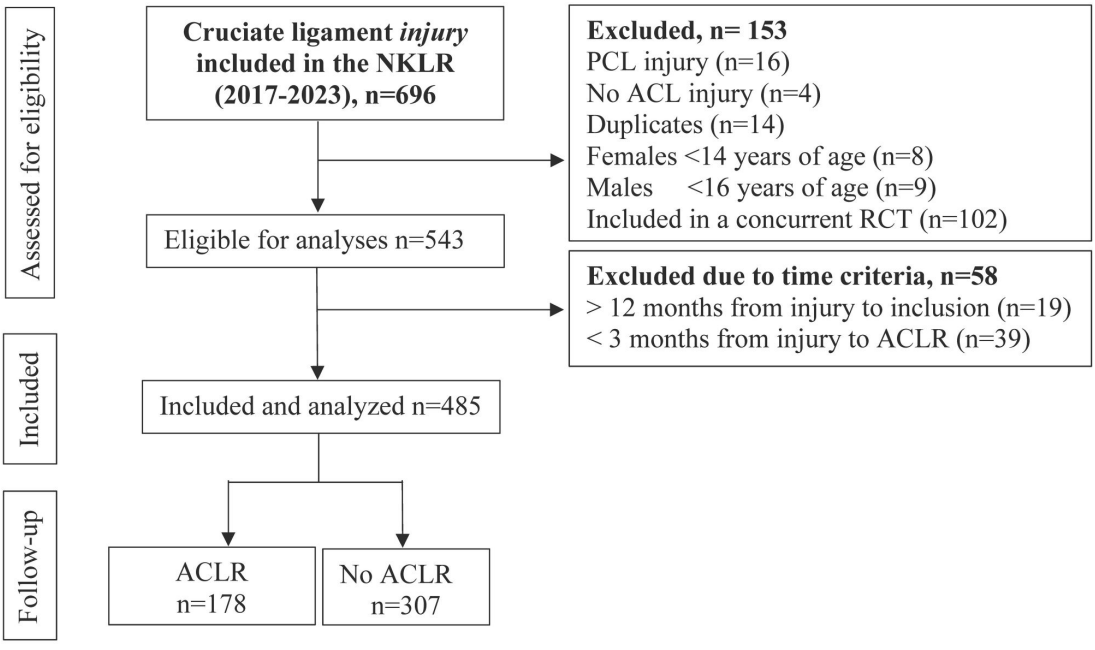

Figure 1 Flow diagram over the study selection procedure. ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; NKLR, Norwegian Knee Ligament Register; PCL, posterior cruciate ligament; RCT, randomised controlled trial.

scheduled for surgery (defined as primary ACLR within 90 days of injury), those presenting >12 months after injury and participants in an ongoing register-based RCT (figure 1).

Data collection, variables and outcome measures

At inclusion, baseline demographics (age, sex) were automatically generated by the personal identification number, while patients reported their height, weight, date of injury, preinjury activity level and activity at the time of injury. Activity level was categorised according to Hefti *et al*'s classification[25] into highly-pivoting, less-pivoting or non-pivoting sports, adapted for Norwegian sports.[26] Patients also completed KOOS at inclusion, and then at predefined intervals following both non-ACLR and ACLR, with electronic reminders if the questionnaire was unanswered after 3 months. The treating surgeon or physiotherapist filled out the ACL injury form designed for non-operative patients, which included history of previous knee injuries, the degree of knee hyperextension and detailed MRI findings including (1) presence, location and type of meniscal tears, (2) presence, degree and additional brace treatment of medial and lateral collateral ligament (MCL and LCL) injuries and (3) presence and location of cartilage injuries. In the event of subsequent surgery, ACLRs are captured through the mandatory NKLR registration and linked to the patient's original record via their personal ID number. The surgeon documents the reason for ACLR, surgical technique details and intraoperative findings immediately after surgery. Outcome measures used in this study were ACLRs and the validated KOOS questionnaire for patient-reported outcomes.

Statistical analysis

Statistical analyses were performed using Stata SE V.17 (StataCorp LLC, College Station, Texas, USA), adhering to CHAMP (CHecklist for statistical Assessment of Medical Papers) guidelines.[27] Descriptive statistics were presented with mean (SD) for normally distributed continuous variables, and median (IQR) for non-normally distributed data. Normality was assessed using Shapiro-Wilk tests and q–q plots.[28] Categorical variables were reported as count (n) and percentages (%). Survival of non-ACLR treatment was analysed with Kaplan-Meier curves including stratification by preinjury activity level, and the difference between activity levels was tested with the log-rank test. Non-operated patients were followed until ACLR, death, emigration or until 31 December 2023. We performed Cox multivariate regression analysis to assess the association between selected variables that potentially could influence the need for ACLR. Concomitant meniscal injuries were included as a dichotomous independent variable, and all assumptions for the Cox regression analysis were met. All tests were two-sided and p values <0.05 were considered statistically significant. Baseline differences between ACLR and non-ACLR patients were examined using descriptive statistics, and Student's t-test was used to test the difference in KOOS between groups. Missing variables were excluded from the analyses (without imputation), and the amount of missing data is specified in the separate analyses if >5% missing.

Patient and public involvement

A user representative from the NKLR was involved in the registry development including the expansion to include all ACL injuries.

Equity, diversity and inclusion

The study population represents a previously understudied and heterogeneous group of ACL-injured patients, included regardless of demographics, insurance or healthcare setting. The findings are relevant and generalisable to populations using similar treatment algorithms. The research group consisted of members of both genders, with women as first and last authors, junior and senior researchers and clinicians, representing diverse disciplines across multiple sites.

RESULTS

Baseline characteristics

We included 485 patients with a primary ACL injury (figure 1). Mean (SD) age at injury was 35 (12) years, with 25% (n=122) of patients younger than 25 years old (table 1). The majority of patients (93%, n=452) were physically active in sports prior to injury, 36% in Level 1 pivoting sports. Alpine sports and soccer were the most frequently reported activities at the time of injury. Of all patients, 40% (n=193) had isolated ACL injuries, while meniscal and MCL injuries were the most frequently reported additional injuries. The KOOS sport/recreation and QoL subscales had the lowest scores of all subscales at baseline (online supplemental table 1).

Outcomes after initial non-operative treatment

Kaplan-Meier analysis showed that 63% of patients remained non-operatively treated at 2 years (CI 58% to 67%) (figure 2). At study completion (mean follow-up 3.3 years), 307 of the 485 included patients remained non-operatively treated while 178 patients had undergone ACLR. Those who remained non-operated were older, less active in Level 1 pivoting sports and had fewer meniscal injuries at baseline compared with ACLR patients (table 2). Patient-reported outcomes revealed similar outcomes at 2-year follow-up, despite slightly lower baseline scores in the delayed ACLR group (figure 3) (online supplemental table 1 and 2).

ACL reconstructions and additional injuries

A significantly higher proportion of patients active in Level 1 pivoting sports before injury underwent ACLR (52%) compared with those in less pivoting or non-pivoting sports (Level 2–4) (figure 4). Cox regression analysis showed that younger patients, those engaged in Level 1 activities prior to injury and those with meniscal injuries at baseline had a statistically significant higher hazard for undergoing subsequent ACLR compared with older patients, those active in non-pivoting sports and those with isolated ACL injury (table 3). Among patients who eventually underwent ACLR, the reason for reconstruction was available for 49% (n=88). Knee instability was the most frequently cited reason for surgery (85%, n=75), while meniscal injuries were reported as the main reason in 11% (n=10) of patients (table 4). The most common types of meniscal tears found at arthroscopy were ramp lesions, longitudinal tears and lateral posterior root tears. Among those who underwent ACLR, 56% (n=100) patients had concurrent meniscal repair of one or both menisci. Cartilage injuries were described in 35% (n=63) of ACLR patients, with International Cartilage Regeneration and Joint Preservation Society (ICRS) grade 1–2 being the most common.

DISCUSSION

This nationwide cohort study revealed that a diverse patient population opted for non-operative treatment. At 2 years, 63% remained non-operatively treated. Younger patients, those

Table 1 Baseline patient characteristics

	Initial non-operative treatment decided (n=485)
Sex N (%)	
Female	274 (56)
Male	211 (44)
Age at injury (years)	
Mean (SD)	35.2 (12)
Median (range), IQR	34.5 (13.7–69.0), IQR 24.7–44.2
Age intervals at inclusion (years)	
<25	122 (25)
25–34	122 (25)
35–44	124 (26)
>45	117 (24)
Height (cm), mean (SD)	173.0 (9.3)
Weight (kg), mean (SD)	76.2 (15.8)
BMI (kg/m^2), mean (SD)	25.4 (4.4)
Non-smokers	435 (90)
Non-tobacco users	405 (84)
Time from injury to inclusion (days)	
Median (min-max), IQR	75.0 (0–357), IQR: 49–118
Total follow-up time (days)	
Mean (SD)	1202 (685)
Median (min-max), IQR	1139 (9–2383), IQR: 619–1768
Activity level preinjury	
Level 1 (highly pivoting eg, soccer)	174 (36)
Level 2 (less pivoting eg, alpine skiing)	126 (26)
Level 3 (non-pivoting eg, running)	152 (31)
Level 4 (low activity level)	32 (7)
Activity at time of injury	
Alpine sports	140 (29)
Soccer	114 (24)
Handball	27 (6)
Other team sports (incl. basketball)	20 (4)
Other sports*	78 (16)
Fall, jump, violence, play	60 (12)
Unrelated to sports (work, traffic)	26 (5)
Other	20 (4)
Previous surgery on ipsilateral knee	13 (3)
Previous ACL injury on contralateral knee	36 (7)
Degree of knee hyperextension (n=335)	
<5 degrees	296 (88)
5–10 degrees	35 (11)
>10 degrees	4 (1)
Injury details (MRI)	
Isolated ACL injury	193 (40)
ACL injury and other injuries	292 (60)
Meniscal injury	(n=193)
Medial only	116 (61)
Lateral only	59 (30)
Both	18 (10)
Type of tear†	Medial / Lateral
Radial	15 (13) / 15 (25)
Longitudinal	28 (24) / 16 (27)
Horizontal	15 (13) / 5 (8)
Anterior root	2 (2) / 0
Posterior root	5 (4) / 12 (20)
Degenerative	11 (10) / 3 (5)
Bucket handle	8 (7) / 3 (5)
Complex rupture	10 (9) / 4 (7)
Ramp lesion	22 (19) / 1 (2)
Cartilage injury	22 (5)
Medial collateral ligament injury‡	120 (25)
Grade 1	45 (9)
Grade 2	58 (12)
Grade 3	13 (3)
Brace treatment	54 (11)
Lateral collateral ligament injury	15 (3)
Grade 1	8 (2)
Grade 2	6 (1)
Grade 3	0
Brace treatment	8 (2)

Variables are presented as count (%), unless reported otherwise. Sample size (n) is specified when it differs from the total of 485, and reflects different timing of introduction of certain selected variables added to the NKLR.
*Includes skiing, cycling, martial arts, floorball, ice-hockey, racket sports, volleyball, skateboard, dancing and other physical activity
†% is calculated based on the total number of injuries to the medial (n=116) and lateral (n=59) meniscus, respectively.
‡MCL and LCL injuries are based on clinical examination.
ACL, anterior cruciate ligament; BMI, body mass index; LCL, lateral collateral ligament; MCL, medial collateral ligament; NKLR, Norwegian Knee Ligament Register.

engaged in Level 1 activities prior to injury and those with meniscal injuries at baseline, had a statistically significant higher risk of undergoing ACLR than their reference groups. KOOS scores were similar between non-operative and delayed ACLR patients.

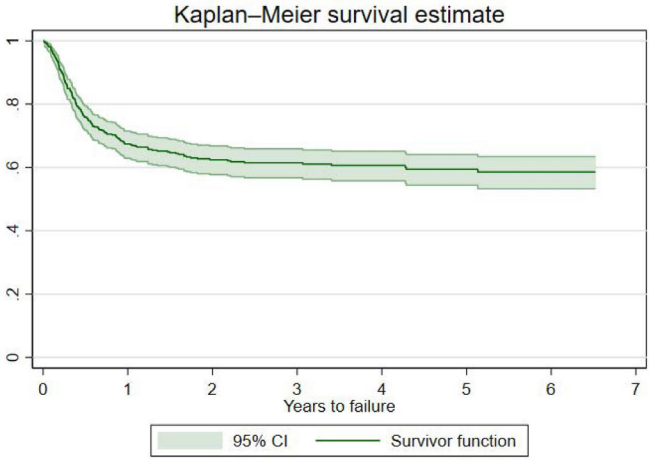

Figure 2 Kaplan-Meier survival curve for non-operative treatment, presented with survival curve and 95% CIs.

Table 2 Patient characteristics and outcomes by treatment group

	ACLR (n=178)		Non-ACLR (n=307)	
Patient characteristic				
Sex				
Female	94 (53)		180 (59)	
Male	84 (47)		127 (41)	
Age at injury (years), mean (SD)	32.3 (11.8)		36.9 (12)	
BMI (kg/m^2), mean (SD)	25.3 (SD 4)		25.4 (SD 4.5)	
Preinjury activity level				
Level 1 (highly pivoting)	82 (46)		92 (30)	
Level 2 (less pivoting)	38 (21)		88 (29)	
Level 3 (non-pivoting)	50 (28)		102 (33)	
Level 4 (sedentary)	8 (5)		24 (8)	
Baseline injury details				
Activity at time of injury	(n=178)		(n=303)	
Alpine sports	38 (21)		102 (33)	
Soccer	60 (34)		54 (18)	
Handball	12 (7)		15 (5)	
Other team sports (incl. basketball)	9 (5)		11 (4)	
Other sports	23 (13)		49 (16)	
Fall, jump, violence, play	21 (12)		39 (13)	
Unrelated to sports (work, traffic)	6 (3)		19 (6)	
Other	9 (5)		14 (5)	
Time from injury to inclusion (days)				
Mean (SD)	94.5 (59)		90.7 (67)	
Median	77 (IQR: 54–117)		72 (IQR: 45–119)	
Isolated ACL injury	70 (39)		123 (40)	
ACL and other injuries	108 (61)		184 (60)	
Meniscal injury	82 (46)		108 (35)	
Medial	47		69	
Lateral	22		34	
Both	13		5	
Type of tear	Medial (n=49)	Lateral (n=27)	Medial (n=67)	Latera l(n=32)
Radial	8	6	7	9
Longitudinal	15	6	13	10
Horizontal	7	2	8	3
Anterior root	0	0	2	0
Posterior root	3	8	2	4
Degenerative	3	0	8	3
Bucket handle	4	2	4	1
Complex rupture	2	3	8	1
Ramp lesion	7	0	15	1
Cartilage injury				
No	166 (94)		295 (96)	
Yes	10 (6)		12 (4)	
Medial collateral ligament injury†	n=37		n=83	
Grade 1	17		28	
Grade 2	16		42	
Grade 3	2		11	
Lateral collateral ligament injury**	n=4		n=11	
Grade 1	2		6	
Grade 2	1		5	
Grade 3	0		0	
KOOS, mean (95% CI)	n=102		n=201	
Sport and recreation	34 (29–39)		40 (36–43)	
Quality of Life	30 (26–34)		40 (37–43)	

Variables are presented as count (%), unless reported otherwise.
*Includes skiing, cycling, martial arts, floorball, ice-hockey, racket sports, volleyball, skateboard, dancing, and "other physical activity"
†Grade not documented; n=2.
ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Scale.

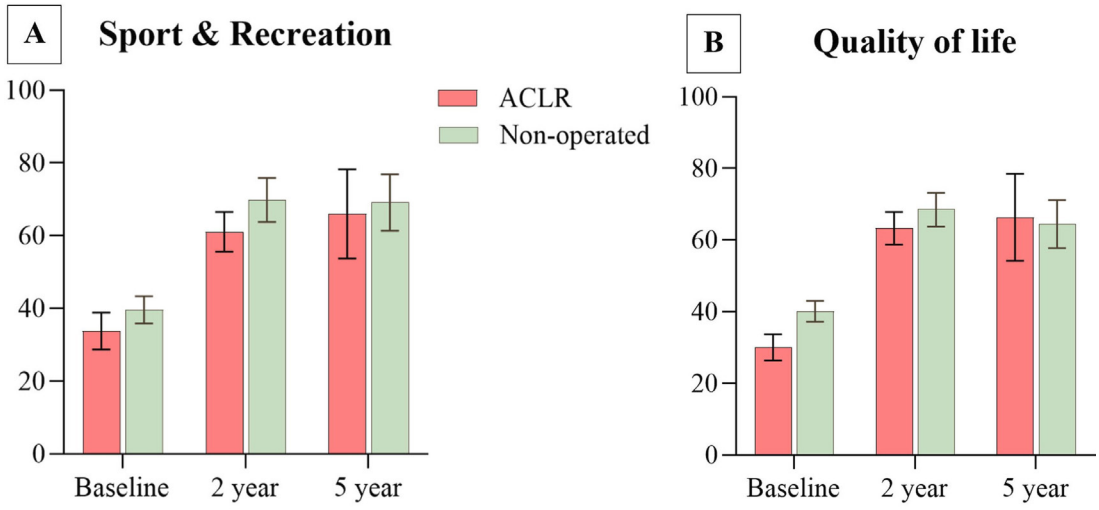

Figure 3 Patient-reported outcomes measured by KOOS at inclusion (baseline) for all, and then at 2 and 5 years after non-operative treatment or ACLR, respectively. Presented with mean and 95% CIs. 0 represents worst and 100 represents optimal knee function. (A) Sport and recreation subscale, (B) quality of life subscale. The only statistically significant difference between ACLR and non-surgical patients was the baseline QoL score (p<0.001). ACLR, anterior cruciate ligament reconstruction; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, quality of life.

Non-operatively treated patients

This study demonstrates that patients undergoing non-operative treatment represent all age groups and are typically active preinjury. The patients were on average older than those undergoing ACLR in the NKLR (35 vs 28 years) and likely represented a less high-risk patient group. Nevertheless, one-fourth were younger than 25 years old, and approximately 1 in 3 were active in pivoting sports preinjury. Despite Norwegian guidelines recommending early ACLR for patients with concomitant injuries requiring surgery and those returning to pivoting sports or physically demanding jobs,[29 30] 36% of patients in our study were active in Level 1 sports preinjury—an unexpected finding for a non-operative group. Although not explained by our data, we may speculate that these reflected a low-intensity of participation or a willingness to modify their activity level after injury in order to avoid surgery and further knee injury.

The Swedish national knee registry, the only other registry with published data on non-operatively treated patients, reports a younger and more male-dominated cohort with shorter time to ACLR compared with the Norwegian cohort.[31] These differences may reflect that a proportion of their patients were initially scheduled for surgery and not truly intended for non-operative treatment. Other prospective studies have described small, selected populations[32 33] providing less generalisable findings compared with our larger, unselected cohort.

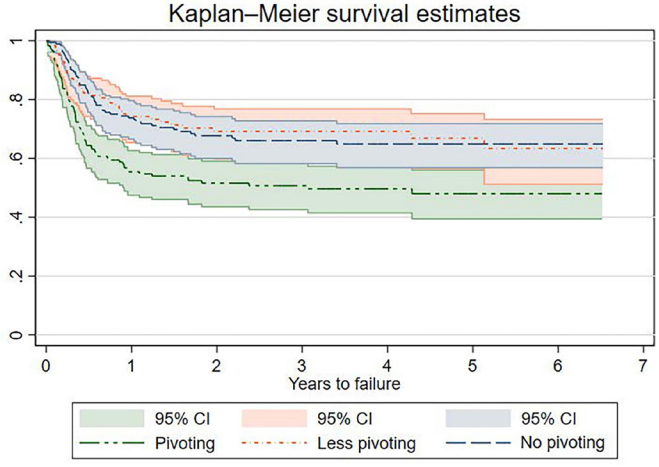

Figure 4 Kaplan-Meier survival curve for non-operative treatment, stratified by activity level prior to injury, presented with survivor function and 95% CIs. Log-rank test: p value <0.001.

Most non-operatively treated patients remain non-operated after two years

Our findings support that when non-operative treatment is selected as the initial approach, nearly two-thirds of patients remain non-ACLR at short-term follow-up—63% at 2 years in

Table 3 Cox regression analysis exploring the association between risk factors and delayed ACLR

	HR (95% CI)	P value
Sex		
Male	1 (ref.)	
Female	0.88 (0.6 to 1.2)	0.399
Age (years)		
<25	1.95 (1.2 to 3.2)	0.006
25–34	1.45 (0.89 to 2.36)	0.136
35–44	1.54 (0.96 to 2.47)	0.075
>45	1 (ref.)	
Pre-injury activity level		
Level 1	1.54 (1.1 to 2.2)	0.02
Level 2	0.98 (0.65 to 1.48)	0.919
Levels 3 and 4	1 (ref.)	
Meniscal injury at baseline		
Yes	1.63 (1.2 to 2.2)	0.001
No	1 (ref.)	

Variables are presented as count (%), unless reported otherwise. N is specified if it differs from the total of 178 (due to the different timing of introduction of certain variables added to the NKLR).
ACLR, anterior cruciate ligament reconstruction; NKLR, Norwegian Knee Ligament Register.

Table 4 Surgical details for those who underwent ACLR (n=178)

Reason for ACLR (n=88)		
Meniscal injury	10 (11)	
Combined instability	7 (8)	
Instability in ADL	45 (51)	
Instability in sports	23 (26)	
Activity level as indication for ACLR	3 (3)	
Other	0	
Physical therapy prior to surgery (n=88)	87 (99)	
Age at ACLR		
Mean (SD)	33 (12)	
Median, IQR	32, 23–43	
Time (days) from primary ACL injury to surgery		
Median, IQR	225, 160–375	
Time (days) from inclusion to surgery		
Median, IQR	139, 75–262	
Graft choice		
BPTB autograft	147 (83)	
Hamstring autograft	18 (10)	
Quadriceps tendon autograft	13 (7)	
Overall meniscal injury and/or procedure		
None	62 (35)	
Medial meniscus	92 (52)	
Lateral meniscus	68 (38)	
Both meniscus	44 (25)	
Type of meniscal tear	Medial (n=82)	Lateral (n=57)
Radial	1 (1)	6 (11)
Longitudinal	18 (22)	22 (39)
Anterior root	0	2 (4)
Posterior root	1 (1)	19 (33)
Degenerative	12 (15)	6 (11)
Bucket handle	11 (13)	2 (4)
Complex	4 (5)	0
Ramp lesion	35 (43)	0
Meniscal procedure*		
Suture	75 (42)	51 (29)
Resection (partial)	16 (9)	16 (9)
Cartilage injury		
No injury	115 (65)	
ICRS 1–2	43 (24)	
ICRS 3–4	20 (11)	
Cartilage procedure (debridement)†	10 (5)	
MCL reconstruction	3 (2)	
LCL reconstruction	0	

Variables are presented as count (%), unless reported otherwise. N is specified if it differs from the total of 178 (due to the different timing of introduction of certain variables added to the NKLR).
*26 patients had sutures and 3 patients had resection on both menisci.
†No microfractures or other procedures were reported.
ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; ADL, activities of daily living; BPTB, bone-patellar tendon-bone; ICRS, International Cartilage Regeneration and Joint Preservation Society; LCL, lateral collateral ligament; MCL, medial collateral ligament; NKLR, Norwegian Knee Ligament Register.

our cohort, which is comparable to the Delaware-Oslo cohort's nearly 70%.[34] RCTs also report that 40–50% of patients assigned to initial non-operative treatment are reconstructed within 2 years.[7–9] The slightly higher proportion of ACLR in these trials may be explained by selection bias (excluding surgery-averse patients) and thorough RCT follow-up, which might have facilitated cross-over to surgery. Also, the the Knee Anterior Cruciate Ligament, Nonsurgical versus Surgical Treatment (KANON) (n=59) and the Conservative versus Operative Methods for Patients with ACL Rupture Evaluation (COMPARE) (n=82) trials included younger populations and reported slightly higher preinjury activity levels compared with our cohort. This difference, however, disappears in our subgroup analyses, where nearly 50% of the patients under 25 years in our cohort and those active in Level 1 pivoting sports underwent ACLR. In summary, our findings support that when non-operative treatment is selected as the initial approach, nearly two thirds of patients remain non-ACLR at short-term follow-up.

Factors associated with delayed ACLR

Determining whether ACLR or rehabilitation alone is optimal for a given patient remains a key clinical challenge, and prediction models still show limited accuracy.[34–36] Our findings that age and activity level are associated with higher ACLR rates align with previous research.[34 37 38] While many potential predictive factors have been studied, only age and activity level are consistently reliable indicators for predicting ACLR after initial rehabilitation.[19] Studies of predictive factors require careful interpretation: their findings may reflect current clinical guidelines and selection bias rather than true prediction, and they cannot establish causation or explain why patients choose specific treatments or achieve certain outcomes. When patients opt for ACLR shortly after injury, which is often the case,[38] their decisions may reflect expectations, custom practice and fear rather than experienced knee instability.[32 39]

Meniscal injuries

The risk of additional meniscal injury is a key concern that often drives early ACLR recommendations,[14 40] yet our findings showed that knee instability, not meniscal injury, predominantly drove the decision to undergo surgery. While arthroscopy during ACLR revealed more meniscal injuries than baseline MRI, the types and severity were similar. The proportion of meniscal procedures in the delayed ACLR patients matched the overall NKLR of 60%,[21] supporting that delayed ACLR did not lead to increased meniscal procedures compared with early ACLR at 2 years.[41]

Why so many patients with MRI-verified meniscal injuries (40%) underwent non-operative treatment in the first place remains unclear, particularly given recent emphasis on meniscal preservation. This may reflect minor injuries expected to heal, MRI misclassification or misinterpretation. It may also indicate a knowledge gap in how surgeons define or interpret 'surgery-demanding' meniscal injuries in clinical guidelines, and in how patient preferences influence the treatment choice. Despite the mentioned limitations in our data, we found no evidence that non-operative treatment leads to a concerning increase in severe meniscal injuries.

Patient-reported outcomes

KOOS scores improved markedly from baseline, reaching 60–70/100 in the sport/recreation and QoL subscales at 2 years, which is similar to scores seen in both non-operative and early ACLR patients in previous RCTs.[7 8] However, regardless of treatment choice, patients' reported knee function remained well below normal values.[42 43] While outcomes were similar between treatment groups, KOOS may not adequately capture relevant differences, such as knee instability—the main reason for delayed

surgery in our study. We also lack crucial information on activity level and patient satisfaction after non-operative treatment.

A highly clinically relevant question is whether outcomes are worse for patients undergoing delayed ACLR as a result of 'failed' non-operative treatment, compared with those who remain non-operative or have early ACLR. While RCTs show similar outcomes between early ACLR and non-operative treatment with the option of delayed ACLR, some observational studies suggest potentially inferior outcomes with delayed ACLR—though the clinical significance remains unclear.[6 31 44] Further research specifically addressing the impact of delayed ACLR is needed, yet initial rehabilitation rather than primary ACLR is currently being recommended for many patients.[45 46] Our findings of similar short-term outcomes between non-operative and delayed ACLR patients do not contradict this approach.

CLINICAL AND RESEARCH IMPLICATIONS

When counselling ACL-injured patients, information should include that with current treatment algorithms, two-thirds of those treated non-operatively remain non-operatively treated at 2 years and patient-reported outcomes are similar for the patients who stay non-operatively treated and those that undergo ACLR later on. These findings suggest that non-operative treatment with an option of delayed ACLR is a viable treatment option for selected patients—typically those older and less active in level one sports—though long-term follow-up is needed. Additionally, patient-reported and surgeon-reported reasons for choosing non-operative treatment should be incorporated into registry updates. The low inclusion rate compared with ACLRs highlights the need to improve registry coverage of non-operative cases, which could also support the development of future prediction models.

STRENGTHS AND LIMITATIONS

To our knowledge, this represents the first and largest prospective cohort with such detailed data on non-operatively treated ACL injured patients, in a real-world setting. The study was planned as a descriptive cohort study ahead of the first inclusion of non-operatively treated patients. The prospective longitudinal design and systematic data collection within a well-established ACL register enables nationwide comprehensive capture of non-operatively treated patients and enhances the validity of our findings.

Several limitations warrant consideration. First, our findings should not be generalised to all ACL injured patients. This cohort represents selected patients who received initial non-operative treatment based on patient preference, surgeon recommendations and likely influence from Norwegian clinical guidelines. As such, the group consists of fewer high-risk patients compared with the general, younger, ACLR population or elite-level athletes. Despite this being a larger cohort than most non-operative studies, only a limited fraction of initially non-operative patients was registered during this period. Non-inclusion reasons can only be speculated, but likely stem from voluntary registration for non-operative cases versus mandatory reporting for reconstructions, plus limited healthcare personnel awareness of registration. The voluntary registration recruited fewer patients than expected, given that about 13 000 primary ACLRs were registered during this 7-year period. We can speculate that patients with symptomatic ACL tears are more likely to be referred from primary healthcare, while those managing well may not and therefore are not included. However, additional selection bias is unlikely because very few patients decline participation in the NKLR. A technical glitch prevented some patients from receiving the KOOS questionnaire. Although affecting patients at random, it resulted in lower response rates than expected and limits our available outcome data. These limitations precluded meaningful comparisons between non-operative and the general cohort in the NKLR of operatively treated patients, but increased coverage will enable future research in this area.

Using ACLR as an outcome measure has its limitations, as it is influenced by patient and surgeon preferences. Although we excluded patients with early ACLR to reduce misclassification bias, some patients classified as crossing over from non-operative to surgical treatment may have been intended surgical candidates from the beginning. This underscores the need for clearer registration criteria as conversion rates may be skewed toward a falsely high ACLR rate.

We do not have details on why or how non-operative treatment was chosen. We speculate that the decision reflects existing Norwegian guidelines and shared decision-making processes, but such details are not captured in the NKLR. Although reasons for delayed ACLR are reported and included in our analysis, these findings should be interpreted cautiously as this variable was only added to the registry in 2022, limiting availability to the most recent portion of our cohort (n=88, 44%). Finally, we do not have data on what the non-operative treatment contained, such as rehabilitation protocols or adherence to it, which could influence both patient-reported outcomes and ACLR conversion rates. Variables on rehabilitation, return to sport and patient satisfaction have now been added to the NKLR to inform future studies.

CONCLUSION

ACL injured patients registered in the NKLR and initially treated non-operatively were generally active individuals (1 in 3 were active in pivoting sports preinjury), with a mean age at injury of 35 years. At 2-year follow-up, 63% remained non-operated. Younger patients, those active in highly pivoting sports preinjury and those who had signs of any type of meniscal injury on baseline MRI were more likely to undergo ACLR compared with older patients, those with lower activity levels and those without meniscal injuries, respectively. Among those who eventually underwent ACLR, the main reason for surgery was instability. The non-operatively treated and ACLR patients had similar KOOS at 2 years. These findings suggest that non-operative treatment with an option of delayed ACLR is a sensible treatment option for selected ACL-injured patients.

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