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How does a combined pre-operative and post-operative rehabilitation program influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian Knee Ligament Registry

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ABSTRACT

Background: Preoperative knee function is associated with successful postoperative outcome after ACL reconstruction (ACLR). However, there are few longer-term studies of patients who underwent progressive preoperative and postoperative rehabilitation compared to usual care

Objectives: To compare preoperative and 2 year postoperative patient-reported outcomes (PROs) in patients undergoing progressive preoperative and postoperative rehabilitation at a sports medicine clinic compared with usual care

Methods: We included patients aged 16-40 years undergoing primary unilateral ACLR. The preoperative and 2 year postoperative KOOS of 84 patients undergoing progressive pre- and postoperative rehabilitation at a sports medicine clinic (Norwegian Research Center for Active Rehabilitation [NAR] cohort) were compared with the scores of 2690 patients from the Norwegian Knee Ligament Registry (NKLR). The analyses were adjusted for sex, age, months from injury to surgery, and cartilage/meniscus injury at ACLR.

Results: The NAR cohort had significantly better preoperative KOOS in all subscales, with clinically relevant differences (>10 points) observed in KOOS Pain, ADL, Sports and Quality of Life. At 2 years, the NAR cohort still had significantly better KOOS with clinically relevant differences in KOOS Symptoms, Sports and Quality of Life. At 2 years, 85.7-94.0 % of the patients in the NAR cohort scored within the normative range of the different KOOS subscales, compared to 51.4-75.8 % of the patients in the NKLR cohort.

Conclusion: Patients in a prospective cohort who underwent progressive pre- and postoperative rehabilitation at a sports medicine clinic showed superior patient-reported outcomes both preoperatively and 2 year postoperatively compared to patients in the Norwegian Knee Ligament Registry who received usual care.

What are the new findings?

-This is the first study to utilise ACLR registry data to compare treatment outcomes following usual care with a prospective cohort who underwent progressive pre- and postoperative rehabilitation at a sports medicine clinic

-ACLR patients who underwent progressive pre- and postoperative active rehabilitation at the sports medicine clinic showed superior 2 year patient-reported outcomes compared with usual care.

-86-94 % of the ACLR patients who underwent progressive pre- and postoperative rehabilitation at the sports medicine clinic had 2 year postoperative patient-reported outcomes comparable to the general population

How might it impact on clinical practice in the near future?

-The treatment strategy described in this paper, including progressive pre- and postoperative active rehabilitation and comprehensive functional testing, should be considered in the standard treatment protocol of patients who undergo ACLR

-Based on our previous findings and the 2 year results in this paper, an intensive preoperative rehabilitation protocol including heavy resistance strength training and plyometrics should be considered beneficial, and not harmful, as long as functional criteria for initiation of exercises are met

-Future studies are needed to identify which parts of the described treatment strategy are the key factors responsible for the observed differences compared to usual care

INTRODUCTION

Rupture of the anterior cruciate ligament (ACL) is common in young, active patients.[1, 2] While a substantial proportion of the injured patients undergo surgical ACL reconstruction (ACLR) to restore the mechanical stability in the knee joint, few data exist to guide how to best combine surgery and rehabilitation to optimise knee function. Given that outcomes after ACL reconstruction are not perfect,[3] there is an urgent need to continue to investigate ways to provide better patient outcomes.

At our institution in Norway, acutely injured patients are recommended to undergo progressive rehabilitation for at least 5 weeks before making the decision on ACLR or continued nonsurgical management.[4-6] For the patients who subsequently undergo ACLR, the rationale behind this approach is that optimal preoperative knee function will lead to better postoperative knee function.[7, 8] Thus, we recommend that the patient has 90 % muscle strength and hopping ability on the injured leg compared to the uninjured leg prior to ACLR. In a patient-group with no symptomatic concomitant injuries, we have previously shown significant short-term improvements in knee function and a low rate of adverse events with this approach.[4] However, the longer term outcomes for those who subsequently undergo ACLR have not yet been assessed.

The Norwegian National Knee Ligament Registry (NKLR) was established in 2004, and subsequently, several regional and national ACLR registries have been established following the same model.[9, 10] These registries reflect the outcome after usual care. Data from the ACL registry can provide a control material against which to compare treatment outcomes from prospective cohorts where interventions are more structured (i.e, the patients in our clinic in Norway as described above).

The aim of this study was, therefore, to compare knee function preoperatively and 2 years after ACLR in patients where progressive pre- and postoperative rehabilitation was emphasised, with patient data from the NKLR, representing usual care. We hypothesised that ACLR patients who underwent progressive pre- and postoperative rehabilitation would have higher patient-reported knee function preoperatively and 2 years postoperatively compared to the patients who received usual care.

METHODS

This is a cohort study of patients undergoing either ACLR with progressive pre- and postoperative active rehabilitation at a sports medicine clinic (NAR) or ACLR with usual care (NKLR). The outcome of interest is the preoperative and 2 year postoperative follow-up assessed with the Knee Injury and Osteoarthritis Outcome Score (KOOS) form.[11, 12]

Patients

The cohort receiving the progressive pre- and postoperative active rehabilitation program consists of patients in the Norwegian arm of the Delaware-Oslo ACL Cohort Study.[6, 13] This is a binational prospective cohort study conducted by the University of Delaware (US arm) and the Norwegian Research Center for Active Rehabilitation (NAR; Norwegian arm). These patients will therefore be referred to as the NAR cohort. Patients were consecutively screened for inclusion at the Norwegian Sports Medicine Clinic (Nimi) between 2007 and 2011. They were included in the main cohort if they had sustained a unilateral ACL rupture within the last 3 months, were between 13 and 60 years of age, and participated ≥ twice per week in pivoting sports. Patients were excluded if they had bilateral injuries, previous injury to either knee, or if the MRI at inclusion showed other grade III knee ligament injury, fracture or full-thickness articular cartilage injuries. Patients with meniscus injuries were excluded only if they had symptoms during plyometric activities that were not resolved within 3 months from injury. All patients were followed regardless of whether they underwent ACLR or not; however, only patients who underwent ACLR were eligible for analysis in this paper. The patients in the NAR cohort underwent ACL reconstruction at 7 different hospitals and received their rehabilitation at Nimi between 2007 and 2012.

The cohort receiving usual care consists of patients recorded in the Norwegian Knee Ligament Registry (NKLR) between June 2006 and December 2010. The NKLR prospectively collects data on all patients undergoing cruciate ligament surgery in Norway, including those enrolled in the NAR cohort. Further details on both cohorts have been published elsewhere.[4, 6, 14, 15] Approval from the

Regional Committee for Medical Research Ethics was obtained, and patients signed a written consent form prior to the data collection in both cohorts.

For this study, we extracted data on all patients included in the NAR cohort or the NKLR, aged 16 to 40 years, undergoing primary unilateral ACLR. To ensure that the cohorts were comparable, we excluded patients who had concomitant cartilage surgery or knee ligament surgery; concomitant PCL injury, LCL injury or injuries to the posterolateral corner; previous cruciate ligament injury to the contralateral knee; or previous knee surgery to the index knee. The covariates obtained to evaluate the study cohorts were sex, age, months from injury to surgery, ACL graft, cartilage injury at ACLR, and meniscus injury at ACLR. These data were extracted from the NKLR. The patients in the NAR cohort were identified and extracted from the NKLR so they were not included in both cohorts.

Rehabilitation

All patients in the NAR cohort underwent a 5-week preoperative rehabilitation program, which has previously been described in detail, including an appendix presenting the specific exercises, progression and exercise dosage.[4] The aim of the preoperative rehabilitation was to regain at least 90 % quadriceps and hamstrings strength, as well as hop performance on four single-legged hop tests[13, 16, 17] prior to surgery.[18] The rehabilitation program consisted of heavy resistance strength training, plyometrics and neuromuscular exercises, and was initiated as soon as joint effusion and range of motion (ROM) deficits were resolved (mean 60.4 days after injury).

The postoperative rehabilitation was to a larger extent individually tailored based on concomitant surgery, graft source and the patient's functional status**.** The postoperative rehabilitation was divided into three phases.[18] In the first phase (approx. 0-2 months postoperatively), the aim was to eliminate effusion, restore ROM and minimise muscular atrophy. Exercises in this phase included daily quadriceps contractions, ROM exercises and cycling as soon as tolerated. The aim of the second phase (approx. 2-6 months postoperatively) was to regain full control of weight-bearing terminal knee extension and at least 80 % muscle strength and hopping ability. Neuromuscular training, strength training and plyometrics were progressively introduced during this phase. The strength training was

initiated with 2 sets of 30 repetitions (low load) and gradually progressed to 4 sets of 4-6 repetitions (high load). Plyometric exercises were introduced once the strength training progressed to high load (typically 4 months postoperatively). The aim of the third phase (approx. 6-12 months postoperatively) was to regain at least 90 % muscle strength and hopping ability, as well as to enable the transition to sports. This phase consisted of heavy resistance strength training and increasingly demanding plyometric exercises, as well as sport-specific drills.

Outcome measures

The patients completed the KOOS preoperatively (after preoperative rehabilitation) and 2 years postoperatively. If patients underwent an ACL revision, the 2 year KOOS from the primary ACL reconstruction was used. The KOOS is a knee-specific self-assessment instrument for knee injuries which can lead to posttraumatic osteoarthritis. The form includes 42 items in 5 separately scored subscales: Pain (9 items), other symptoms (7 items), function in activities of daily living (ADL; 17 items), function in sport and recreation (Sports; 5 items), and knee-related quality of life (QoL; 4 items). KOOS has previously been validated for patients undergoing ACL reconstruction.[11, 12] A 10 point difference, in any subscale, was considered a clinically relevant difference.[19] To detect a group difference of 10 points with an estimated standard deviation of 20, alpha level of .05 and 80 % power, the a priori sample size calculation showed that 64 patients were needed in each group.

Statistics

Differences in group characteristics were assessed with the chi square test for nominal data, the Mann Whitney U-test for ordinal data and t-tests for interval data. Because patients with meniscus injuries were excluded from the NAR cohort only if they exhibited symptoms, a preliminary analysis was conducted to assess the interaction between the presence of meniscus injuries and cohort on all KOOS subscales, preoperatively and at 2 years. No significant interaction was found ($p \geq 0.352$), thus the KOOS in the two cohorts were not differently affected by meniscus injuries. Similarly, no significant interaction was found ($p \geq 0.264$) between low/high volume hospital or injury activity ($p \geq 0.138$) and cohort on any KOOS subscale. The median number of ACL reconstructions per hospital

was 28, and a low volume hospital was defined as hospitals with 28 surgeries or less. Injury activity was classified as being injured during sports vs other activities.

A one-way between-groups analysis of covariance (ANCOVA) was conducted to compare KOOS in the two cohorts preoperatively and 2 years postoperatively. The beta value and 95 % CI was reported, representing the difference in KOOS score associated with the NAR protocol compared to usual care. The covariates included in the analysis were sex, age, time from injury to surgery, as well as the presence of cartilage and meniscus injury registered at ACLR. Because the NAR cohort had significantly higher preoperative KOOS, an additional analysis of the 2 year postoperative KOOS was performed with preoperative KOOS added as a covariate. To avoid bias from ceiling effects in the NAR cohort, the analysis was stratified by the preoperative KOOS subscale score. Low/high preoperative scores were defined as scores below/above the median preoperative scores (cutoff points: Pain: 77.78, Symptoms: 75, ADL: 91.18, Sports: 45, QoL: 37.5).

The Statistical Product and Service Solutions (SPSS) for Windows, version 18.0 (SPSS, Chicago, Illinois) was used to analyse the data.

To quantify the percentage of patients with KOOS within the normative range, we calculated sex-specific KOOS cutoff points for each subscale utilising the Jacobson method as described by Mann et al.[20] For this method, KOOS data on a Swedish general population[21] in the age group 18-34 years were used as the "functional population" data, and the preoperative KOOS from the NKLR were used as the "dysfunctional population" data.[20]

RESULTS

From the NAR cohort, 84 of 94 eligible patients completed the 2 year KOOS (89.4 %). We were unable to contact 4 patients, 2 patients withdrew from the study, 2 patients declined to attend the follow-up, and 2 patients had moved abroad. From the NKLR database, 5769 patients were eligible.

As 3079 patients had missing data on either time from injury to surgery, all KOOS subscales at follow-up, or both, 2690 patients in the NKLR cohort were included in the analyses (46.6 %).

Sixty-one (72.6 %) patients in the NAR cohort had achieved the preoperative functional aims. There were no significant differences between the two cohorts in age, sex, time to surgery, or presence or severity of cartilage injuries (Table 1). Further, there was no significant difference in the presence of meniscus injuries; however, a higher proportion of patients in the NAR cohort had medial meniscus injuries treated with suture or fixation.

Table 1. Patient characteristics of the Norwegian Research Center for Active Rehabilitation (NAR) cohort which underwent progressive pre- and post-operative rehabilitation and the Norwegian Knee Ligament Registry (NKLR) cohort which represents usual care

	NAR (n=84)	**NKLR (n=2690)**	**p-value**
Sex, men/women (% men)	39/45 (46.4)	1362/1328 (50.6)	0.448
Age, mean (SD)	25.3 (7.2)	24.9 (7.7)	0.676
Months from injury to surgery, mean (SD)	6.3 (4.1)	6.8 (4.2)	0.358
ACL graft, n (%)			
BPTB	31 (36.9)	548 (28.7)	0.104
Hamstring	53 (63.1)	1358 (71.1)	0.116
Cartilage injury, n (%)	10 (11.9)	435 (16.2)	0.294
ICRS grade			
I	3 (3.6)	119 (4.7)	0.906
II	4 (4.8)	130 (5.1)	
III	1 (1.2)	43 (1.7)	
IV	2 (2.4)	8 (0.3)	
Meniscus injury, n (%)	30 (35.7)	857 (31.9)	0.456
Medial meniscus injury	21 (25.0)	518 (19.3)	0.190
Resection	6 (7.1)	257 (9.6)	0.458
Suture/fixation	11 (13.1)	166 (6.2)	0.011
Untreated	4 (4.8)	87 (3.2)	0.354
Lateral meniscus injury	18 (21.4)	510 (19.0)	0.570
Resection	11 (13.1)	324 (12.0)	0.771
Suture/fixation	2 (2.4)	66 (2.5)	0.966
Untreated	5 (6.0)	116 (4.3)	0.413

NAR: Norwegian Research Center for Active Rehabilitation; NKLR: Norwegian Knee Ligament Registry; BPTB: Bone-patellar tendon-bone; ICRS: International Cartilage Repair Society
ICRS grade missing from 135 patients in the NKLR
ACL graft source missing from 779 patients in the NKLR
8 medial menisci and 4 lateral menisci were treated with trephination in the NKLR

Table 2 shows the KOOS preoperatively and at 2 years for both cohorts. The NAR cohort, who had performed progressive preoperative rehabilitation, had significantly better preoperative KOOS in all subscales. The differences in all subscales except Symptoms were clinically relevant, with a group difference of 24.6 points observed in KOOS Sports. At 2 years, the NAR cohort still showed significantly better KOOS in all subscales, and clinically relevant differences were found in KOOS Symptoms, Sports and QoL. The largest group difference was still in KOOS Sports (17.7). At 2 years, the percentage of patients in the NAR cohort scoring within the normative range in the different KOOS subscales ranged from 85.7 to 94 %, while 51.4 to 75.8 % of the patients in the NKLR cohort scored within the normative range.

Table 2. Preoperative and 2 year postoperative KOOS and percentage of patients with KOOS within the normative range

KOOS subscale	Cohort	Preoperative				2 year			
		Mean (SD)	% within normative range (95 % CI)	Beta (95 % CI)	p-value	Mean (SD)	% within normative range (95 % CI)	Beta (95 % CI)	p-value
Pain	**NAR**	87.0 (10.7)	63.1 (52.8 to 73.4)	11.5 (8.0 to 15.0)	<0.001	93.5 (10.3)	89.3 (82.7 to 95.9)	7.6 (4.4 to 10.9)	<0.001
	NKLR	75.9 (16.8)	34.9 (33.0 to 36.8)			86.0 (15.1)	65.3 (63.5 to 67.1)		
Symptoms	**NAR**	82.6 (12.9)	59.5 (49.0 to 70.0)	9.5 (5.8 to 13.1)	<0.001	89.2 (11.9)	86.9 (79.7 to 94.1)	11.9 (8.0 to 15.8)	<0.001
	NKLR	73.6 (17.3)	39.6 (37.6 to 41.6)			77.4 (18.0)	51.4 (49.5 to 53.3)		
ADL	**NAR**	94.7 (10.1)	81.0 (72.6 to 89.4)	10.0 (6.5 to 13.3)	<0.001	98.0 (5.6)	94.0 (88.9 to 99.1)	5.5 (2.8 to 8.3)	<0.001
	NKLR	85.1 (16.3)	50.5 (48.5 to 52.5)			92.5 (12.8)	75.8 (74.2 to 77.4)		
Sports	**NAR**	69.1 (21.4)	61.9 (51.5 to 72.3)	24.6 (19.0 to 30.2)	<0.001	85.1 (16.2)	86.9 (79.7 to 94.1)	17.7 (12.1 to 23.2)	<0.001
	NKLR	45.2 (26.6)	23.3 (21.6 to 25.0)			67.6 (25.9)	57.2 (55.3 to 59.1)		
QoL	**NAR**	49.6 (20.0)	41.7 (31.2 to 52.2)	13.8 (9.9 to 17.8)	<0.001	78.6 (20.4)	85.7 (78.2 to 93.2)	10.8 (5.9 to 15.7)	<0.001
	NKLR	36.0 (18.1)	18.2 (16.6 to 19.8)			67.7 (22.7)	68.4 (66.6 to 70.2)		

Beta represents the difference in KOOS associated with the NAR cohort vs the NKLR after adjustment for sex, age, time from injury to surgery, meniscus injury at ACLR, and cartilage injury at ACLR. Positive values indicate higher scores in the NAR cohort.

After adjusting for the preoperative KOOS, the NAR cohort had significantly better KOOS Symptoms, Sports and Recreation and Quality of Life scores (Table 3). In patients who had preoperative scores below the median score, the NAR cohort showed 20.6 higher KOOS Sports scores (p=0.003), and 12.3 points higher KOOS QoL scores (p=0.006).

Table 3. Difference in 2 year postoperative KOOS in patients with below and above median preoperative scores after adjustment for preoperative KOOS

	All patients		Low preoperative score				High preoperative score			
			N				N			
	Beta (95 % CI)	p-value	NAR	NKLR	Beta (95 % CI)	p-value	NAR	NKLR	Beta (95 % CI)	p-value
Pain	2.9 (0.0 to 5.8)	0.053	12	1059	3.4 (-5.9 to 12.6)	0.472	72	1296	2.9 (0.4 to 5.3)	0.023
Symptoms	8.5 (4.9 to 12.2)	<0.001	33	1270	6.2 (-0.1 to 12.5)	0.053	51	1123	9.7 (5.4 to 13.9)	<0.001
ADL	2.3 (-0.1 to 4.8)	0.065	16	1271	4.5 (-2.0 to 11.0)	0.173	68	1085	1.5 (-0.7 to 3.7)	0.191
Sports	7.6 (2.4 to 12.7)	0.004	14	1253	20.6 (7.0 to 34.1)	0.003	70	1088	5.1 (0.2 to 10.0)	0.042
QoL	5.5 (0.8 to 10.2)	0.022	27	1477	12.3 (3.6 to 21.0)	0.006	57	894	2.1 (-2.9 to 7.2)	0.409

Beta represents the difference in KOOS associated with the NAR cohort vs the NKLR after adjustment for preoperative KOOS, sex, age, time from injury to surgery, meniscus injury at ACLR, and cartilage injury at ACLR. Positive values indicate higher scores in the NAR cohort.

Low/high preoperative scores are defined as scores below/above the median preoperative scores (cutoff points: Pain: 77.78, Symptoms: 75, ADL: 91.18, Sports: 45, QoL: 37.5).

DISCUSSION

This study compared the preoperative and 2 year postoperative patient-reported knee function in patients who underwent progressive preoperative and postoperative rehabilitation at a sports medicine clinic versus usual care. The main findings of this study are the large differences in the KOOS Sports and Quality of Life (QoL) subscales, favouring the NAR cohort. These patients were recommended to regain 90 % quadriceps and hamstrings strength, as well as hopping performance, prior to surgery. Compared to usual care, they had superior preoperative patient-reported knee function, and still exhibited superior patient-reported knee function 2 years after surgery, with 86-94 % of patients scoring within the normative range in the different KOOS subscales.

Clinical implications

The patients in the NAR cohort also exhibited significantly better 2 year KOOS Symptoms, Sports, and QoL scores after adjusting for the preoperative scores. Clinically relevant differences were established for the patients who had low KOOS Sports and QoL preoperative scores. As the patients in the NAR cohort had preoperative KOOS that were comparable to the 2 year outcome after usual care, the lack of a large effect from surgery to 2 years postoperatively is most likely attributed to ceiling effects in the NAR cohort. The stratified analysis (table 3) supports this view, showing large and clinically relevant differences between the cohorts in the patients with below median preoperative KOOS Sports and QoL scores, but not in the patients with above median preoperative scores. Of the five KOOS subscales, the KOOS Sports and QoL are shown to be the most responsive and to contain the most patient-relevant items after ACLR. [11, 22]

Several studies of preoperative determinants of successful rehabilitation after ACLR concluded that results may be optimised when muscle strength and range-of-motion deficits are reduced.[7, 8, 23-25] Additionally, a recent randomised study showed that a 6 week preoperative rehabilitation program led to improved outcomes 12 weeks after surgery.[26] All patients in the NAR cohort underwent progressive rehabilitation prior to surgery, which led to significant improvements in knee function and few adverse events.[4] The current study shows that these patients not only had

significantly better preoperative knee function, but also superior knee function 2 years after surgery compared to usual care. Thus, the results of this study indicate that there is an untapped potential for improving knee function prior to ACLR in the standard practice in Norway.

The optimal preoperative rehabilitation program is, however, still unknown. In comparison to the study by Shaarani et al.,[26] the patients in the NAR cohort followed a more intensive preoperative protocol, including perturbation training and introduction of plyometric exercises and heavy resistance strength training as soon as tolerated (approximately 2 months after injury).[4] Randomised studies comparing different preoperative rehabilitation programs are therefore needed. Note that the time from injury to surgery was not different between the NAR cohort (6.3 ± 4.1 months) and the NKLR (6.8 ± 4.2 months), indicating that the preoperative rehabilitation did not entail postponing the date of surgery for these patients.

Why did the outcomes differ between groups?

We acknowledge that being treated at a sports medicine clinic may include benefits over and above the rehabilitation protocol itself. It is likely that patient education and psychological strategies utilised by the doctors and physiotherapists treating the NAR cohort differ from usual care. Clinicians treating the NAR cohort placed heavy emphasis on educating the patients about their injury, the ACL reconstruction procedure and the importance of rehabilitation. The rehabilitation focus was to regain knee function and muscle strength using functional milestones and repeated testing prior to surgery, and at 6 months, 1 year and 2 years postoperatively. Thus, we believe these patients benefitted from more comprehensive follow-ups and clearer goal setting than usual care. While offering emotional and listening support is considered a natural part of the clinicians' jobs, no standardised form of cognitive behavioural therapy was used and none of the patients were referred to sports psychologists. On the other hand, such an intense rehabilitation program could worsen patient outcomes if the knee was inherently unstable. We believe our study addressed a question that had equipoise – does intense rehabilitation benefit or harm patients who may undergo ACL reconstruction.

The major limitation of this study is that the study design does not allow us to solidly infer about causality, i.e. whether it was the rehabilitation or other unmeasured factors which caused superior outcomes in the NAR cohort. Another limitation is the lack of KOOS early after injury. Although the short-term benefit of the preoperative rehabilitation in the NAR cohort has been shown in a previous publication,[4] the NKLR does not have access to patient outcomes in the period between injury and surgery. The patients in the NAR cohort may be hypothesised to be more motivated for rehabilitation or to have a higher socioeconomic level than the general population. However, the NKLR comprises patients from all sports medicine clinics, and the treatment expenses for the patients in the NAR cohort were covered by the public health care system (expenses for surgery as well as rehabilitation for 6 months after injury and 6 months after surgery), or by compulsory sports insurance. Further, only 2 patients (1.2 % per year) in the NAR cohort underwent revision surgery, which is comparable to the previously reported annual revision rate of 0.9 % in the NKLR.[9] The major strength of this study is the robustness of the outcome data from the NKLR cohort due to the large number of patients. However, a large percentage of the patients had missing data. The baseline or 2 year KOOS did not differ in any relevant way between patients with complete data and patients with partially complete data (mean differences ranging from 1.3 to 4.7 in favour of patients with complete data), nor was there any relevant difference in demographics, concomitants or surgical data (data not shown). Furthermore, the NAR cohort is included from a prospective study with an 89.4 % follow-up rate, benefitting from more continuous and comprehensive evaluation than what is common in registry studies. It is also relevant that this study evaluates outcomes of the largest patient group that experiences ACL injuries and receives ACL reconstruction - young active patients of both sexes.

Conclusion

ACL reconstructed patients, aged 16 to 40 years, who followed a progressive pre- and postoperative active rehabilitation program at a sports medicine clinic showed superior 2 year postoperative patient-reported outcomes compared with patients who underwent usual care. Implementation of this treatment strategy will potentially enable the patient to regain knee function 2 year postoperatively that is comparable to the general population.

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