

# Patient demographics and surgical characteristics in ACL revision: a comparison of French, Norwegian, and North American cohorts

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## Abstract

**Purpose** The goal of this paper is to compare patient factors, intra-operative findings, and surgical techniques between patients followed in large cohorts in France, Norway, and North America.

**Methods** Data collected on 2,286 patients undergoing revision anterior cruciate ligament reconstruction (ACLR) were obtained. These data included 1,216 patients enrolled in the Multicenter ACL Revision Study (MARS) in North America, 793 patients undergoing revision ACLR and recorded in the Norwegian Knee Ligament Registry (NKLR), and 277 patients recorded in the revision ACL database of the Société Française d'Arthroscopie (SFA) in France. Data collected from each database included patient demographics (age, sex, height, and weight), graft choice and reason for failure of the primary ACLR, time from

primary to revision ACLR, pre-revision patient-reported outcome scores (Knee Injury and Osteoarthritis Outcome Score, subjective International Knee Documentation Committee), associated intra-articular findings and treatments at revision, and graft choice for revision reconstruction.

**Results** Patient demographics in the three databases were relatively similar. Graft choice for primary and revision ACLR varied significantly, with more allografts used in the MARS cohort. Hamstring autograft was favoured in the NKLR, while bone–patellar tendon–bone autograft was most common in the SFA cohort. Reasons for failure of the primary ACLR were comparable, with recurrent trauma noted in 46–56 % of patients in each of the three cohorts. Technical error was cited in 44–51 % of patients in the MARS and SFA cohorts, but was not clearly elucidated in the NKLR cohort. Biologic failure of the primary graft was more common in the MARS cohort. Differences in associated intra-articular findings were noted at the time of revision ACLR, with significantly more high-grade cartilage lesions noted in the MARS group.

A full list of MARS Group and SFA Revision ACL Group is given in the [Appendix](#).

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**Conclusions** Significant differences exist between patient populations followed in revision ACL cohorts throughout the world that should be considered when applying findings from such cohorts to different patient populations.

**Level of evidence** Retrospective comparative study, Level III.

**Keywords** Anterior cruciate ligament · Reconstruction · Revision · Cohort · International

## Introduction

Registries and multi-centre prospective cohort studies are contributing more and more to our knowledge regarding anterior cruciate ligament reconstruction (ACLR). An important question is the applicability of data from one cohort to patients in other locations. Previous work has demonstrated many similarities but also significant differences in patients and operative techniques between two large cohorts of primary ACLRs: the US-based Multicenter Orthopaedic Outcomes Network (MOON) cohort and the Norwegian Knee Ligament Registry (NKLK) [15].

The relative rarity of revision ACLR requires an even greater reliance on such multi-centre studies to inform clinical decision-making. To provide such data, large cohorts of patients undergoing revision ACLR are being followed in several locations throughout the world, including the Multicenter ACL Revision Study (MARS) in North America [21], the NKLK in Norway [5], and the cohort of the Société Française d'Arthroscopie (SFA) in France [22]. Papers including data from large cohorts have already begun to appear regarding revision ACLR with more certainly to be published in the future [1, 3, 14, 18, 22, 26].

The relative dearth of data regarding revision surgery has likely contributed to increased variability in practice patterns surrounding this surgery relative to primary ACLR. Therefore, a clear understanding of the similarities and differences in patients and surgical techniques used in these different cohorts will be useful to those seeking to apply the findings of these groups to their own patient populations.

The purpose of the current study is to compare the patient characteristics and surgical techniques between these cohorts of revision ACL reconstruction. We hypothesize that patient demographics, graft choice for the primary ACLR, reasons for failure of the primary reconstruction, time from primary ACLR to revision reconstruction, patient-reported outcome scores prior to revision surgery, associated intra-articular pathology at revision reconstruction, and graft choice for revision reconstruction vary among the three cohorts.

## Materials and methods

### Data collection in MARS, NKLK, and the SFA cohorts

The MARS cohort was conceived to evaluate the outcomes of revision ACLR when it was determined that existing prospective cohorts not specifically focused on revision ACLR lacked sufficient numbers of revision cases for efficient and meaningful analysis [21]. With the backing of the American Orthopaedic Society for Sports Medicine (AOSSM), the MARS group began enrolling patients on March 1, 2006. A prospective longitudinal cohort design was established to determine prognosis and identify predictors of outcome of revision ACLR. Pre-operatively, subjects complete a patient questionnaire that contains a series of validated patient-oriented outcome questionnaires including the knee injury and osteoarthritis outcome score (KOOS) [20], Marx activity rating scale [16], the 36-item short-form health survey (SF-36) [24], and subjective International Knee Documentation Committee (IKDC) score [7]. The surgeon completes a form detailing the injury, treatment history of the knee, associated intra-articular injuries, a detailed examination under anaesthesia according to IKDC guidelines [6, 9], surgical technique, and graft utilized in the revision surgery. The 87 enrolling surgeons include those in academic and private settings at 52 sites in 28 American states and two Canadian provinces.

The NKLK is designed to collect information prospectively on all cases of cruciate ligament reconstruction in Norway, including those patients undergoing revision ACLR. Data collected include mechanism of injury, time since injury, intra-articular findings (meniscal and chondral pathology), method of ligament reconstruction, and treatment of any other pathology. The patients also complete the KOOS form in advance of surgery. Data regarding prior knee surgery (including the primary ACLR) are not recorded; however, these data are available if the primary reconstruction was also included in the registry. Greater than 95 % of ACLRs currently performed in Norway are enrolled in the registry [5].

The SFA revision ACL cohort was initially designed as a retrospective cohort study of all revision ACLRs between 1994 and 2003 followed by prospective data collection from 2004 to 2006. Data were collected at 10 orthopaedic centres in France. Participation was limited to patients undergoing revision ACLR with autograft following failure of a primary autograft ACLR. Preoperatively, subjects complete a subjective IKDC score. The surgeon completes a form detailing the injury, treatment history of the knee, associated intra-articular injuries, a detailed examination under anaesthesia according to IKDC guidelines, surgical technique, and graft utilized in the revision surgery.

## Retrospective data collection for this analysis

After approval was obtained from appropriate institutional review boards, de-identified data from MARS, the NKLR, and the SFA cohort were accessed. Data collected from each database included patient demographics (age, sex, height, and weight), graft choice and reason for failure of the primary ACLR, time from primary to revision ACLR, pre-revision patient-reported outcome scores (KOOS, subjective IKDC), associated intra-articular findings and treatments at revision, and graft choice for revision reconstruction. These data were compiled from MARS data from 2006 to 2011, NKLR data from 2004 to 2011, and SFA data from 1994 to 2006.

## Statistical analysis

Fisher's exact and chi-squared tests were utilized to compare categorical data between the three cohorts. Nonparametric methods were utilized to compare patient age and time from injury to reconstruction between the groups because these data did not fit a normal distribution. Mean and standard deviations for KOOS subscales and subjective IKDC were calculated for each database and compared using ANOVA.

## Results

During the data collection period, 1,216 patients were enrolled in the MARS database, 793 patients undergoing revision ACLR were recorded in the NKLR, and 277 patients were entered into the SFA revision ACL database.

The median age at the time of revision ACLR was 26 years in the MARS cohort, 28 years in the NKLR population, and

27 years in the SFA cohort (Table 1). The SFA cohort included more males (69.1 %) than the MARS (57.8 %) and NKLR (55.8 %) cohorts ( $p < 0.0001$ ). While mean height was similar between the three cohorts, mean weight and BMI were significantly different, with the MARS cohort exhibiting the highest values, followed by the NKLR and the SFA cohorts (Table 1).

## Primary ACLR graft choice

Graft choice for the primary ACLR was available for 99.8 % of MARS patients, 34.4 % of NKLR patients, and 98.9 % of SFA patients. The NKLR does not collect data regarding prior surgery, thus the primary graft type is only available for those patients in whom the primary reconstruction was also collected in the registry. Primary ACLR graft choice varied greatly between the three databases ( $p < 0.0001$ ) (Table 2). Bone–patellar tendon–bone (BTB) autograft was the most commonly used primary graft in the MARS cohort (40.4 %) and the SFA cohort (70.0 %), while hamstring autograft was the most common primary graft choice in the NKLR (73.6 %). Allograft was frequently utilized in the MARS cohort (29.0 %) and very rare in the NKLR (0.4 %), while the SFA cohort includes only autografts by design. Artificial grafts (0.8 %) and grafts containing both autograft and allograft tissue (2.3 %) were also present in the MARS cohort but not in the other two groups.

## Reason for failure of the primary reconstruction

The MARS cohort and SFA cohort both include an assessment of the reason for failure of the primary ACLR. These data are available in the NKLR database for the 482 patients (60.8 %) enrolled after 2007. Surgeons in all three groups

**Table 1** Patient demographics (at revision ACL reconstruction)

	MARS	NKLR	SFA	Significance
Age (years) (median, IQR)	26 (20–34)	28 (21–37)	27 (23–32)	<b>M v. N <math>p &lt; 0.0001</math></b> <b>M v. S <math>p = 0.019</math></b> N v. S $p = n.s.$
Sex (percent male)	57.8 %	55.8 %	69.1 %	<b><math>p &lt; 0.0001</math></b>
Height (m) (mean $\pm$ SD)	1.74 $\pm$ 0.09	1.75 $\pm$ 0.09	1.73 $\pm$ 0.08	Overall $p = n.s.$
Weight (kg) (mean $\pm$ SD)	80.1 $\pm$ 18.0	77.0 $\pm$ 14.9	71.0 $\pm$ 13.4	<b>Overall <math>p &lt; 0.0001</math></b> <b>M v. N <math>p = 0.014</math></b> <b>M v. S <math>p &lt; 0.0001</math></b> <b>N v. S <math>p &lt; 0.0001</math></b>
BMI (kg/m <sup>2</sup> ) (mean $\pm$ SD)	26.1 $\pm$ 4.6	24.9 $\pm$ 4.2	23.5 $\pm$ 3.3	<b>Overall <math>p &lt; 0.0001</math></b> <b>M v. N <math>p = 0.0001</math></b> <b>M v. S <math>p &lt; 0.0001</math></b> <b>N v. S <math>p &lt; 0.0001</math></b>

Bold indicates  $p$  values that are less than 0.05

MARS Multicenter ACL Revision Study, NKLR, Norwegian Knee Ligament Registry, SFA Société Française d'Arthroscopie, IQR inter-quartile range, M MARS, N NKLR, S SFA, SD standard deviation

**Table 2** Primary ACL reconstruction data

	MARS ( <i>n</i> = 1,216)	NKLR <i>n</i> = variable <sup>a</sup>	SFA ( <i>n</i> = 277)	Significance
Graft choice		<i>n</i> = 284		<b><i>p</i> &lt; 0.0001</b>
BTB autograft	491 (40.4 %)	63 (30.1 %)	194 (70.0 %)	
Hamstring autograft	317 (26.1 %)	209 (73.6 %)	73 (26.4 %)	
Quadriceps autograft	6 (0.5 %)		7 (2.5 %)	
Other	7 (0.6 %)			
Allograft	353 (29.0 %)	1 (0.4 %)		
Hybrid	29 (2.3 %)			
Artificial	10 (0.8 %)			
Not reported	3 (0.2 %)	11 (3.9 %)	3 (1.1 %)	
Reason for failure of primary reconstruction <sup>b</sup>		<i>n</i> = 482		<b><i>p</i> &lt; 0.0001</b>
Technical error	618 (50.8 %)		124 (44.8 %)	
Traumatic	680 (55.9 %)	226 (46.9 %)	128 (46.2 %)	
Biologic	330 (27.2 %)		8 (2.9 %)	
Infection	3 (0.2 %)	7 (2.5 %)	2 (0.7 %)	
“Graft Failure”		206 (42.7 %)		
Other	34 (3 %)	49 (10.2 %)		
Not reported	2 (0.2 %)	53 (11.0 %)	66 (23.8 %)	
Median time from primary reconstruction to revision (years)	3.5 IQR: 1.5–8.4	NR	3.9 IQR: 2.1–6.6	<i>p</i> = n.s.

Bold indicates *p* values that are less than 0.05

MARS Multicenter ACL Revision Study, NKLR Norwegian Knee Ligament Registry, SFA Société Française d’Arthroscopie, BTB bone–patellar tendon–bone, NR not reported, IQR inter-quartile range

<sup>a</sup> Number of patients in the NKLR for whom primary reconstruction data were available varied. Data regarding primary graft choice were available in 284 patients in whom the primary reconstruction was performed after 2004. Data regarding reason for failure of the primary reconstruction were available in the 482 patients enrolled after 2007

<sup>b</sup> The total of percentages exceeds 100 % because surgeons were allowed to document multiple causes for failure of primary ACL reconstruction

frequently cited multiple causes of failure in the same patient. Multiple causes were cited in 35 % of patients in the MARS cohort, 12 % of patients in the NKRL, and 18 % of patients in the SFA cohort. Reasons for failure of the primary ACLR were comparable. Recurrent trauma noted in 46–56 % of patients in each of the three cohorts. Technical error was cited in 45–51 % of patients in the MARS and SFA cohorts, but was not clearly elucidated in the NKLR cohort. The NKRL included a category “graft failure” that was inclusive of technical errors as well as biologic failures. This reason for failure was cited in 42.7 % of patients (Table 2). Biologic failure was more commonly cited in the MARS cohort (27.1 %) than in the SFA cohort (2.9 %).

#### Time to revision ACLR

The median time from primary ACLR to revision ACLR was similar in the MARS (3.5 years) and SFA (3.9 years) cohorts (*p* = n.s.). These data are not available in the NKLR database.

#### Patient-reported outcome data prior to revision ACLR

Pre-revision KOOS scores were available for 1,214 patients (99.8 %) in the MARS cohort and for 709 patients

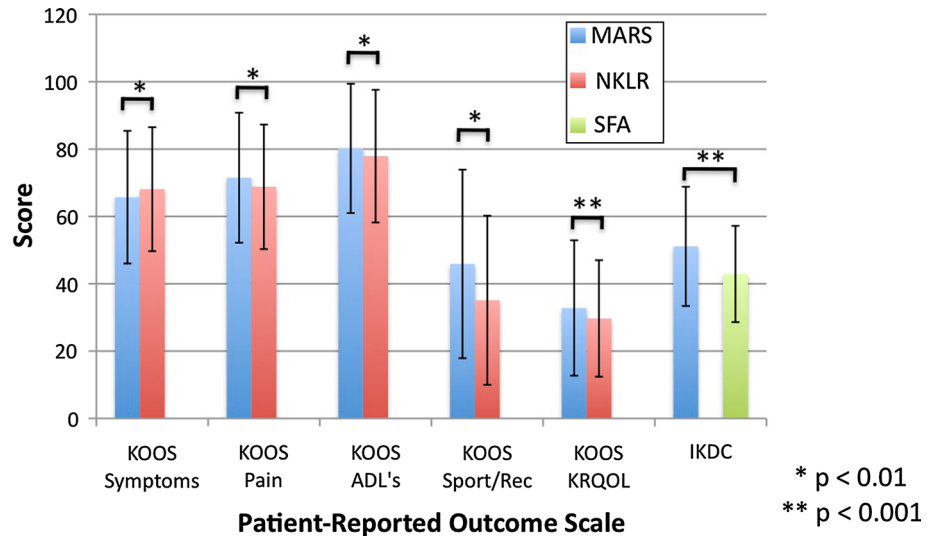
(89.4 %) in the NKLR cohort. Statistically significant differences between the two databases were noted in each KOOS subscale (*p* ≤ 0.01) with the MARS group scoring higher than the NKLR group on all subscales but symptoms; however, only the difference in the sport/recreation subscale exceeded the eight points previously described as the minimum clinically significant difference (Fig. 1) [19, 25]. KOOS scores were not collected in the SFA cohort.

Pre-revision IKDC scores were available for 1,213 patients (99.8 %) in the MARS cohort and for 219 patients (79.1 %) in the SFA cohort. The mean score in the MARS cohort (51.1) was significantly higher than in the SFA cohort (42.9) (*p* < 0.0001); however, this difference does not exceed the 11.5 points that represents a clinically significant difference [8, 25]. IKDC scores were not collected in the NKLR cohort.

#### Graft selection for revision ACLR

Graft choice for revision ACLR was quite variable between the three groups (Table 3). In the MARS cohort, allografts (49.4 %) and autografts (47.9 %) were used with similar frequency, with BTB autografts (26.2 %) used slightly more than hamstring autografts (20.1 %). In the NKLR, hamstring autograft (56.0 %) was the most commonly used

**Fig. 1** Pre-revision patient-reported outcomes scores (KOOS and IKDC) for patients in the MARS, NKLR, and SFA cohorts. No KOOS data are available for the SFA cohort, and no IKDC scores are available for the NKLR cohort



**Table 3** Revision ACL reconstruction data

	MARS (n = 1,216)	NKLR (n = 793)	SFA (n = 277)	Significance
Graft choice				<b>p &lt; 0.0001</b>
BTB autograft	318 (26.2 %)	257 (32.4 %)	155 (55.9 %)	
Hamstring autograft	245 (20.1 %)	444 (56.0 %)	107 (38.6 %)	
Quadriceps autograft	19 (1.6 %)	13 (1.6 %)	6 (2.2 %)	
Other	1 (0.1 %)	5 (0.6 %)	6 (2.2 %)	
Allograft	601 (49.4 %)	30 (3.8 %)		
Hybrid	32 (2.6 %)			
Not reported		44 (5.5 %)	3 (1.1 %)	
Medial meniscus injury	551 (45.3 %)	188 (23.7 %)	155 (56.0 %)	<b>p &lt; 0.0001</b>
Lateral meniscus injury	444 (36.5 %)	119 (25.1 %)	56 (20.2 %)	<b>p &lt; 0.0001</b>
Medial articular cartilage injury	590 (48.5 %)	268 (33.8 %)	136 (49.1 %)	<b>p &lt; 0.0001</b>
Lateral articular cartilage injury	491 (40.4 %)	156 (19.7 %)	64 (23.1 %)	<b>p &lt; 0.0001</b>
Patellofemoral articular cartilage injury	506 (41.6 %)	119 (15.0 %)	90 (32.5 %)	<b>p &lt; 0.0001</b>

Bold indicates p values that are less than 0.05

MARS Multicenter ACL Revision Study, NKLR Norwegian Knee Ligament Registry, SFA Société Française d'Arthroscopie, BTB bone–patellar tendon–bone

graft followed by BTB autograft (32.4 %). Other graft types were rare. In the SFA, BTB autograft (55.9 %) was most common, followed by hamstring autograft (38.6 %). Quadriceps autografts were used in 1–2 % of cases in each cohort.

**Meniscal pathology and treatment**

Medial meniscus injury was more common in the SFA (56.0 %) and MARS (45.3 %) cohorts than in the NKLR cohort (23.7 %) (p < 0.0001). Meniscus repair was more frequent in the MARS cohort (30.3 %), followed by the NKLR (20.2 %) and SFA (12.2 %) cohorts (Fig. 2). In contrast, lateral meniscus injury was most common in the MARS cohort (36.5 %) and less frequent in the NKLR (25.1 %) and SFA (20.2 %) cohorts (p < 0.0001). Repair

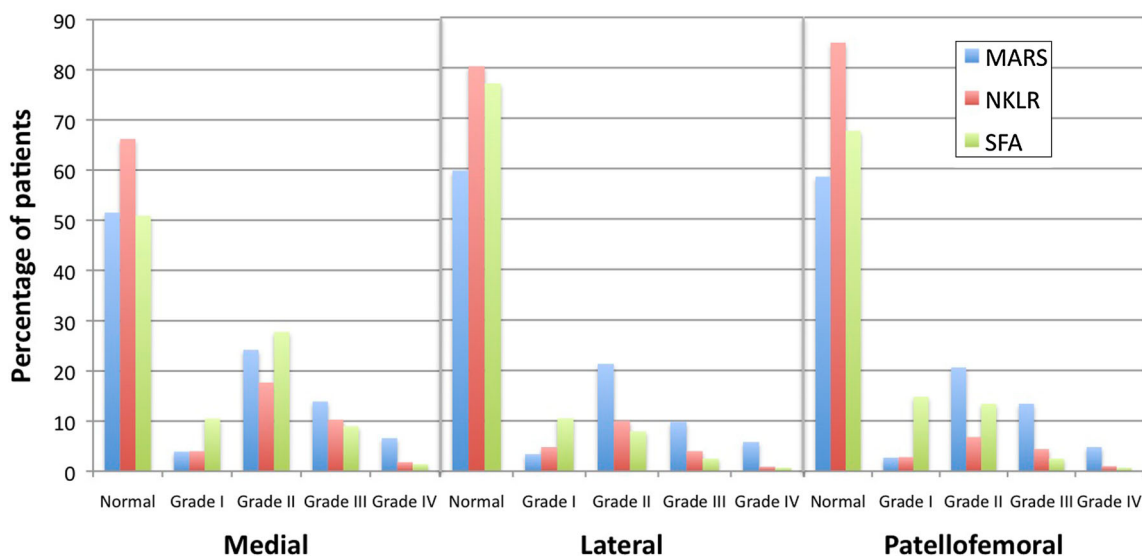
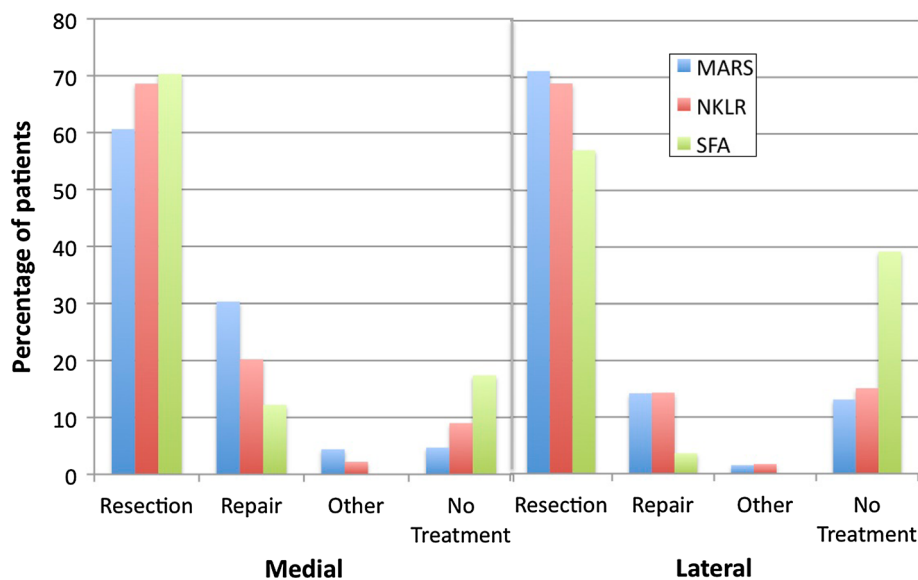
frequency was similar in the MARS (14.2 %) and NKLR (14.3 %) cohorts and rare in the SFA cohort (3.6 %) (Fig. 2).

**Articular cartilage pathology**

Medial articular cartilage injury was more common in the SFA (49.1 %) and MARS (48.5 %) cohorts than in the NKLR cohort (33.8 %) (p < 0.0001). The distribution of medial cartilage injuries by severity was similar among the three cohorts, although grade IV lesions were more common in the MARS cohort than the other two groups (Fig. 3).

Lateral articular cartilage injury was most common in the MARS cohort (40.4 %) and less frequent in the NKLR (19.7 %) and SFA (23.1 %) cohorts (p < 0.0001). There

**Fig. 2** Treatment of patients with medial and lateral meniscus pathology in the MARS, NKLR, and SFA cohorts



**Fig. 3** The incidence of medial, lateral, and patellofemoral compartment chondral damage at the time of revision ACL reconstruction

were a higher proportion of high-grade (III–IV) lesions in the MARS cohort than in other two groups (Fig. 3).

Patellofemoral articular cartilage injury was more common in the MARS (41.6 %) and SFA (32.5 %) cohorts than in the NKLR cohort (15.0 %) ( $p < 0.0001$ ). There were again a higher proportion of high-grade (III–IV) lesions in the MARS cohort than in other two groups (Fig. 3).

## Discussion

The most important findings of this study are that significant differences exist between patient populations followed

in revision ACL cohorts in France, Norway, and North America. These differences include graft choice in both primary and revision ACL surgery and the prevalence of associated intra-articular pathology encountered at the time of revision ACLR.

Patient demographic factors were relatively consistent across the three studies. All three studies included significantly more males than females, with the SFA cohort demonstrating the highest percentage of males (nearly 70 %). While statistically different due to the large numbers of patients in each group, patient age was similar among the groups, with the median age in each group falling between 26 and 28 years. Similarly, BMI ranged from 23 to 26 in the three groups. Differences between the

groups were statistically significant, but it remains unclear whether differences of this magnitude are clinically important.

Primary graft choice varied greatly between the groups. Most notably, primary reconstruction with allografts was much more common among revisions in the MARS group than in the NKLR. This difference reflects the much higher use of allograft in the USA than in Norway. The exact percentage of primary ACLRs in the USA that are performed with allograft tissue are unknown; however, it has been reported to be increasing [13]. It is unknown whether the proportion of primary allografts among patients undergoing revision relative are comparable to the overall proportion of primary ACLRs performed with allograft. Revision ACL graft choice also varied greatly in the three cohorts. Allograft was most common in the MARS cohort, while BTB and hamstring autografts were most common in the SFA and NKLR cohorts, respectively.

Reasons for failure of the primary ACLR were similar between cohorts, with recurrent trauma, technical error, and multiple factors most commonly noted in both the MARS and SFA cohorts. The NKLR noted a similar risk of recurrent trauma, but did not separately report biologic failures and most technical errors, limiting comparisons with the other two cohorts. The current findings are consistent with previous reports of failure etiology [4, 10–12, 23]. Biologic failure, which has previously been reported to contribute to a very small proportion of failures [17], was noted in over 27 % of revisions in the MARS cohort. The increased use of allografts in primary reconstruction may contribute to this increased risk of biologic failure.

Patient-reported outcomes prior to reconstruction were similar in the MARS and NKLR groups, with a clinically significant difference only noted in the sport/recreation function subscale. This finding is in contrast to prior work comparing primary ACLRs in the USA and Norway in which clinically significant differences were noted only in the symptoms subscale [15]. The reason for this difference is unclear. IKDC scores in the MARS group were significantly higher than in the SFA cohort. This difference may represent differences in the patients that choose to undergo repeat surgery in each group or be a function of the impact of cultural differences on the IKDC score.

Meniscal and articular cartilage pathology, particularly in the lateral and patellofemoral compartments, was generally higher in the MARS group. This finding may be related to the increased weight and BMI noted in the MARS group [2]. Another possibility is that increased prevalence of contact sports in the USA leads to an increase in contact ACL injuries in the MARS group and thus more associated injuries [15]. Articular cartilage and meniscal damage were commonly noted to coexist in the same compartment as has been previously reported [3].

The strengths of this paper include its large sample size, primarily prospective data collection, and the completeness of the data sources utilized. Weaknesses include the use of some retrospectively collected data in the SFA database and some inconsistencies in data collected across the different studies. The use of more consistent patient-reported outcome scores would facilitate comparison among such databases. It should also be noted that the data collected in the MARS and especially the SFA cohort may not accurately represent the typical revision ACLR technique in the USA and France, respectively, given that they do not represent registry data as are present in the NKLR.

## Conclusion

Significant differences exist between patient populations followed in revision ACL cohorts in France, Norway, and the North America. Differences in patient demographics as well as graft choice in both primary and revision ACL surgery and the prevalence of associated intra-articular pathology should be carefully considered by practicing clinicians when applying findings from such cohorts to their own patient population.

## Appendix

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### SFA Revision ACL Group

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