Cross-cultural Comparison of Patients Undergoing ACL Reconstruction in the United States and Norway

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Abstract

Data from large prospectively collected ACL cohorts are being utilized to address clinical questions regarding ACL injury demographics and outcomes of ACL reconstruction. These data are affected by patient and injury factors as well as surgical factors associated with the site of data collection. The aim of this paper is to compare primary ACL reconstruction data from patient cohorts in the United States and Norway, demonstrating the similarities and differences between two large cohorts.

Primary ACL reconstruction data from the Multicenter Orthopaedic Outcomes Network (MOON) in the United States and the Norwegian National Knee Ligament Registry (NKLR) were compared to identify similarities and differences in patient demographics, activity at injury, preoperative Knee injury and Osteoarthritis Outcome Score (KOOS), time to reconstruction, intraarticular pathology, and graft choice.

713 patients from the MOON cohort were compared with 4928 patients from the NKLR. A higher percentage of males (NKLR 57%, MOON 52%; $p < 0.01$) and increased patient age (NKLR 27 years, MOON 23 years; $p < 0.001$) were noted in the NKLR population. The most common sports associated with injury in the MOON cohort were basketball (20%), soccer (17%), and American football (14%); while soccer (42%), handball (26%), and downhill skiing (10%) were most common in the NKLR. Median time to reconstruction was 2.4 (Interquartile range [IQR] 1.2 – 7.2) months in the MOON cohort and 7.9 (IQR 4.2 – 17.8) months in the NKLR cohort ($p < 0.001$). Both meniscal tears (MOON 65%, NKLR 48%; $p < 0.001$) and articular cartilage defects (MOON 46%, NKLR 26%; $p < 0.001$) were more common in the MOON cohort. Hamstring autografts (MOON 44%, NKLR 63%) and patellar tendon autografts (MOON 42%, NKLR 37%)

were commonly utilized in both cohorts. Allografts were much more frequently utilized in the MOON cohort (MOON 13%, NKLR 0.04%; $p < 0.001$).

Significant diversity in patient, injury, and surgical factors exist among large prospective cohorts collected in different locations. Surgeons should investigate and consider the characteristics of these cohorts when applying knowledge gleaned from these groups to their own patient populations.

Introduction

The ACL is the most frequently injured ligament in the knee and its subsequent reconstruction is a commonly performed orthopaedic procedure, yielding clinically stable ligament reconstruction in most patients.[4, 19] However, a multitude of issues surrounding ACL surgery and postoperative rehabilitation remain unresolved. Some issues can and should be addressed by conducting properly designed randomized controlled trials. However, large prospective longitudinal cohorts are the preferred study design when assessing the incidence of ACL graft failure, providing information on postoperative activity level and patient oriented outcome scores, and identifying prognostic factors associated with outcome data.

Prospective ACL reconstruction cohorts are ongoing in the United States, Norway, Denmark, and Sweden. The Multicenter Orthopaedic Outcomes Network (MOON) was established in the United States in 2002 to determine the prognosis and predictors of ACL reconstruction outcomes.[25] Similarly, the Norwegian National Knee Ligament Registry (NKLR) was established in 2004 after review of evidence from the Scandinavian joint replacement registries indicated that a national knee ligament registry could be highly beneficial.[8, 9, 11, 13] A key question in the analysis and interpretation of outcomes from these two prospective databases is their applicability to geographically and culturally diverse populations. Different patient demographics, activities associated with injury, preoperative treatment algorithms, surgical techniques, and patient expectations make for markedly different patient populations throughout the world. Attempts to

generalize results from one specific population to another could lead to inaccurate conclusions unless the similarities and clinically relevant differences are known.

The aim of this paper is to compare primary isolated ACL reconstruction data from the MOON cohort and NKLR. These two prospective cohorts are among the largest in the world to assess outcomes of ACL reconstruction, with multiple investigators collecting data on two continents.[3, 6, 12, 14] We hypothesize that there are statistically and clinically relevant differences between the cohorts as well as important similarities that should be noted by surgeons attempting to extrapolate results from such databases to their own patients.

Materials and Methods

Prospective Data Collection in MOON and NKLR

The MOON group began enrolling ACL reconstruction patients at seven academic medical centers in the United States in 2002. A prospective longitudinal cohort design was established to determine the prognosis and identify predictors of outcome. Preoperatively, subjects complete a 13-page form that included the mechanism of injury; time from injury to reconstruction; additional injuries before reconstruction; a series of validated patient-oriented outcome questionnaires including the Knee Injury and Osteoarthritis Outcome Score (KOOS),[18] Marx activity score,[15] SF-36,[24] and International Knee Documentation Committee (IKDC) score;[10] sports participation history; co-morbidities; demographics; and any ongoing therapies.[14, 21, 25] The surgeon completes a detailed examination under anesthesia including the contralateral knee and detailed operative assessment and treatment of meniscus and articular cartilage

injuries using the standard modified Outerbridge score.[14] The details of ACL reconstruction technique and rehabilitation milestones are also recorded. MOON enrolls approximately 500 patients undergoing primary ACL reconstruction annually.

The NKLR is designed to collect information prospectively on all cases of cruciate ligament reconstruction in Norway. Data collected includes mechanism of injury, time since injury, intraarticular findings (meniscal and chondral pathology), method of ligament reconstruction, and treatment of any other pathology. Cartilage lesions are graded according to the International Cartilage Repair Society (ICRS) (published in the newsletter of the ICRS, issue spring 1998). The patients are also asked to complete the KOOS form in advance of surgery. Approximately 1600 patients undergoing primary ACL reconstruction are enrolled annually, noted to be greater than 95 % of annual ACL reconstructions in Norway.[6]

Retrospective Data Collection for this Analysis

After approval was obtained from appropriate institutional review boards, data from both the MOON cohort and NKLR were accessed. Each prospectively collected database included information about patient demographics (age and sex), activity associated with injury, time from injury to reconstruction, preoperative KOOS scores, meniscal and articular cartilage findings and treatments at reconstruction, and graft choice for reconstruction. These data were compiled from two years of MOON data on all primary ACL reconstructions performed between January 1 and December 31, 2002, and between June 1, 2007 and May 31, 2008; and from three and one half years of NKLR data on all primary ACL reconstructions performed between June 7, 2004, and December 31, 2007.

Statistical Methods

Pearson's chi-square test was utilized to compare the proportion of men and women and the incidence of meniscal pathology in each cohort. Nonparametric methods (Mann-Whitney U test) were utilized to compare patient age and time from injury to reconstruction between the two groups as the data did not fit a normal distribution. A score in each of the five KOOS subscales was calculated for each patient utilizing the KOOS scoring sheet as published online.[18] Mean and standard deviations for each subscale were calculated for all patients for whom data was available in the respective databases and compared using a t-test as the data fit a normal distribution.

Results

Demographics

During the data collection period, 950 ACL reconstructions were enrolled in the MOON cohort. Revision ACL reconstruction was performed in 132 patients (14%), leaving 818 primary ACL reconstructions. Concurrent PCL, MCL, LCL, or posterolateral corner injury was noted in 105 patients (13%) who were excluded, leaving 713 patients undergoing isolated ACL reconstruction for this analysis. During the data collection period, 5720 ACL reconstructions were logged in the NKLR. Revision ACL reconstruction was performed in 391 patients (7%), leaving 5329 ACL reconstructions for analysis. Concurrent PCL, MCL, LCL, or posterolateral corner injury was noted in 401 patients (8%) who were excluded, leaving 4928 patients undergoing isolated ACL reconstruction for this analysis.

The median age at reconstruction in the MOON cohort was 23 years (Interquartile range [IQR], 17-35), while the median for patients in the NKLR population was 27 years (IQR, 19-36) ($p < 0.001$). The MOON cohort included 371 male patients (52%) and the NKLR population included 2825 male patients (57%) ($p < 0.01$).

Activity Associated with Injury (Figure 1)

In the MOON cohort, ACL injuries were associated with a sport in 88% of those for whom an injury mechanism was known. The most frequent activities associated with ACL injury in the MOON cohort were basketball (20%), soccer (17%), American football (14%), skiing (7%), other sports injuries (20%), work injuries (3%), motor vehicle accidents (1%), and other non-sport activities (6%). Injury mechanism was unknown in 3% of patients and not reported in 11% of patients.

In the NKLR, ACL injuries were associated with a sport in 87% of those for whom an injury mechanism was known. The most common activities associated with injury in the NKLR population were soccer (42%), handball (16%), downhill skiing (10%), other sports injuries (17%), work injuries (3%), motor vehicle accidents (2%), and other non-sport activities (8%). Injury mechanism was unknown in 1% of patients and not reported in 1% of patients.

Time from Injury to Reconstruction

A specific date of injury was known in 457 patients in the MOON cohort, allowing calculation of the median time from injury to reconstruction in 64% of patients. The median time from injury to reconstruction was 2.4 months (IQR, 1.2 – 7.2 months). A specific date of injury was known in 4672 patients in the NKLR population, allowing

calculation of the median time to injury in 95% of patients. The median time from injury to reconstruction in the NKLR population was 7.9 months (IQR, 4.2-17.8 months) ($p < 0.001$).

Pre-operative KOOS (Figure 2)

A preoperative KOOS was available for 643 patients (90%) in the MOON cohort and for 4182 patients (85%) in the NKLR population. Patients in both databases exhibited higher scores in the pain, other symptoms, and function in activity of daily living (ADL) subscales than in the function in sport and recreation (sport/rec) and knee related quality of life (QOL) subscales. Statistically significant differences between the two databases were noted in each KOOS subscale except knee related quality of life; however, only the difference in the "other symptoms" subscale exceeded the 8 points previously described as the minimum clinically significant difference.[17] Differences in the other KOOS subscales are too small to be clinically significant.

Meniscal Pathology and Treatment (Figure 3)

In the MOON cohort, 461 patients (65%) had meniscal pathology. There were 273 medial tears and 319 lateral tears. In the NKLR population, 2386 patients (48%) had meniscal pathology. There were 1642 medial tears and 1235 lateral tears. The prevalence of meniscal pathology was significantly higher in the MOON cohort ($p < 0.001$).

In the MOON cohort, medial meniscal lesions were treated with resection (45%), repair (39%), trephination (2%), or observation (12%). Lateral meniscal lesions were treated with resection (61%), repair (14%), trephination (3%), or observation (21%). In the NKLR population, medial meniscal lesions were treated with resection (62%), repair

(22%), trephination (1%), replacement (0.1%), or observation (10%). Lateral meniscal lesions were treated with resection (70%), repair (9%), trephination (2%), or observation (13%). Treatment was not reported in 1% of patients in the MOON database and 6% of patients in the NKLR.

Resection was more frequently utilized in the NKLR population for all meniscal lesions, while repair and observation were more common in the MOON cohort ($p < 0.05$). Trephination alone and replacement were rare in both databases.

Articular Cartilage Pathology and Treatment (Table 1)

In the MOON cohort, 326 patients (46%) had an articular cartilage injury of any type noted at reconstruction. Modified Outerbridge grade 3 or 4 lesions were noted in 133 patients (19%). Grade 3 and 4 lesions were most commonly located on the lateral tibial plateau, patella, and medial femoral condyle. In the NKLR population, 1302 patients (26%) were noted to have an articular cartilage injury of any type at reconstruction. ICRS grade 3 or 4 lesions were noted in 343 patients (7%). Grade 3 and 4 lesions were most commonly located on the medial and lateral femoral condyles. The incidence of articular cartilage pathology was significantly higher in the MOON cohort ($p < 0.001$).

In the MOON cohort, cartilage debridement (chondroplasty) was the most common treatment for grade 3 and 4 articular cartilage defects in all locations (65%). Observation alone was also common (25%). Microfracture was also utilized (14%), most commonly on the medial and lateral tibial plateaus and the medial femoral condyle. In the NKLR population, observation alone was most commonly utilized for grade 3 and 4 articular cartilage lesions in all locations (44%). Cartilage debridement (17%) and microfracture

(15%) were frequently utilized, with microfracture utilized most commonly on the medial and lateral femoral condyles and medial tibial plateau. In no cases in either the MOON or NKLR populations were mosaicplasty or autogenous chondrocyte implantation (ACI) utilized. Observation alone was generally utilized for grade 1 and 2 articular cartilage lesions in both cohorts.

Graft selection

In the MOON cohort, the most common grafts were doubled semitendinosus and gracilis autograft (309 patients, 44%) and patellar tendon autograft (300 patients, 42%). Other autografts accounted for four patients (0.6%) while allograft was utilized in 95 patients (13%). In the NKLR population, the most common grafts were doubled semitendinosus and gracilis autograft (2932 patients, 60%), patellar tendon autograft (1830 patients, 37%). Other autograft accounted for 148 patients (3%) while allograft was utilized in two patients. The use of allograft was significantly higher in the MOON cohort than in the NKLR ($p < 0.001$)

Soccer Subgroup Analysis (Figure 4)

Soccer was the only sport contributing a large number of patients in both populations. The MOON cohort contained 120 patients (17%) who injured their ACL playing soccer. They were 46% male and had a median age of 18 (IQR, 16-28). Meniscal pathology was noted in 74 soccer players (62%); articular cartilage pathology was identified in 42 soccer players (35%), and 13 patients (11%) were noted to have grade 3 or 4 articular cartilage defects. The NKLR population contained 2050 patients (42%) who injured their ACL playing soccer. They were 72% male and had a median age of 25 (IQR, 19-33). Meniscal

pathology was noted in 1004 soccer players (49%); articular cartilage pathology was identified in 503 soccer players (24%); and 144 patients (7%) were noted to have grade 3 or 4 articular cartilage defects.

Discussion

Prospective cohorts are the preferred clinical research design to define prognosis and identify modifiable predictors of outcomes. Data obtained from ongoing prospective cohorts throughout the world are available to physicians everywhere via a multitude of electronic sources and influence care of countless patients. [3, 6, 12, 14] A key question for physicians is how applicable these data are to their individual patient populations. The most important finding of the current study is that there are significant differences in demographic and treatment data between the MOON and the NKLR cohorts.

Demographics of patients undergoing ACL reconstruction can vary considerably. Our data demonstrate that patients undergoing ACL reconstruction in Norway are on average older and more likely to be male than patients in the MOON cohort. Gender differences may be explained by differences in sport participation rates among men and women in the two countries or differences in the frequency of utilization of injury prevention training protocols in female athletes. These protocols have been heavily researched and instituted in Norway, possibly decreasing the incidence of ACL tears in females athletes.[23] Age differences are likely affected by the fact that in the United States a large percentage of athletes compete for high school and college sports teams, while in Norway most athletes compete for club teams. Whereas many Americans cease playing team sports at the completion of school, many Norwegians continue to play for club teams long after finishing school, contributing to the older demographics noted in the

NKLR population. Similarly, healthcare system differences may introduce bias into which patients present to surgeons for reconstruction given that not all Americans have insurance and easy access to providers. Finally, treatment algorithms for ACL injuries differ between the two countries, with nonoperative management of ACL injuries attempted much more frequently in Norway. It has been estimated that 50% of ACL injuries in Norway are treated nonoperatively,[6, 7] while surveys of the centers participating in MOON data collection place the nonoperative treatment rate at 5 - 10%.

The activity associated with the injury to the ACL reflects the national popularity of various sports and activities and varies greatly between the two databases, as soccer was the only sport representing greater than 10% of injuries in both databases. In order to eliminate differences in activity at injury as a confounding variable, we compared patients from both databases who were injured playing soccer. Differences were again noted between the two groups in amount of intraarticular pathology. However, further analysis reveals that other differences still exist between the two groups. The overall differences in both age and gender between the two populations are even larger in the soccer subset. These demographic differences may explain differences in the rates of intraarticular injury between the two groups, or they may be related to other, unknown factors such as interrater differences in identifying and describing pathology.

Additional intraarticular pathology in patients in the MOON database does not entirely explain the poorer preoperative score in the “other symptoms” KOOS subscale noted in patients in the MOON. Clinically significant differences remain even when comparing patients without intraarticular pathology other than ACL injury (data not shown). The difference may be related to differences in time from injury to KOOS in the two patient

groups. The KOOS was obtained immediately preoperatively in both databases leading to a larger time between injury and KOOS in the NKLR group.

Differences in treatment philosophy greatly influence the timing of ACL reconstruction as well as the choice of ACL graft and treatment of associated intraarticular pathology. The median time from injury to reconstruction in the NKLR population was three times that in the MOON cohort. While some have hypothesized that increased time to reconstruction may increase the incidence of intraarticular pathology,[2, 5, 22] our data do not support this concept, as a greater incidence of intraarticular pathology was noted in the MOON cohort in spite of much earlier reconstruction. The fact that an increased percentage of meniscal tears in the NKLR group involved the medial meniscus may support the hypothesis, as the medial meniscus is known to be a restraint to anterior tibial translation in the case of ACL deficiency. However, as above, one must be wary of differences in patient demographics and injury mechanism when making this comparison. Similarly, the fact that 35% of patients in the MOON database were unable to identify a specific injury date may lead to an underestimation of median time to reconstruction in this group.

While treatment of meniscal tears was similar between the two databases, the approaches to grade 3 and 4 articular cartilage defects were quite different. Surgeons in the MOON cohort were much more likely to report debriding cartilage while surgeons in the NKLR were more likely to treat lesions with observation. This difference may be real or due to differences in classification resulting from semantics – does one refer to a small amount of cartilage shaving as debridement or simply as observation? Surgeons utilized microfracture and abrasion techniques at similar rates in both databases.

This paper addresses differences in these databases related only to patient and injury characteristics and findings and techniques utilized at reconstruction. A weakness of this analysis is that we have not reviewed any outcome data. However, multiple studies have documented the influence that intraarticular pathology at the time of reconstruction can have on outcome.[1, 16, 20, 26] An additional weakness is our comparison of data from different time periods between the two databases. The time periods chosen for data extraction were based on data availability at the time of writing. Analysis of the MOON data from the two periods of data collection revealed no differences with the exception of a trend toward decreased allograft use in recent years. We do not believe the timing of data collection influenced the findings of this study. Another important limitation that might bias the results is that the NKLR is a national registry, with a compliance rate of more than 95%, while the MOON cohort is comprised exclusively of surgeons at seven academic institutions in the United States. Thus the NKLR gathers a much broader cross section of surgeons and patients than the MOON cohort. Further research is needed to establish if data from the MOON cohort can be generalized to the entire population of the United States.

We have identified and described numerous demographic and treatment differences in the MOON and NKLR populations with the potential to influence outcome data. Similar differences potentially exist between other databases from various locations around the world. Surgeons should investigate the patient and treatment characteristics of such databases when applying knowledge gleaned from these groups to their own patient populations.

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Table 1: Treatment and Location of Grade 3 and 4 Articular Cartilage Defects.

Database	Lesions	Treatment / Location	Debridement	Microfracture	Observation	Other	Not Reported
MOON*	43 (6%)	Patella	37 (86%)	---	6 (14%)	---	---
NKLR#	38 (0.8%)		6 (16%)	1 (2.6%)	19 (50%)	1 (2.6%)	11 (29%)
MOON	18 (2.5%)	Trochlea	12 (67%)	2 (11%)	4 (22%)	---	---
NKLR	18 (0.4%)		---	1 (5.6%)	12 (67%)	---	5 (28%)
MOON	39 (5.5%)	Medial Femoral Condyle	21 (54%)	5 (13%)	12 (31%)	---	1 (2.6%)
NKLR	209 (4.2%)		42 (20%)	44 (21%)	78 (37%)	3 (1.4%)	42 (20%)
MOON	8 (1.1%)	Medial Tibial Plateau	4 (50%)	2 (25%)	2 (25%)	---	---
NKLR	47 (1%)		6 (13%)	2 (4.3%)	21 (45%)	1 (2.1%)	17 (36%)
MOON	31 (4.4%)	Lateral Femoral Condyle	21 (68%)	1 (3.2%)	9 (29%)	---	---
NKLR	66 (1.3%)		13 (20%)	9 (14%)	33 (50%)	---	11 (17%)
MOON	54 (7.6%)	Lateral Tibial Plateau	30 (57%)	8 (15%)	15 (28%)	1 (1.8%)	---
NKLR	32 (0.6%)		1 (3.1%)	1 (3.1%)	17 (53%)	2 (6.2%)	11 (34%)

* MOON = Multicenter Orthopaedic Outcomes Network
# NKLR = Norwegian Knee Ligament Registry

Figure Legends

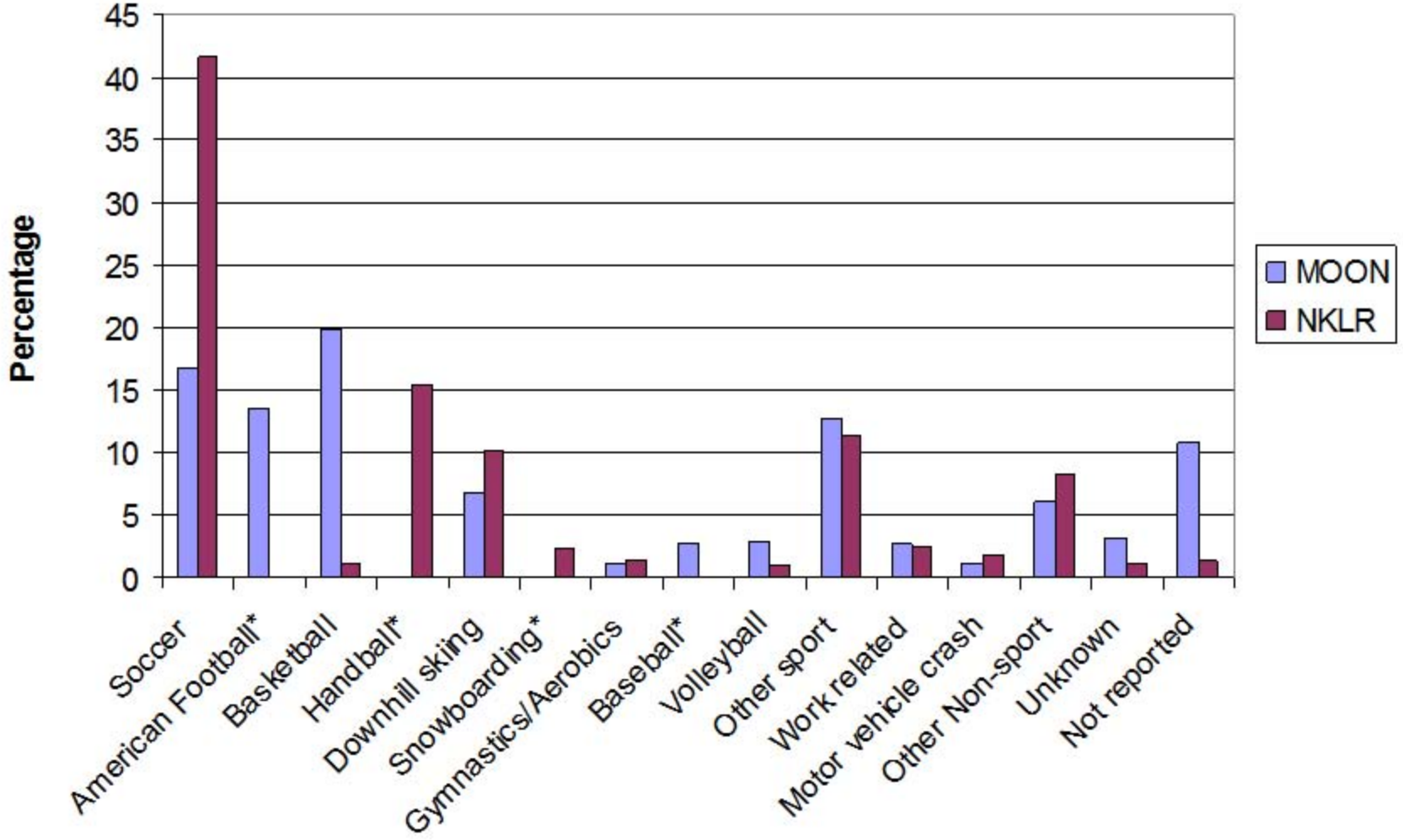
Figure 1: The activity associated with ACL injury is shown. Greater than 85 % of patients with a known mechanism of injury were injured playing a sport.

Figure 2: Pre-operative KOOS scores and statistically significant differences are shown. A clinically significant difference (greater than 8 points) is noted only in the “other symptoms” subscale.

Figure 3: Treatment of medial and lateral meniscal pathology in both the MOON and NKLR databases is shown. Resection is more commonly utilized in the NKLR database while repair (medial meniscus) and observation (lateral meniscus) are more common in the MOON database..

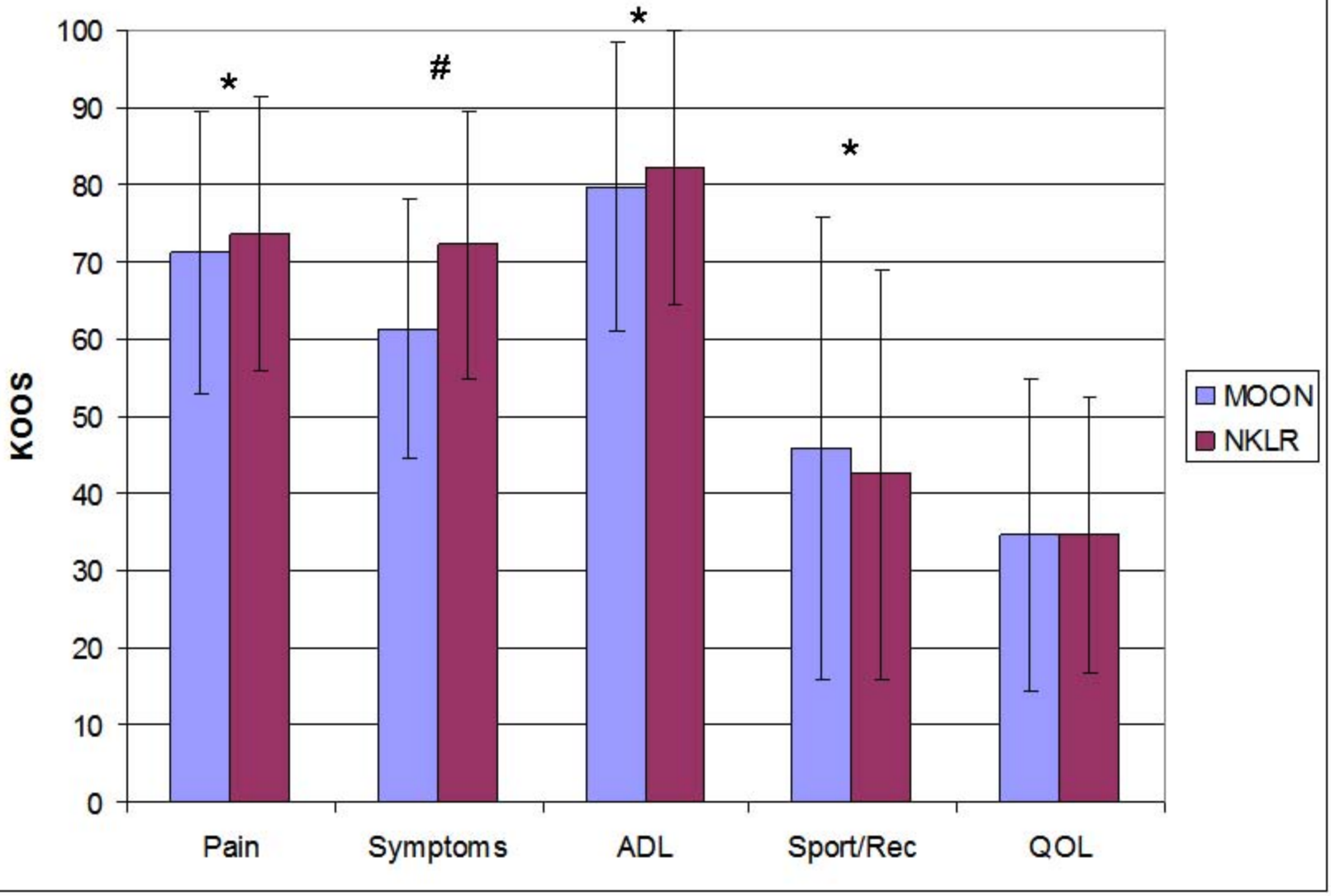
Figure 4: The incidence of meniscal and articular cartilage pathology in the MOON and NKLR databases are shown in all patients in the in the soccer subgroup. Higher rates are noted in the MOON database in both groups but the differences are smaller in the soccer subgroup.

Figure 1: Activty Associated with ACL Injury



* These sports had specific categories in only one database. In the other database they are represented under "other sport"

Figure 2: Pre-operative KOOS



* $p < 0.002$
# $p < 0.001$

Figure 3: Treatment of Meniscal Pathology

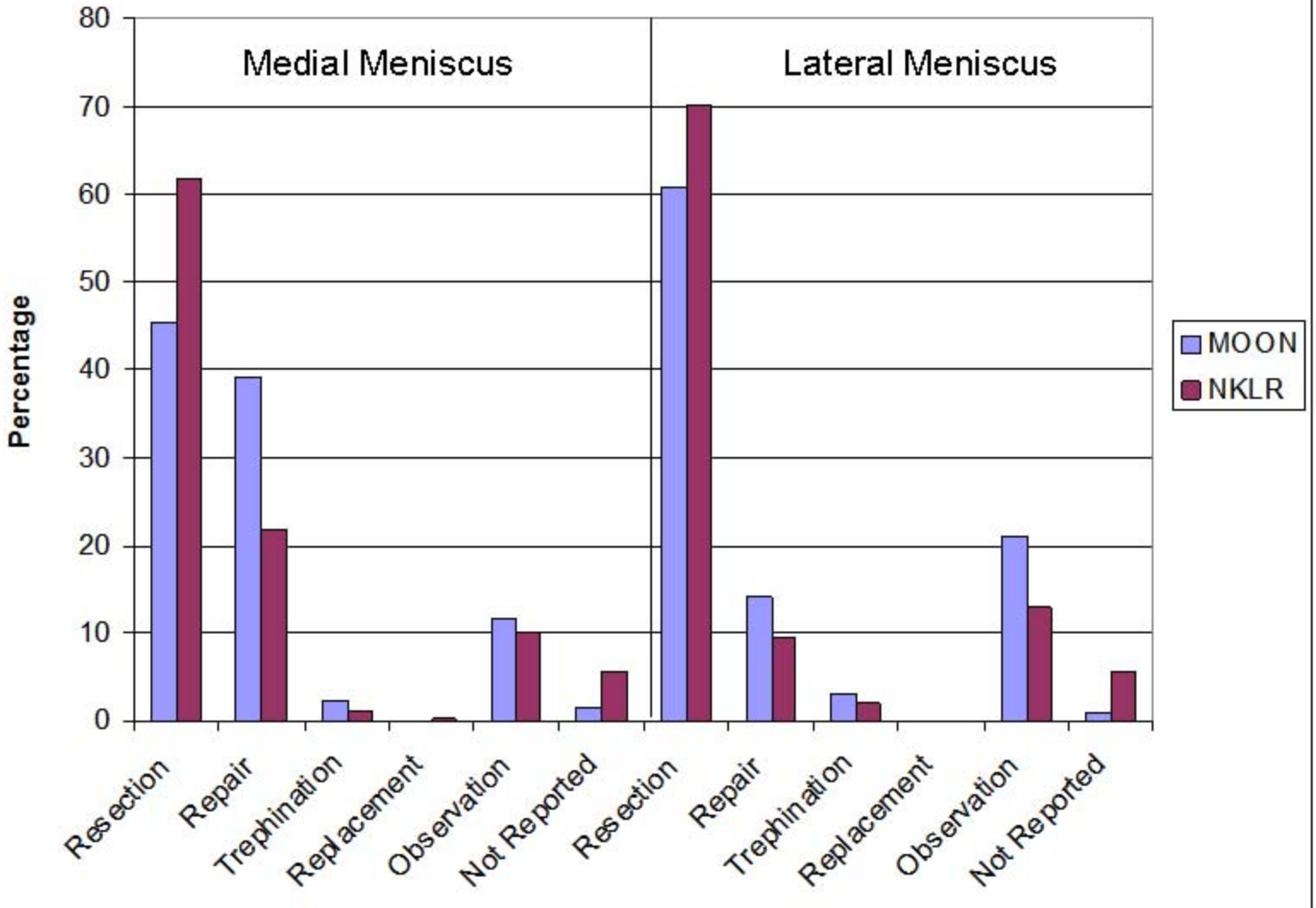


Figure 4: Intra-Articular Pathology in All Patients and Soccer Patients