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Effect of Gender and Sports on the Risk of Full-Thickness Articular Cartilage Lesions in Anterior Cruciate Ligament–Injured Knees

A Nationwide Cohort Study From Sweden and Norway of 15 783 Patients

Jan Harald Røtterud,[*†‡] MD, Einar A. Sivertsen,[†] MD, PhD, Magnus Forssblad,[§||] MD, PhD, Lars Engebretsen,[¶#] MD, PhD, and Asbjørn Årøen,[¶#] MD, PhD
Investigation performed at Department of Orthopedic Surgery, Akershus University Hospital, Lørenskog, Norway

Background: The presence of an articular cartilage lesion in anterior cruciate ligament–injured knees is considered a predictor of osteoarthritis.

Purpose: This study was undertaken to evaluate risk factors for full-thickness articular cartilage lesions in anterior cruciate ligament–injured knees, in particular the role of gender and the sport causing the initial injury.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: Primary unilateral anterior cruciate ligament reconstructions prospectively registered in the Swedish and the Norwegian National Knee Ligament Registry during 2005 through 2008 were included (N = 15 783). Logistic regression analyses were used to evaluate risk factors for cartilage lesions.

Results: A total of 1012 patients (6.4%) had full-thickness cartilage lesions. The median time from injury to surgery was 9 months (range, 0 days-521 months). Male patients had an increased odds of full-thickness cartilage lesions compared with females (odds ratio = 1.22; 95% confidence interval, 1.04-1.42). In males, team handball had an increase in the odds of full-thickness cartilage lesions compared with soccer (odds ratio = 2.36; 95% confidence interval, 1.33-4.19). Among female patients, no sport investigated showed a significant decrease or increase in the odds of full-thickness cartilage lesions. The odds of a full-thickness cartilage lesion increased by 1.006 (95% confidence interval, 1.005-1.008) for each month elapsed from time of injury until anterior cruciate ligament reconstruction when all patients were considered, while time from injury to surgery did not affect the odds significantly in those patients reconstructed within 1 year of injury (odds ratio = 0.98; 95% confidence interval, 0.95-1.02). Previous surgery increased the odds of having a full-thickness cartilage lesion (odds ratio = 1.40; 95% confidence interval, 1.21-1.63). One year of increasing patient age also increased the odds (odds ratio = 1.05; 95% confidence interval, 1.05-1.06).

Conclusion: Male gender is associated with an increased risk of full-thickness articular cartilage lesions in anterior cruciate ligament–injured knees. Male team handball players had an increased risk of full-thickness lesions. No other sports investigated were found to have significant effect on the risk in either gender. Furthermore, age, previous surgery, and time from injury to surgery exceeding 12 months are risk factors for full-thickness cartilage lesions.

Keywords: registry; anterior cruciate ligament (ACL); cartilage lesions; sports; gender; risk; timing

Knee trauma leading to anterior cruciate ligament (ACL) injuries are common, especially in the young athlete, often resulting in major knee problems for the individual and large costs for society. The reported long-term risk of osteoarthritis (OA) after ACL injury and subsequent ACL reconstruction varies considerably,[15,21] but development of OA and severely impaired quality of life attributable to knee-related symptoms occur also in the young and active population. This is demonstrated in long-term follow-up studies at 6 to 14 years after ACL injury of both female and male soccer and team handball players, which have shown high rates of radiographic OA and knee-related symptoms.[16,20,28] The mechanisms of the degenerative development in the ACL-injured knee are not fully understood, but factors related to the individual, the injury, and the treatment are considered to play a role. Cartilage lesions are identified in up to 46% of ACL-injured knees,[18]

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and current knowledge suggests that cartilage lesions together with meniscal injuries are strong predictors of later degenerative changes in the ACL-injured knee.[8,14,19,21] Thus, it is important to identify risk factors for sustaining cartilage lesions to improve prevention and treatment, as well as provide guidelines for return to sports. Previous studies have found associations between the presence of a cartilage lesion and patient age, previous surgery, and the time since the initial ACL injury,[10,27] but only a few studies have investigated the role of gender and the sport leading to the injury.[22,23]

In the present study, we study patients undergoing primary ACL reconstructive surgery using prospectively collected data from the national knee ligament registries in Sweden and Norway. The primary objective of the study is to evaluate risk factors for full-thickness articular cartilage lesions (International Cartilage Repair Society [ICRS] grades 3 and 4)[13] identified during primary ACL reconstruction and, in particular, to evaluate the role of gender and the sport leading to the injury. The hypothesis of the study is that age, time from injury to surgery, and previous surgery are related to the presence of a full-thickness cartilage lesion, while gender and the sport leading to the injury are not related to full-thickness lesions.

MATERIALS AND METHODS

Norwegian National Knee Ligament Registry and Swedish National Knee Ligament Registry

The annual incidence of primary ACL reconstructions in the general population is estimated to be 34 per 100 000 inhabitants in Norway and 32 in Sweden, while the younger population at risk has more than a twofold increase in the incidence.[12] According to the national registries, the total number of primary ACL reconstructions in Norway and Sweden is approximately 4000 per year. In the 2 countries, the main indication for ACL reconstruction is giving-way episodes of the knee during sports or activities of daily living. In the age group from 15 to 25 years, most patients are treated surgically, which also applies to the majority of competitive and recreational athletes.

Since June 2004, surgical procedures in Norway on the ACL, posterior cruciate ligament, lateral collateral ligament, medial collateral ligament, and posterolateral corner are prospectively registered in the Norwegian National Knee Ligament Registry (NKLR). Both primary and revision reconstructions are registered, as well as reoperations. The registration is voluntary and both surgeon- and patient-based. Registration includes previous surgery; gender; age; sport or activity causing the injury; as well as date of injury; frequency of cartilage lesions with localization, size, ICRS grading, and treatment; meniscal lesions; choice of graft and fixation; and other variables. The development of the NKLR has been thoroughly described in a previous study.[11]

The Swedish National Knee Ligament Registry (SKLR) was designed in basically the same manner as the Norwegian registry, and started registration in January 2005. With few exceptions, the same parameters are included in the 2 registries to facilitate collaborative studies. The registration procedure is paper-based in Norway and web-based in Sweden. This methodologic difference has been found not to affect the data quality of the registries.[12] The compliance of both registries is found to be satisfactory, with high reporting rates. In Norway, 97% of primary ACL reconstructions are reported to the registry,[11] while over 90% are reported in Sweden.[25]

Ethics

Participation in the SKLR and NKLR is voluntary, both for surgeons and patients. In Norway, patients are asked to sign an informed consent form that contains information about the NKLR, type of data recorded, data protection, follow-up procedure, and possible participation in later research projects. The Norwegian registry has been approved by the Norwegian Data Inspectorate. In Sweden, no written consent is necessary for national clinical databases. All data extracted from both the Norwegian and Swedish registry are anonymous to ensure that the researchers only have access to nonidentifiable data.

Data Collection and Processing

The databases of both registries were searched for patients registered with unilateral primary ACL reconstructions occurring from January 1, 2005, to December 31, 2008. A total of 6135 primary ACL reconstructions were identified in the Norwegian registry and 9726 in the Swedish registry. The data were then scanned thoroughly for registration errors by 2 of the authors (J.H.R. and E.A.S.). Because of obvious registration errors, 3 cases from the Norwegian registry and 75 cases from the Swedish registry needed to be excluded, resulting in a total of 15 783 patients included in the study; 6132 (39%) were from the NKLR and 9651 (61%) from the SKLR.

The activity or sport performed at the time of the index trauma is classified into a specified category. When the category "other" is used, a further specification of the activity

*Address correspondence to Jan Harald Røtterud, MD, Department of Orthopedic Surgery, Akershus University Hospital, 1478 Lørenskog, Norway (e-mail: janhrot@medisin.uio.no).
†Department of Orthopedic Surgery, Akershus University Hospital, Lørenskog, Norway.
‡Institute of Clinical Medicine, Akershus University Hospital, University of Oslo, Norway.
§Capio Artro Clinic AB, Stockholm, Sweden.
||Stockholm Sports Trauma Research Center, Karolinska Institutet, Stockholm, Sweden.
¶Oslo Sports Trauma Research Center, Oslo, Norway.
#Department of Orthopedics, Oslo University Hospital Ullevål, Oslo, Norway.
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or sport is often given, making it possible to reclassify into a more precise category of activity or sport. Because of large differences in the number of cases in each category and similarities in possible trauma mechanisms, we grouped the categories as follows: soccer, team handball, skiing (alpine, telemark, and cross-country), snowboarding/skateboarding, skating sports (ice hockey, bandy, and rollerblading), racket sports, martial arts, basketball/volleyball/floorball, gymnastics/dancing, motorsports, American football/rugby, hiking/jogging, work/traffic, other, and unknown. Time from injury to surgery, when available (n = 15 343), was registered in months.

Statistics

Statistical analyses were performed using SPSS 16 (SPSS Inc, Chicago, Illinois). The study's primary objective was to evaluate the role of the sport causing the initial injury as a risk factor for full-thickness articular cartilage lesions. Basing our approach on previous literature and clinical assumption, we considered age (continuous variable), gender, previous knee surgery, and time from injury to surgery (continuous variable) as possible confounders and risk factors for cartilage lesions. These factors, together with the sport/activity variable, were included in a logistic regression model as independent variables and full-thickness cartilage lesion as the dependent variable. Full-thickness cartilage lesions and meniscal injuries detected concomitantly were considered mainly to be caused by the initial trauma. Thus, the correlation between the variables was considered as mainly spurious and meniscal injuries were not included as a risk factor for full-thickness cartilage injuries. Patients registered with any kind of cartilage surgery before the ACL reconstruction (n = 198) were excluded from the logistic regression analysis.

The adjusted analysis was first performed on the whole cohort (n = 15 585), and all of the above-mentioned possible confounders and risk factors showed a significant relationship to full-thickness lesions. Because the main purpose was to evaluate the sport at the time of ACL injury as a risk factor for full-thickness lesions, it was important that the data properly reflected the cartilage status at the time of injury. To minimize the effect of time from injury, we performed the same adjusted logistic regression analysis on the subset of patients operated on within 12 months from injury (n = 9123). Then all factors except time from injury to surgery showed a significant relationship to full-thickness lesions. Thus, the final logistic regression analysis was performed on the subset of patients operated on within 12 months from injury (n = 9123), stratified by gender and adjusted for sport/activity, previous knee surgery, and age. Soccer was chosen as the reference category within the sport activity variable, as soccer was the most frequent sport performed at the time of ACL injury in both genders.

All *P* values less than .05 were considered statistically significant. Odds ratios (ORs) were estimated and presented with 95% confidence intervals (CIs) when the number of cases (observed full-thickness cartilage lesions) was $\geq$1.

RESULTS

Of a total of 15 783 unilateral primary ACL reconstructions in our data set, there were 6699 (42%) female patients and 9084 (58%) males. The median age at surgery was 26 years (range, 8-69 years), and the median time from injury to surgery was 9 months (range, 0 days-521 months). Twenty-six percent (4146) of the patients were reported with knee joint surgery before ACL reconstruction.

A total of 4196 (26.6%) of the patients had 1 or more articular cartilage lesions (ICRS grades 1-4); 1012 patients (6.4%) had 1 or more full-thickness cartilage lesions (ICRS grades 3-4) and of these, 432 (7.0%) were from the NKLR and 580 (6.0%) from the SKLR. The total number of full-thickness cartilage lesions was 1216; of these, 92 (7.6%) were located on the medial facet of the patella, 68 (5.6%) on the lateral facet of patella, 81 (6.7%) in the trochlea, 619 (50.9%) on the medial femoral condyle, 147 (12.1%) on the lateral femoral condyle, 113 (9.3%) at the medial tibial plateau, and 96 (7.9%) at the lateral tibial plateau. The area of the cartilage lesion was estimated to be <2 cm^2 in 567 (46.6%) of the full-thickness lesions and ≥ 2 cm^2 in 614 (50.5%); the area was not estimated in 35 lesions (2.9%).

Soccer was the most frequent sport performed when sustaining the ACL injury, with 6473 patients (41.0%) (Table 1). Except for team handball and volleyball/basketball/floorball, the distribution of injuries in the different sports and activities was similar between the nations (Table 1). The total and gender-wise distribution of the observed full-thickness cartilage lesions in different sports and activities are shown in Table 2.

For all patients and for those in the subset operated on within 12 months, the odds of full-thickness cartilage lesions were comparable for all variables, except for time to surgery and the sport/activity variable (Table 3). The odds of a full-thickness cartilage lesion increased by 1.006 (95% CI, 1.005-1.008) for each month that elapsed from time of injury until surgery in the overall patient population, while the odds were nonsignificant in those operated on within a year (OR = 0.98; 95% CI, 0.95-1.02). The sport/activity variable was statistically significant in the subset of those operated on within a year, but not in the overall population (Table 3). Male patients had increased odds compared with females both in the overall population (OR = 1.22; 95% CI, 1.04-1.42) and in those operated on within a year (OR = 1.36; 95% CI, 1.07-1.72). Previous knee joint surgery increased the odds of having a full-thickness cartilage lesion, and the same was observed with a year of increasing age (Table 3).

Compared with male soccer players, male team handball players showed an increase in the odds of full-thickness cartilage lesions (OR = 2.36; 95% CI, 1.33-4.19). Work and traffic accidents also increased the odds in male patients (Table 4). Among female patients, no sports or activities with significant decreases or increases in the odds of full-thickness cartilage lesions were found (Table 4). In female snowboarding/skateboarding, racket sports, motorsports, and American football/rugby, the sample sizes of ACL-injured individuals were small, and no full-thickness cartilage lesions were observed in the subset of

TABLE 1
Distribution of Patients by Sport/Activity at Time of Anterior Cruciate Ligament Injury by Country

	Norway (n = 6132)		Sweden (n = 9651)		Total (N = 15 783)	
Sport/Activity	No.	%[a]	No.	%[a]	No.	%[b]
Soccer	2462	40.2	4011	41.6	6473	41.0
Team handball	902	14.7	490	5.1	1392	8.8
Skiing[c]	813	13.3	1231	12.8	2044	13.0
Snowboarding/skateboarding	150	2.4	135	1.4	284	1.8
Skating sports[d]	49	0.8	122	1.3	171	1.1
Racket sports	31	0.5	95	1.0	126	0.8
Martial arts	124	2.0	245	2.5	369	2.3
Basketball/volleyball/floorball	171	2.8	1118	11.6	1289	8.2
Hiking/jogging	187	3.0	194	2.0	381	2.4
Work/traffic	327	5.3	441	4.6	768	4.9
Dancing/gymnastics	103	1.7	196	2.0	299	1.9
American football/rugby	14	0.2	63	0.7	77	0.5
Motorsports	60	1.0	200	2.1	260	1.6
Other	556	9.1	1002	10.4	1558	9.9
Unknown	183	3.0	109	1.1	292	1.9

[a]Percentages within country.
[b]Percentages within total.
[c]Alpine, telemark, and cross-country skiing.
[d]Ice hockey, bandy, and rollerblading.

TABLE 2
Distribution of Patients With Observed Full-Thickness Articular Cartilage Lesions (ICRS Grade 3-4[a]) by Sport/Activity at Time of Anterior Cruciate Ligament Injury by Sex

	Females (n = 6699)		Males (n = 9084)		Total (N = 15 783)	
Sport/Activity	No.	%[b]	No.	%[b]	No.	%[b]
Soccer	87	4.2	259	5.9	346	5.3
Team handball	50	4.6	24	7.8	74	5.3
Skiing[c]	72	6.4	71	7.8	143	7.0
Snowboarding/skateboarding	1	1.3	10	4.8	11	3.9
Skating sports[d]	2	9.1	13	8.7	15	8.8
Racket sports	2	4.3	12	15.2	14	11.1
Martial arts	9	6.0	9	4.1	18	4.9
Basketball/volleyball/floorball	22	4.0	55	7.5	77	6.0
Hiking/jogging	22	10.4	18	10.6	40	10.5
Gymnastics/dancing	20	8.8	3	4.2	23	7.7
American football/rugby	0	0	4	7.3	4	5.2
Motorsports	1	4.8	10	4.2	11	4.2
Work/traffic	22	9.8	62	11.4	84	10.9
Other	52	7.2	76	9.1	128	8.2
Unknown	10	8.1	14	8.3	24	8.2
Total	372	5.6	640	7.0	1012	6.4

[a]ICRS, International Cartilage Repair Society. Grade 1, nearly normal: superficial lesions, soft indentation, and/or superficial fissures and cracks; grade 2, abnormal: lesions extending down to <50% of cartilage depth; grade 3, severely abnormal: cartilage lesions extending down >50% of cartilage depth as well as down to calcified layer; grade 4, severely abnormal: osteochondral lesions, extending just through the subchondral bone plate, or deeper lesions down into trabecular bone.
[b]Percentages within sport/activity.
[c]Alpine, telemark, and cross-country skiing.
[d]Ice hockey, bandy, and rollerblading.

TABLE 3
Logistic Regression Analysis of Full-Thickness Cartilage Lesions (ICRS Grade 3-4[a]) in All Patients and Patients Operated on Within 12 Months of Anterior Cruciate Ligament Injury[b]

	All Patients (n = 15 585)			Patients Operated on Within 12 Months After Injury (n = 9123)		
Variable	OR	(95% CI)	*P* Value	OR	(95% CI)	*P* Value
Sex						
Female[c]	1	ref	ref	1	ref	ref
Male	1.22	(1.04-1.42)	.012	1.36	(1.07-1.72)	.011
Age, y	1.05	(1.05-1.06)	<.001	1.06	(1.05-1.07)	<.001
Previous surgery						
No[c]	1	ref	ref	1	ref	ref
Yes	1.40	(1.21-1.63)	<.001	1.34	(1.04-1.72)	.024
Time to surgery, mo	1.006	(1.005-1.008)	<.001	0.98	(0.95-1.02)	.369
Sport/activity			.086			.010

[a]ICRS, International Cartilage Repair Society. Grade 1, nearly normal: superficial lesions, soft indentation, and/or superficial fissures and cracks; grade 2, abnormal: lesions extending down to <50% of cartilage depth; grade 3, severely abnormal: cartilage lesions extending down >50% of cartilage depth as well as down to calcified layer; grade 4, severely abnormal: osteochondral lesions, extending just through the subchondral bone plate, or deeper lesions down into trabecular bone.
[b]OR, odds ratio; CI, confidence interval.
[c]Reference category.

patients operated on within a year, hence no ORs were estimated (Table 4).

DISCUSSION

Male Patients in General and Male Team Handball Players at Risk

The new and most important findings of this study are that gender and sports are related to full-thickness articular cartilage lesions in ACL-injured knees. Males in general have an increased risk of full-thickness lesions compared with females, and male team handball players have an increased risk compared with other male athletes. Although the sport/activity factor was a statistically significant predictor for full-thickness articular cartilage lesions in males, the sport/activity factor was not statistically significant among females. Male team handball was the only sport investigated that was found to have a significant effect on the risk of full-thickness articular cartilage lesions when using soccer as the reference category. Even though it was not significant, there was also a trend in male racket sports toward a higher risk of full-thickness lesions.

Slauterbeck et al[23] found that there was a trend toward more femoral cartilage lesions in males, but their finding was not statistically significant. Our study suggests that regardless of localization, there is a significantly increased risk of full-thickness cartilage lesions in males. The increased overall risk of cartilage lesions in males compared with females might be explained by higher levels of energy involved when the ACL tears in males. Given that males on the average have higher body weight and muscle mass than females, the energy and risk of coinjuries to the joint might increase, resulting in more severe injuries in males. This is supported by the findings of Bowers et al,[5] showing that the presence of concomitant intra-articular injuries in ACL-injured knees is related to anthropometric factors like increased weight, height, and body mass index. Another contributory explanation of the overall gender difference might be the trauma mechanism itself, as noncontact injuries are found to be a more frequent injury mechanism in females than in males.[2,29] There is no evidence, however, of noncontact ACL injuries causing fewer cartilage lesions than contact injuries. Unfortunately, our data do not include registration of whether the injury is contact or noncontact, making it impossible to evaluate this as a risk factor.

Why male team handball players seem to have an increased risk of full-thickness cartilage lesions compared with other male sports is not clear. Because of the lack of data on height and weight in our material, we are not able to tell whether any differences in these factors could explain this finding. However, 1 explanation of the findings in male team handball might be that the relative amount of top- and medium-level athletes in male team handball is high compared with the other sports in which the relative amount of recreational athletes is higher. The overall intensity in training and competition might therefore be expected to be higher in team handball than the other male sports, which again can affect the trauma and injury patterns. Traffic and work accidents are in many cases high-energy injuries, and this could explain why these accidents are causing a higher OR of full-thickness lesions in males. Why this is not the case among females is uncertain, but it could be attributable to less energy in female work accidents. Piasecki et al[22] found in a study of gender differences among high school athletes (basketball, soccer, skiing) sustaining ACL injury that female basketball players had fewer cartilage lesions on the medial femoral condyle, while there were no gender differences in cartilage injury in

TABLE 4
Gender-Stratified Logistic Regression Analysis of Full-Thickness Cartilage Lesions (ICRS Grade 3-4[a]) in Patients Operated on Within 12 Months[b]

	Females			Males		
Variable	OR	(95% CI)	*P* Value	OR	(95% CI)	*P* Value
Sport/activity			.484			.012
Soccer[c]	1	ref	ref	1	ref	ref
Team handball	1.08	(0.61-1.91)	.787	2.36	(1.33-4.19)	.003
Skiing[d]	0.86	(0.48-1.52)	.600	1.08	(0.69-1.68)	.750
Snowboarding/skateboarding	—	—	—	1.23	(0.44-3.43)	.689
Skating sports[e]	3.13	(0.38-25.79)	.289	1.82	(0.71-4.59)	.217
Racket sports	—	—	—	2.57	(0.96-6.86)	.059
Martial arts	0.30	(0.04-2.24)	.239	0.74	(0.27-2.07)	.571
Basketball/volleyball/floorball	0.50	(0.19-1.31)	.159	1.07	(0.62-1.85)	.814
Hiking/jogging	1.60	(0.72-3.52)	.248	1.67	(0.73-3.86)	.228
Dancing/gymnastics	1.48	(0.63-3.52)	.372	0.72	(0.10-5.33)	.750
American football/rugby	—	—	—	1.11	(0.15-8.25)	.922
Motorsports	—	—	—	0.51	(0.16-1.65)	.261
Work/traffic	1.51	(0.66-3.45)	.324	2.17	(1.35-3.50)	.001
Other	0.63	(0.30-1.33)	.223	1.75	(1.13-2.72)	.012

[a]ICRS, International Cartilage Repair Society. Grade 1, nearly normal: superficial lesions, soft indentation, and/or superficial fissures and cracks; grade 2, abnormal: lesions extending down to <50% of cartilage depth; grade 3, severely abnormal: cartilage lesions extending down >50% of cartilage depth as well as down to calcified layer; grade 4, severely abnormal: osteochondral lesions, extending just through the subchondral bone plate, or deeper lesions down into trabecular bone.
[b]OR, odds ratio; CI, confidence interval.
[c]Reference category.
[d]Alpine, telemark, and cross-country skiing.
[e]Ice hockey, bandy, and rollerblading.

soccer or skiing. Unfortunately, the gender-stratified subgroups of the different sports in the study of Piasecki et al were quite small, and the findings are probably applicable only to a narrow age group of patients as only high school athletes were included.

The index trauma in our study occurred in highly diverse activities that were not restricted to competitive sports, but included recreation, work, and other daily activities as well. This variety makes it challenging to evaluate the index trauma as a risk factor for full-thickness articular cartilage lesions as large data sets with high compliance are needed. This might be the reason why few reports on this subject are found. Our study's main advantage is the large quantity of population-based data with high reporting rates, generating enough cases to enable us to evaluate the trauma-inducing sport as a risk factor for full-thickness articular cartilage lesions with sufficient power required in the statistical analysis. This is the first study to do this in a nationwide manner, involving 2 countries with a total population of approximately 14 million inhabitants. Although there might be some differences between the 2 countries in the reporting of data, the reporting of articular cartilage lesions are found to be identical.[12] Any possible bias from cross-cultural differences in merging data from the 2 registries should therefore be low. With the high reporting rates of both registries, selection bias should be minimal, and we believe our findings must be considered valid to the cohort of primary ACL-reconstructed individuals in the Norwegian and Swedish populations. A weakness of this study, however, is the fact that we have no data on nonoperated ACL-injured patients. Currently, these patients are not included in the registries. Care should, of course, be taken when applying findings from our cohort to other populations around the world,[18] but if the characteristics of our cohort and the actual population are comparable, our findings should be valid also in other populations. Although popular sports differ between different regions, male team handball might provide a model of a male pivoting sport on artificial turf with high knee loading and impact forces.

The main limitation of the study is the delay between index trauma and registration of cartilage lesions. Ideally, our data should have been registered immediately after the initial trauma, ensuring that no cartilage lesions caused by secondary injuries or chronic instability and repeated pivoting would be included in the study. However, our results indicate that the presence of full-thickness cartilage lesions is independent of time from injury during the first 12 months. Hence, our findings among the cohort operated on within 12 months should reflect the cartilage status at time of injury. Another possible limitation is that even though we have precise data on the type of activity at the time of injury, we have no information about the athletes' level, and our data tell us only to some degree and indirectly about the actual energy involved. Thus, further research is needed to explain why ACL-injured males seem to have higher risk of full-thickness cartilage lesions than females and why male team handball players are at particular risk compared with other male athletes. To obtain this, more precise data on the energy and mechanism of the trauma are needed to explore the real-time sequence of the ACL injury. This knowledge will be important in the development of prevention programs for these combined serious knee injuries.[3] A study by Takeda et al[26] showed that damage to the articular cartilage was one of the most important negative predictors on the rate of return to sports after ACL reconstruction, underlining the importance of prevention.

Age, Previous Knee Surgery, and Time to Surgery Exceeding 12 Months Increase Risk of Full-Thickness Articular Cartilage Lesions

The findings regarding age and previous knee surgery are consistent with previous studies showing that both are related to cartilage lesions.[10,23,27] However, the effect of the timing of ACL reconstruction on subsequent cartilage and meniscal injuries has been debated. A recent systematic review and meta-analysis found no evidence of difference in clinical outcome between delayed and early surgery.[24] However, restoration of strength, range of motion, and minimal swelling before ACL reconstruction are considered important to reduce the risk of postoperative complications[4] and improve functional outcome.[9] Furthermore, present literature suggests that the occurrence of degenerative changes such as cartilage lesions is related to the time from injury to surgery.[7,10,17,23] Suggestions about when to operate to avoid these cartilage lesions have been made, but no consensus exists in the literature.

Church and Keating[7] reported a significant increase in degenerative changes in patients operated on with more than 12 months' delay after injury versus patients operated on within the first 12 months. The number of patients included was quite small, with only 80 patients in the delayed group, making it somewhat difficult to generalize these findings. In a study by Slauterbeck et al,[23] patients with a surgical delay of more than a year were more likely to have femoral cartilage lesions. This was, however, a single-surgeon survey with patients recruited from a sports medicine practice, introducing possible bias in the selection of patients. Our findings are comparable with those of both Church and Keating[7] and Slauterbeck et al,[23] as we found that time to surgery is related to a higher number of full-thickness cartilage lesions, but not in those operated on within 12 months. A possible explanation could be that some full-thickness lesions occur at the time of the initial trauma, while most other lesions occur after more than 12 months because of repeated pivoting and secondary trauma to the cartilage. A finite element model has predicted that an unstable knee will be at risk of cartilage thinning or injury, especially at the medial femoral condyle.[1] However, the cartilage injury could also be related to the initial trauma. In a recent review by Brophy et al[6] on the incidence and treatment of articular cartilage lesions in ACL-injured knees, the incidence of articular cartilage lesions varied between 16% and 46% in acute ACL injuries. Our findings indicate that during the first year after ACL injury, the initial trauma is a more important factor for full-thickness cartilage lesions than time since injury.

The present study suggests that ACL reconstruction can be delayed until adequate postinjury rehabilitation is achieved and up to 12 months after injury without significant risk of new full-thickness cartilage lesions. However, our study tells us nothing about the effect of timing of surgery on later OA development. To evaluate this, a control group of nonoperated ACL-injured individuals and follow-up of those operated on are needed.

CONCLUSION

The current study demonstrates that males have increased risk of full-thickness articular cartilage lesions (ICRS grade 3-4) in ACL-injured knees compared with females. We found that the sport/activity factor causing the initial trauma was a statistically significant predictor for such lesions in ACL-injured knees that were reconstructed within a year. When stratifying males and females, we found that male team handball players have an increased risk of full-thickness lesions compared with other male athletes, while no other sport investigated had a significant effect on the risk in either gender. In addition, age, time from injury to surgery, and previous knee surgery are risk factors for full-thickness cartilage lesions in ACL-injured knees, as proposed in the hypothesis of the study. However, time from injury to surgery does not affect the risk during the first year. We recommend that these findings be considered when deciding about possible means to prevent full-thickness articular cartilage lesions in the knee and the timing of ACL surgery.

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REFERENCES

1. Andriacchi TP, Briant PL, Bevill SL, Koo S. Rotational changes at the knee after ACL injury cause cartilage thinning. *Clin Orthop Relat Res*. 2006;442:39-44.
2. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med*. 1995;23(6):694-701.
3. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med*. 2005;39(6): 324-329.

4. Beynnon BD, Johnson RJ, Abate JA, Fleming BC, Nichols CE. Treatment of anterior cruciate ligament injuries, part I. *Am J Sports Med*. 2005;33(10):1579-1602.
5. Bowers AL, Spindler KP, McCarty EC, Arrigain S. Height, weight, and BMI predict intra-articular injuries observed during ACL reconstruction: evaluation of 456 cases from a prospective ACL database. *Clin J Sport Med*. 2005;15(1):9-13.
6. Brophy RH, Zeltser D, Wright RW, Flanigan D. Anterior cruciate ligament reconstruction and concomitant articular cartilage injury: incidence and treatment. *Arthroscopy*. 2010;26(1):112-120.
7. Church S, Keating JF. Reconstruction of the anterior cruciate ligament: timing of surgery and the incidence of meniscal tears and degenerative change. *J Bone Joint Surg Br*. 2005;87(12):1639-1642.
8. Drogset JO, Grontvedt T. Anterior cruciate ligament reconstruction with and without a ligament augmentation device: results at 8-year follow-up. *Am J Sports Med*. 2002;30(6):851-856.
9. Eitzen I, Holm I, Risberg MA. Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. *Br J Sports Med*. 2009;43(5):371-376.
10. Granan LP, Bahr R, Lie SA, Engebretsen L. Timing of anterior cruciate ligament reconstructive surgery and risk of cartilage lesions and meniscal tears: a cohort study based on the Norwegian National Knee Ligament Registry. *Am J Sports Med*. 2009;37(5):955-961.
11. Granan LP, Bahr R, Steindal K, Furnes O, Engebretsen L. Development of a national cruciate ligament surgery registry: the Norwegian National Knee Ligament Registry. *Am J Sports Med*. 2008;36(2):308-315.
12. Granan LP, Forssblad M, Lind M, Engebretsen L. The Scandinavian ACL registries 2004-2007: baseline epidemiology. *Acta Orthop*. 2009;80(5):563-567.
13. International Cartilage Repair Society. Articular cartilage injury classification. *Newsletter ICRS*. 1998;(1):5-8.
14. Keays SL, Newcombe PA, Bullock-Saxton JE, Bullock MI, Keays AC. Factors involved in the development of osteoarthritis after anterior cruciate ligament surgery. *Am J Sports Med*. 2010;38(3):455-463.
15. Lohmander LS, Englund PM, Dahl LL, Roos EM. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. *Am J Sports Med*. 2007;35(10):1756-1769.
16. Lohmander LS, Ostenberg A, Englund M, Roos H. High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthritis Rheum*. 2004;50(10):3145-3152.
17. Maffulli N, Binfield PM, King JB. Articular cartilage lesions in the symptomatic anterior cruciate ligament-deficient knee. *Arthroscopy*. 2003;19(7):685-690.
18. Magnussen RA, Granan LP, Dunn WR, et al. Cross-cultural comparison of patients undergoing ACL reconstruction in the United States and Norway. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(1):98-105.
19. Magnussen RA, Mansour AA, Carey JL, Spindler KP. Meniscus status at anterior cruciate ligament reconstruction associated with radiographic signs of osteoarthritis at 5- to 10-year follow-up: a systematic review. *J Knee Surg*. 2009;22(4):347-357.
20. Myklebust G, Holm I, Maehlum S, Engebretsen L, Bahr R. Clinical, functional, and radiologic outcome in team handball players 6 to 11 years after anterior cruciate ligament injury: a follow-up study. *Am J Sports Med*. 2003;31(6):981-989.
21. Oiestad BE, Engebretsen L, Storheim K, Risberg MA. Knee osteoarthritis after anterior cruciate ligament injury: a systematic review. *Am J Sports Med*. 2009;37(7):1434-1443.
22. Piasecki DP, Spindler KP, Warren TA, Andrish JT, Parker RD. Intraarticular injuries associated with anterior cruciate ligament tear: findings at ligament reconstruction in high school and recreational athletes: an analysis of sex-based differences. *Am J Sports Med*. 2003;31(4):601-605.
23. Slauterbeck JR, Kousa P, Clifton BC, et al. Geographic mapping of meniscus and cartilage lesions associated with anterior cruciate ligament injuries. *J Bone Joint Surg Am*. 2009;91(9):2094-2103.
24. Smith TO, Davies L, Hing CB. Early versus delayed surgery for anterior cruciate ligament reconstruction: a systematic review and meta-analysis. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(3):304-311.
25. Swedish National Knee Ligament Registry. Annual Report 2008. www.artroclinic.se/Info/Rapport.pdf.
26. Takeda T, Matsumotu H, Fujikawa K. Influence of secondary damage to menisci and articular cartilage on return to sports after anterior cruciate ligament reconstruction. *J Orthop Sci*. 1997;2(4):215-221.
27. Tandogan RN, Taser O, Kayaalp A, et al. Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc*. 2004;12(4):262-270.
28. von Porat A, Roos EM, Roos H. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. *Ann Rheum Dis*. 2004;63(3):269-273.
29. Yu B, Garrett WE. Mechanisms of non-contact ACL injuries. *Br J Sports Med*. 2007;41(Suppl 1):i47-i51.