Occupational ACL Injuries Are Associated with Inferior Clinical Outcomes and Lower Return to Sport Rates: A Comparative Analysis of 301 Patients

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Background: Anterior cruciate ligament (ACL) injuries present a substantial socioeconomic burden. Although outcomes after ACL reconstruction are well-documented, the prognostic role of the injury context, particularly occupational injuries (OI), remains unclear. Emerging data suggest OI may lead to delayed intervention and poorer recovery trajectories.

Purpose: This study compares outcomes and return to activity rates between patients sustaining ACL ruptures in occupational versus non-occupational settings (Non-OI).

Methods: This retrospective longitudinal study analyzed 301 patients undergoing primary ACL reconstruction (2019–2024). Patients were classified into Occupational Injury (OI, n=110) or Non-Occupational Injury (Non-OI, n=191) based on Workers' Compensation status. Primary outcomes were Subjective Knee Value (SKV) and Return to Sport (RTS) rates at a minimum 1 year follow-up. Secondary outcomes were associated meniscal injuries, reoperation rate and graft rupture rate. Multivariable regression was performed to control for emerging confounders.

Results: At mean follow-up of 33.1 ± 14.8 months the OI group was older (mean 38.2 vs. 23.4 years; p<0.001) and had a longer surgical delay (3.7 vs. 1.5 months; p=0.007). The OI group demonstrated lower SKV (71.0 ± 1.8 vs. 81.8 ± 1.2; p<0.001) and lower RTS rates (48.8% vs. 78.6%; p<0.001). In multivariable analysis, occupational status was the only independent predictor of lower SKV (β:-9.7 (95% CI: -14.4 – -4.9; p < 0.001) as well as RTS (OR: 0.44 (95% CI: 0.21 – 0.92; p =0.029)).

Conclusion: Occupational ACL injuries are associated with older age, delayed intervention, and demonstrate inferior subjective clinical outcomes and RTS rates. These findings underscore the negative prognostic impact of OI, highlighting the need to continue studying this specific population, with the aim of improving their clinical outcomes and bringing them closer to those observed in patients with non-occupational injuries.

What this study adds: Occupational ACL injuries are associated with worse subjective clinical outcomes (SKV) and lower return to sport rates, regardless of re-rupture rates or surgical complications.

How this study might affect research, practice or policy: It is essential to implement targeted management strategies, including early referral and personalized rehabilitation that addresses psychological barriers and work demands, aiming to optimize outcomes.

Study Design: Retrospective longitudinal study

Level of evidence: Level II

Keywords: Anterior cruciate ligament; Occupational injuries; Anterolateral ligament; Subjective knee function; Return to sport

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Introduction

Anterior cruciate ligament (ACL) injuries are among the most common ligamentous injuries of the knee joint, particularly affecting young, active individuals and populations involved in high-demanding activities such as competitive sports or physically strenuous occupations. Epidemiological studies estimate the annual incidence of ACL ruptures to range

between 0.01% and 0.05%, corresponding to approximately 68.6 ACL reconstructions per 100,000 inhabitants annually in European populations [1][2][3]. These injuries not only compromise joint stability, but are also associated with a substantial socio-economical burden due to extended rehabilitation, work absenteeism, and reduced return-to-activity rates [4][5].

It is well-established that ACL ruptures are frequently accompanied by concomitant intra-articular lesions, most commonly involving the menisci. Literature reports indicate that concomitant meniscal injuries are present in 47% to 61% of ACL ruptures, with the medial meniscus being predominantly affected in chronic cases [6][7][8][9]. Moreover, the presence of associated meniscal and chondral lesions has been linked to inferior functional outcomes, higher rates of postoperative complications, and accelerated progression toward degenerative joint disease [10][11].

While ACL outcomes are well-documented, the specific influence of the injury context occupational versus sports/recreational remains underreported. Emerging data suggest that patients sustaining ACL injuries in the occupational setting tend to have delayed surgical intervention, a higher prevalence of meniscal and chondral lesions, and worse postoperative recovery trajectories, especially regarding return to physical activity and work capacity [12][13]. Furthermore, specific work-related factors, including physical job demands and delayed return to function expectations, may further influence clinical outcomes.

The aim of the present study is to conduct a comprehensive epidemiological and clinical analysis of ACL injuries within a single-center comparing clinical outcomes and return to sport between patients sustaining ACL injuries in occupational versus non-occupational settings, while controlling for confounders that may arise. Additionally, this study seeks to characterize associated intra-articular lesions, complications and graft rupture rate of the same cohort. This analysis aims to provide meaningful insights and clarifying the prognostic implications of occupational ACL injuries in an active population.

Materials and Methods

Patient Selection and Definitions

This retrospective longitudinal study included patients undergoing primary ACL reconstruction between February 2019 and February 2024. Inclusion criteria were: primary ACL rupture, skeletal maturity, and a minimum follow-up of 12 months. Exclusion criteria included multi-ligament injuries, concomitant osteotomies, revision surgery, and incomplete clinical data.

Occupational Injury (OI) was defined as any injury sustained during work activities that was legally classified and covered under Workers' Compensation Insurance. Within this cohort, all medical and surgical treatment costs were entirely borne by the insurance carrier. Furthermore, these patients are legally eligible for potential financial indemnity upon clinical discharge or case settlement. In contrast, all other injuries (sports, activities of daily living) were classified as Non-Occupational (Non-OI), where such specific financial and legal frameworks do not apply.

Clinical records, imaging studies, and postoperative follow-ups were retrospectively reviewed. Telephone interviews were carried out to determine the latest clinical status of the patients. Sociodemographic characteristics, injury patterns, surgical techniques, and return to sport were analyzed. All surgeries were performed by experienced orthopedic surgeons following standardized rehabilitation protocols.

Surgical Technique

The initial diagnosis of meniscal injuries was established by magnetic resonance imaging (MRI) and subsequently complemented by diagnostic arthroscopy, since certain lesions may not be identifiable on MRI [13]. The posteromedial compartment was systematically explored. Ramp lesions, when identified, were repaired using suture hook technique through a posteromedial portal. Lateral Extra-Articular Tenodesis (Anterolateral Ligament (ALL) reconstruction or Modified Lemaire) was performed in cases meeting the criteria outlined in the recent International Consensus Statement [14][15]. Most surgeries involved combined ACL and anterolateral ligament (ALL) reconstruction using hamstring autografts.

Outcome Measures

The primary functional outcome was the Subjective Knee Value (SKV), a validated single-item patient-reported outcome [16]. Return to Sport (RTS) was assessed at the final follow-up and defined as the patient's ability to return to their pre-injury level of sports participation (Yes/No).

Statistical Analysis

Continuous variables are presented as mean ± standard deviation (SD) and range. Categorical variables are presented as frequencies (n) and percentages (%). Differences were analyzed using Student’s t-test and Chi-square/Fisher’s Exact tests. A multivariable logistic regression analysis was performed to determine if Occupational Injury was an independent predictor of RTS, adjusting for age, sex, BMI, time to surgery, and meniscal status. Results are reported as Odds Ratios (OR) with 95% Confidence Intervals (CI).

Results

A total of 325 patients were initially identified; after applying the exclusion criteria, 301 patients (84% male) who underwent primary ACL reconstruction were included in the final analysis, with a mean age of 31.4 ± 12.2 years and a mean follow-up of 33.1 ± 14.8 months. There were no patients lost in the follow-up. Most injuries were non-occupational (63.4%), with the remaining (36.6%) occurring in occupational settings.

Meniscal injuries were identified in 77.0% of patients, with medial meniscus tears in 44.0%, lateral meniscus tears in 13.0%, and bimeniscal lesions in 20.0%. Importantly, ramp lesions were identified in 27.2% of all meniscus injuries.

The predominant surgical technique was ACL reconstruction using a hamstring autograft combined with ALL reconstruction (76.3% of cases). The remaining patients underwent a modified Lemaire procedure (11.8% of cases), resulting in a total of 88.1% of patients receiving a lateral extra-articular tenodesis. The overall reoperation rate was 10.3%, with arthrofibrosis representing the most frequent cause (6.3%). Graft rupture occurred in 1.3% of patients, and subsequent meniscectomy was required in 2.3%. Contra-lateral ACL rupture was 0.7%.

In the comparative analysis, patients with occupational injuries (OI group) were markedly older than those with non-occupational injuries (38.2 ± 9.9 vs. 23.4 ± 8.2 years; p<0.001). The OI group also had a longer delay to surgery (3.68 ± 6.68 vs 1.5 ± 1.04 months; p=0.0069) and longer follow-up duration (35.9 ± 15.2 vs. 31.5 ± 14.3 months; p=0.007).

Subjective knee function, assessed by the subjective knee value (SKV), was substantially lower in the OI group (71.0% ± 1.8) compared to the non-occupational group (81.8% ± 1.2; p<0.0001). Of those who were involved in sports prior to the injury, return to sport was achieved in 69.0% of the total cohort, with significantly lower rates in the OI group (48.8%) compared to non-occupational injuries (78.6%; p<0.001) (**Figure 1**).

Given the statistically significant difference in age observed between the OI and Non-OI groups, a multivariate regression analysis was performed to determine whether the Work-Related context influences clinical outcomes independently of age and time from injury to surgery (delay).

Regarding the subjective knee function score (0-100% scale), the multiple linear regression analysis corroborated the negative influence of the occupational context. The model revealed that belonging to the OI group is associated with a mean decrease of 9.7 points in the final classification (Coefficient β:-9.7; 95% CI: -14.4 to -4.9; p < 0.001), independent of age (p=0.065) or surgical delay (p=0.059).

The binary logistic regression model demonstrated that OI status is also a significant independent predictor for failure to return to sports. Patients in the OI group presented an adjusted Odds Ratio (OR) of 0.44 (95% CI: 0.21 – 0.92; p =0.029). These data indicate that, even when adjusting for age and delay from injury to surgery, patients in the occupational group maintain a significantly lower probability of returning to sport compared to the Non-OI group. It is important to note that, in this adjusted model, age alone ceased to be statistically significant (p=0.783), suggesting that the injury context prevails over the age factor in determining the likelihood of returning to sport.

No statistically significant differences were observed in surgical technique, complication and reoperation rates, graft rupture rates, incidence of meniscal injuries (or type of meniscal injuries) between the OI and Non-OI groups (p>0.05). Similarly, there was no significant difference in graft failure rates between isolated ACL reconstruction (n=1; 2.8%) and ACL with LET (n=3; 1.1%; p=0.401).

Regarding surgical delay, there was no statistically significant association between time to surgery and presence of meniscal injury (F(3, 288) = 0.90; p = 0.441) (**Table 1 - 6**).

Table 1. Demographic Characteristics of the Study Population (n=301)

Variable	Mean ± SD or n (%)
Age	31.4 ± 12.2 years
Sex (Male)	253 (84%)
Sex (Female)	48 (16%)
Follow-up time	33.1 ± 14.8 months

Table 2. Clinical Characteristics of the Study Population (n=301)

Variable	Mean ± SD or n (%)	Comments
Meniscal injury	220 (73%)	Medial: 44%, Lateral: 13%, Both: 20%
Combined ACL + ALL recon	230 (76.3%)	Extra-articular in 88.1%
Occupational injury	110 (36.6%)	Non-occupational: 191 (63.4%)

Table 3. Comparison Between Occupational and Non-Occupational Injury Groups

Outcome Variable	Occupational (Mean ± SD) or %	Non-Occupational (Mean ± SD) or %	p-value
Return to Sport	48.8%	78.6%	<0.001
Subjective knee value	71.0% ± 18	81.8%± 12	<0.0001
Complication Rate	3%	7.3%	1.0
Re-rupture Rate	1.1%	1.4%	1.0

Table 4. Postoperative Complications in Total Sample

Complication Type	Incidence (%)
Arthrofibrosis	6.3%
Subsequent meniscectomy	2.3%
Graft tear	1.3%

Table 5. Meniscal Injury Distribution

Type of Meniscal Injury	Frequency (%)
Medial meniscus (Ramp lesions)	27.2%
Lateral meniscus (Root/posterior horn)	13.7%
Both menisci involved	20%
Any meniscal injury	77%

Table 6. Multivariable Regression Analysis for Predictors of Clinical Outcomes

Outcome Variable	Predictor	Coefficient (β) / OR	95% CI	P-value
Subjective Knee Value	Occupational Injury	-9.7	-14.4 – -4.9	< 0.001
	Age	-0.19	-0.38 – -0.01	0.065
	Time to Surgery	-0.12	-0.24 – 0	0.059
Return to Sport	Occupational Injury	0.44	0.21 – 0.92	0.029
	Age	1.00	0.97 – 1.03	0.78
	Time to Surgery	0.98	0.95 – 1.02	0.31

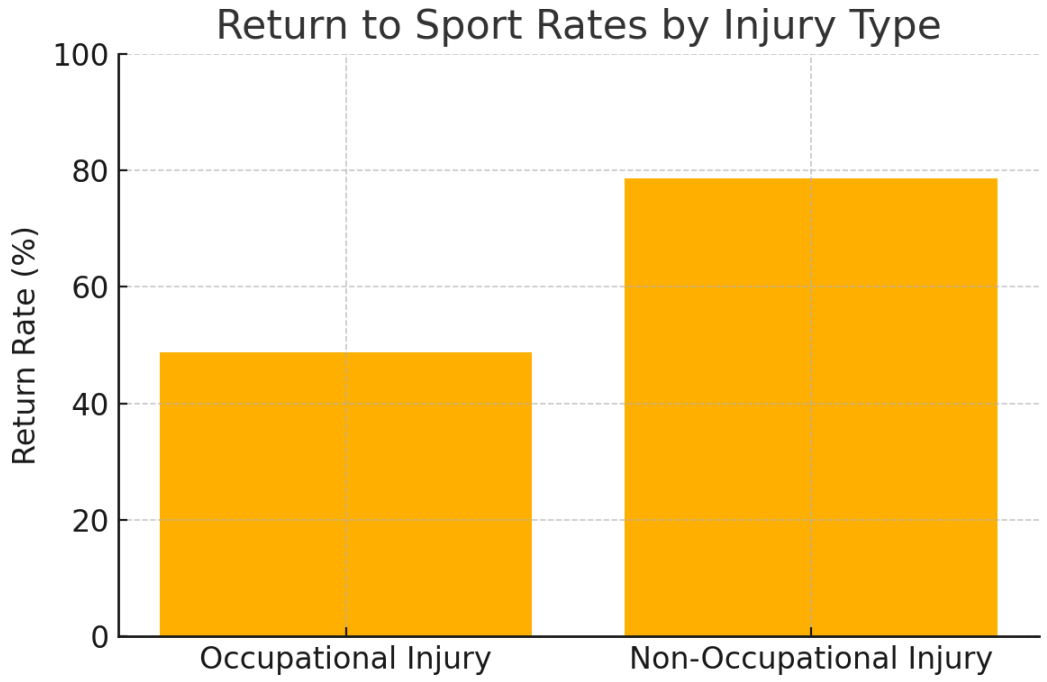


Figure 1. Return to sport rate comparison between occupational and non-occupational ACL injury patients.

Discussion

The most important finding of this study is that patients sustaining anterior cruciate ligament (ACL) injuries in an occupational setting demonstrated notably worse clinical outcomes and inferior return to sport rates compared to non-occupational injuries. This highlights the negative prognostic influence of occupational injury mechanisms, a dimension that remains underrepresented in the current literature [4][5][13].

Patients in OI group demonstrated worse subjective knee value scores (SKV 71.0% vs. 81.8%; p<0.001), with no significant differences in associated lesions, type of surgery (including the addition of extra-articular tenodesis) and complications. This is consistent with previous findings indicating that occupational factors adversely affect perceived recovery and return to activity [4][5][13]. Delayed surgical intervention was more frequent in the OI group and prior meta-analyses have identified delays in reconstruction as detrimental to joint homeostasis, meniscal preservation, and overall functional prognosis [6][8][20]. Nevertheless, as the commonly accepted cut-off for defining a chronic injury is 6 months, well above the mean delay of 2.08 months in our series, we do not believe this factor accounts for the poorer outcomes observed.

Notably, 69% of our total cohort returned to sport, which is marginally lower than the commonly reported 70–80% in broader populations [22][26][27][28]. This may be attributable to additional psychological and physical barriers faced by patients with occupational injuries since patients with non-occupation injuries had a RTS rate of 78.6%, including heightened fear of re-injury, physically strenuous job demands, and lower pre-injury athletic conditioning [26][27][28]. Psychological readiness is a recognized predictor of return to sport and likely contributes to this observed discrepancy [26][28].

Our overall graft rupture rate was low (1.3%), aligning with previous large cohort studies reporting failure rates between 2% and 6% after primary ACL reconstruction [17] although it is still higher than contra-lateral injury (0.7%). Arthrofibrosis was the most frequent complication (6.3%), consistent with recent literature on postoperative morbidity following ACL surgery [18][19].

Age is another critical determinant of functional recovery. The OI group was significantly older (38.2 vs. 23.4 years), and age has been consistently associated with inferior subjective outcomes and reduced return to sport rates [21][22]. This age-related discrepancy could likely compound the impact of delayed surgery and work-related demands on rehabilitation success.

Meniscal injuries were present in over 70% of cases, with medial meniscus involvement being most prevalent, particularly ramp lesions (27.2%). These lesions are increasingly recognized as markers of chronic ACL injuries and have been linked to persistent rotational instability when left untreated [9][23][24]. Although our study did not perform

a direct correlation between surgical delay and ramp lesion prevalence, literature supports their increased occurrence with delayed intervention [7][8][20][25]. However, in our series, no significant differences were observed in medial meniscal injuries, which may be explained by the fact that the surgical delay remained below the 6-month threshold commonly used to define a chronic ACL injury.

Our data also explored the influence of surgical technique, noting no significant differences in re-rupture rates between isolated ACL and combined ACL + lateral extra-articular tenodesis (LET) reconstructions (p=0.401). However, only 11.9% did not undergo external plasty, therefore this difference may justify the lack of statistical significance in this study. It has been proven that the addition of LET diminishes the re-rupture rate even in older populations [29]. Also, and very importantly, the re-rupture rate of ACL+LET of 1.3% is closer to the contralateral ACL rupture of 0.7%, when comparing to the re-rupture rate of 2.8% of the isolated ACL reconstruction. We believe that short-term follow-up could explain the non-significance of the difference, as it has been shown that the protective effect of the lateral extra-articular tenodesis increases and reaches significance with time [30].

Overall, this study reinforces that ACL injuries in the occupational setting are associated with worse subjective functional outcomes, worse return to sports, greater surgical delay, and older patient age. These factors suggest a need for targeted strategies to optimize management in this subgroup. Early referral, expedited surgical pathways, and tailored rehabilitation addressing occupational demands may be essential to improving outcomes in work-related ACL injuries.

This study has several limitations. First, the significant age difference between groups is a major confounder; however, we attempted to control for this using multivariable analysis. Second, the high rate of ALL reconstruction (76.3%) reflects our institution's specific practice patterns and may limit generalizability to centers performing isolated ACLR. However, this approach aligns with growing evidence suggesting that lateral extra-articular procedures are associated with fewer complications, lower re-operation rates, and a significantly reduced risk of graft rupture [30]. Third, we relied on the SKV as the primary patient reported outcome measure due to the retrospective data collection but also because encountered difficulties obtaining responses to the longer KOOS and IKDC questionnaires, particularly among patients with occupational injuries, who were often unwilling to engage in more extensive participation despite repeated attempts; nevertheless SKV is validated score and, most importantly, it has been shown to correlate with other patient reported outcomes as Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee subjective knee form (IKDC-S) [16]. One factor that was not accessed was the type of rehabilitation patients are offered after surgery. Although general guidelines are provided, the place and type of physiotherapy that patients undergo may differ from patients with occupational injuries vs non-occupational injuries, in the specific setting of our country. Another important limitation of this study is that, although we stratified patients based on insurance status, we did not specifically evaluate unmeasured confounders such as ongoing litigation, financial secondary gain, or specific psychosocial factors often associated with Workers' Compensation claims. It is described in the literature that litigation or secondary gain in such cases can adversely influence subjective and functional recovery [13]. Finally, the longer follow-up in the OI group could introduce bias, although statistical adjustment was performed.

Conclusions

Patients sustaining an ACL injury and then ACL reconstruction in the setting of an occupational injury are older, experience delayed time to surgery, lower return to sport rates, and, most importantly, have worse clinical outcomes. No differences were identified in terms of associated lesions, complications and graft rupture rates, using surgical technique between the groups.

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Conflict of Interest

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