Factors Associated with Return to Sports in Patients Undergoing ACL Surgery: A 20-Year Analysis at a Tertiary-Care Children's Hospital

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INTRODUCTION: There has been a well-documented increase in ACL injuries and surgeries in recent years, especially among adolescents and young athletes. Return to sports clearance after ACL surgery is the most challenging decision that may be made by a clinical care team with both short- and long-term consequences on individual and societal levels. The timing of safe return to sports and its effects on the ACL surgery outcomes, including the risk of reinjuries have been the focus of many recent studies. There has also been a general consensus on delaying the return to sports, to allow the surgically treated ACL (e.g., reconstructed graft) ample time to heal and remodel. However, little is known on factors influencing the return to sports timing, in particular among pediatrics and adolescent population. Therefore, the purpose of this study was to use a large database of pediatric, adolescent, and young adult ACL surgeries conducted over a period of 20 years to examine the relation between patient and surgical related factors and timing of the return to sports after ACL surgery.
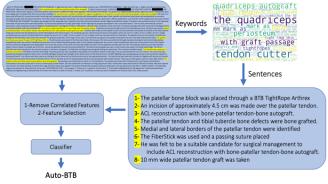
METHOD: Following institutional review board approval, a Natural Language Processing (NLP) pipeline was developed to identify ACL surgery cases from the electronic health records of patients from Boston Children's Hospital Orthopedics and Sports Medicine clinics between 2000-2020 (from >23 million notes). Following training and validation, the model achieved median accuracy of 98%, median sensitivity 97% and median specificity of 98% in identifying ACL surgery cases and extracting variables from clinical visits and operative notes (Table 1). Sports participations were grouped into 3 levels. Level I activities include frequent jumping, cutting, and pivoting (e.g., soccer, basketball), Level II activities involve lateral movements with less pivoting (e.g., racket sports, gymnastics), and Level III activities include straight ahead activities without jumping or pivoting (e.g., running, weightlifting). Linear regression was used to investigate how patient-related (i.e., age, sex, BMI, sports played, and insurance), injury related (i.e., mechanism of injury, primary vs reinjury, concomitant injuries to the PCL, PLC, MCL, and menisci), and surgery related (i.e., year of surgery, days from injury to surgery, surgery duration in minutes, graft type, and meniscus surgery) factors may correlate to the time of return to sports (calculated as the days from surgery to return to sports). We first started with bivariate analysis (e.g., one predictor per model) and then conducted a multivariable analysis on those with significant associations to return to sports.

RESULTS: The model identified 5,648 ACL surgeries from 4,992 unique patients of any age (age: 17.0 ± 4.0; 53% females), of which 4,727 surgeries (4,221 unique patients, age: 15.9 ± 2.2; 55% females) were performed on children and adolescents (<20 years old). On average return to sports was 213 ± 106 days after the surgery date. In a bivariate setting, year (β=2.8; P<0.001), age (β=0.85; P=0.05), female sex (β=13.4; P<0.001), BMI (β=0.76; P=0.013), public insurance (β=14.6; P=0.004), surgery duration (β=0.5; P<0.001), bone-patellar tendon-bone autograft (β=26.8; P<0.001), quadriceps tendon autograft (β=58.5; P<0.001), and medial meniscus repair (β=11.9, P=0.01) were associated with later return to sports. Level I sports (β= -22.6, P<0.001), level II sports (β= -9.2, P=0.009), hamstrings autograft (β= -15.7, P<0.001), and medial meniscectomy (β= -14.1, P=0.042) were associated with earlier return to sports. There were no associations between return to sports timing and playing level III sport, mechanism of injury (contact vs non-contact), reinjury, concomitant injuries to the other ligaments and menisci, days from injury to surgery, allografts and IT band autografts, and lateral meniscus surgeries (P>0.05 for all associations). The multivariable analysis of significant predictors showed that year (β=5.5, P<0.001), female sex (β=21.5; P<0.001), public insurance (β=12.4; P=0.018), surgery duration (β=0.4, P<0.001), and bone-patellar tendon-bone autograft (β=15.9, P=0.004) were associated with later return to sport, while level 1 sports (β==13.5, P=0.003) was associated with an earlier return to sports after ACL surgery.

DISCUSSION: The current largescale single-site study of well over 5,000 surgical cases shows that several patient-, injury-, and surgery-related factors may directly impact the timing of the return to sports after ACL surgery. Data shows that over the years there has been a significant tendency towards later return to sports, which is consistent with recent literature and recommendations. We also saw older patients, females, those with higher BMI and public insurance have been subjected to later return to sports clearance, which could be due to patient preference or later follow ups in those with public insurance along with different recovery speeds. Interestingly, we saw those who played higher risk and more intense sports (levels I and II) were subjected to earlier return to sports, which could have been heavily influenced by patients' (athletes') desire for a faster return to the field. We also saw different trends in how meniscus repair vs meniscectomy would influence return to sports, which warrants further investigation. Finally, we observed marked differences in how bone-patellar tendon-bone or quadriceps autografts were associated with later return to sports, whereas the hamstrings autografts were associated with earlier return to sports. While these differences could have been influenced by patients' recovery and different graft healing speeds, they may have also been affected by the changes in return to sports management over the years, which also corresponds to increased use of bone-patellar tendon-bone or quadriceps autografts over hamstrings autografts.

SIGNIFICANCE: The timing of the return to sports is highly individualized with direct impact on the success of the ACL surgery and patient's recovery and function in both short- and long-term. The current study suggests that several patient-, injury- and surgical-related factors may influence the return to sports timing, which could be used to improve the outcomes and minimize the risk of reinjuries.

Figure 1. Natural language processing pipeline for identifying and extracting ACL surgery information from clinical visits and operative notes, with "Graft Type" as a target variable example and its performance metrics for variables used in this study.

Variables	AUROC	Accuracy	Specificity	Sensitivity
Detect ACL surgery	0.99	1	1	0.99
Type of Sport-median	1	1	1	1
Graft Type	0.99	1	0.99	1
Medial Meniscus Surgery	0.95	0.98	0.93	0.97
Lateral Meniscus Surgery	0.97	0.98	0.96	0.98
Mechanism of Injury	0.95	0.95	0.97	0.92
primary vs reinjury	0.93	0.99	0.99	0.88
PLC Injury	0.86	0.90	0.92	0.79
PCL Injury	0.98	0.97	0.97	1
MCL Injury	0.91	0.90	0.88	0.94
Lateral Meniscus Injury	0.95	0.91	0.89	1
Medial Meniscus Injury	0.93	0.92	0.90	0.96