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# Incidence and Predictors of Second Anterior Cruciate Ligament Injury After Primary Reconstruction and Return to Sport

**Mark V. Paterno, PhD, ATC, PT, SCS**

Division of Occupational Therapy and Physical Therapy, Division of Sports Medicine, Cincinnati Children's Hospital Medical Center, OH

An estimated 200 000 anterior cruciate ligament (ACL) injuries occur annually in the United States,[1,2] with as many as 90% of patients electing to undergo ACL reconstruction (ACLR).[3] Despite the high prevalence of surgery after ACL injury, outcomes vary widely in the literature. Recent evidence suggests that more than 50% of athletes are unable to return to their preinjury level of function after ACLR[4] and between 50% and 100% develop knee osteoarthritis within 5 to 10 years of surgery.[5,6] Considering the high rate of poor outcomes after primary ACLR, we must be very concerned that a large proportion of athletes who have undergone ACLR ultimately suffer a second ACL injury. Future directions in the management of ACL injury after ACLR must focus on prevention. Prior success using an injury-prevention model[7,8] to decrease the rate of primary ACL injury may have important applications in this population.

## INCIDENCE OF SECOND ACL INJURY

To prevent ACL injury after ACLR, we must first determine the incidence and magnitude of the problem and then identify the factors predisposing these athletes to increased risk.[7,8] The incidence of a second ACL injury after ACLR and return to sport (RTS) is not trivial. Over the past decade, a growing body of literature has highlighted a higher rate of ACL injury after ACLR than once assumed. Early reports focused on incidence proportion or crude incidence. Wright et al[9] described the crude incidence of subsequent ACL injury in a subset of data from the Multicenter Orthopaedic Outcome Network (MOON) database in 2007. One in 17 patients (6%) sustained a second ACL injury within 2 years of ACLR; half of these experienced graft failure, and the remainder incurred a contralateral ACL injury. More recently, in a series of publications reporting outcomes at 5,[10] 10,[11] and 15[12] years after ACLR in a common cohort of patients, the authors noted second ACL injury rates, including ipsilateral and contralateral tears, of 12%, 27%, and 31%, respectively. In a systematic review of 5-year outcomes after ACLR, Wright et al[13] reported a 17.2% second-injury rate, with a greater percentage sustaining a contralateral injury (11.8%) than an ipsilateral graft failure (5.8%). These results highlight the wide variability in reported second ACL injury rates after ACLR, ranging from 6% to 31%. This variation complicates our ability to clearly identify the magnitude of the problem in this population.

The potential mechanism underlying this variation in reported second injury rates is likely multifactorial. Heterogeneous samples with respect to variables such as age, surgical procedure, and postinjury activity level may all contribute. In an attempt to control for varying activity rates after patients returned to sport, colleagues and I published 2 articles[14,15] that described the incidence rate normalized to athlete-exposure in pivoting and cutting sports. In these studies, incidence rate provided a more accurate representation of ACL injury proportional to the amount of time the athlete was at risk. This work highlighted the second-injury incidence density at 1 year[14] and 2 years[15] after ACLR and RTS in a young, active population. An athlete between the ages of 10 and 25 years who returned to a pivoting or cutting sport after ACLR was 15 times more likely to sustain an ACL injury in the first 12 months than a previously uninjured athlete.[14] Further, the same population was 5 times more likely to suffer a second ACL injury in the first 24 months after RTS compared with an uninjured cohort.[15] Collectively, these data highlight the large risk of another ACL injury in the early stages of RTS after ACLR. In fact, of the patients who incurred a second ACL injury, 30.4% experienced it in fewer than 20 athlete-exposures after RTS, and more than 52% experienced it in fewer than 72 athlete-exposures.[15] These alarming data highlight the fact that our current system of care is failing in a large segment of this patient population, further validating the magnitude of the problem.

## IDENTIFICATION OF RISK FACTORS

Discovering potential risk factors is the next critical step to decreasing the incidence of second ACL injury in this population. Researchers have begun to report factors related to ipsilateral graft failure, contralateral ACL injury, and second injury (both ipsilateral and contralateral). With respect to graft failure, younger age has consistently been identified as a risk factor.[16–21] Two articles[17,18] based on the MOON data demonstrated that younger patients were at higher risk for graft failure. Adolescents experienced the highest rate of second injury,[18] as the odds of graft failure declined 0.09 for every year increase in age.[17] Similarly, population database reports from the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry,[20,21] Swedish National Anterior Cruciate Ligament Registry,[16] and smaller cohort samples[19,22] also identified younger patients as being at higher risk for graft failure. A second risk factor for ipsilateral ACL reinjury is graft type: specifically the use of allograft tissue. According to MOON data, allograft tissue was 5.2 to 5.6 times more likely to fail than autograft tissue.[17,23] Similarly, information from the Kaiser Permanente Anterior Cruciate Ligament Reconstruction Registry suggested higher graft-failure rates with allograft tissue.[20,21] The combination of allograft tissue and a younger population appeared to increase the likelihood of failure.[20,23] Beyond age and graft type, factors such as surgical technique,[16] body mass index,[20] and posterior tibial slope[24] may increase the risk of subsequent ACL injury, but current evidence is limited.

Relatively fewer authors have addressed the risk factors related to sustaining a contralateral ACL injury after ACLR and RTS. Younger age[20,25] and female sex[20] increased the likelihood of contralateral ACL injury. Younger age and return to a pivoting or cutting sport increased the chance of an ipsilateral graft tear or contralateral ACL injury.[10,19,26] Collectively, the reported risk factors for subsequent ACL injury to either extremity after ACLR and RTS have centered on demographic and surgical factors. With respect to preventing future ACL injury, these demographic data are helpful for identifying at-risk individuals, but they may not represent modifiable factors. Although surgical decision making related to graft type can be altered, a gap in the literature persists regarding other potentially modifiable risk factors to prevent second ACL injury.

To my knowledge, only 1 group has identified biomechanical and neuromuscular risk factors for second ACL injury after ACLR and RTS. Paterno et al[27] assessed biomechanical and neuromuscular variables in a cohort of young athletes who returned to pivoting and cutting sports. These data were used to prospectively identify, through multivariate logistic regression, 4 variables that predicted second ACL injury to either the ipsilateral or contralateral knee after ACLR and RTS with high sensitivity (0.92) and specificity (0.88). These predictive variables consisted of 3 biomechanical variables assessed during a drop–vertical-jump maneuver (increased hip internal-rotation moment during the initial 10% of stance phase in the uninvolved limb, increased peak knee valgus during landing on the involved limb, and side-to-side asymmetries in sagittal-plane knee moment at initial contact with the uninvolved limb having a relatively smaller net knee-extensor moment than the involved limb) and altered postural stability. Interestingly, hip-rotation moment at the onset of stance from a drop vertical jump alone predicted second ACL injury with a sensitivity of 0.77 and a specificity of 0.81. This work represents important foundational, preliminary data highlighting potentially modifiable risk factors after ACLR. However, it is not without limitations. Future authors need to more specifically determine independent risk factors for both ipsilateral graft failure and contralateral ACL injury, as these factors may be unique. Once these factors are more clearly identified in the literature, we will progress toward an injury-prevention model.

## CONCLUSIONS

The current system of care for patients after ACLR is failing. Outcomes in this population could be improved through an injury-prevention model. The magnitude of the problem is clear, as a high incidence of second ACL injury, particularly in young, active patients, is well documented. In addition, a contralateral ACL injury appears to be more common than graft failure in young, active patients. Preliminary work has elucidated risk factors related to second injury rates, which are likely multifactorial. Future researchers must focus on identifying more specific modifiable risk factors, for which prevention strategies can be developed, as well as nonmodifiable risk factors, such as genetic predisposition,[28] related to second ACL injury. As with preventing primary ACL injuries, once risk factors are identified,[29–31] efforts must focus on developing and validating interventions for preventing second ACL injuries.

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*Address correspondence to Mark V. Paterno, PhD, ATC, PT, SCS, Division of Occupational Therapy and Physical Therapy, Cincinnati Children's Hospital Medical Center, 3333 Burnet Avenue, MLC 10001, Cincinnati, OH 45229. Address e-mail to mark.paterno@cchmc.org.*