

Pediatric Anterior Cruciate Ligament Reruptures Are Related to Lower Functional Scores at the Time of Return to Activity

A Prospective, Midterm Follow-up Study

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Background: Skeletally immature patients show a higher rate of anterior cruciate ligament (ACL) reruptures. A better understanding of the risk factors for an ACL rerupture in this population is critical.

Purpose/Hypothesis: The objective of this study was to analyze preoperative, intraoperative, and postoperative characteristics of pediatric patients undergoing ACL reconstruction and determine the relationship of these factors with an ACL rerupture. It was hypothesized that patients with worse activity scores and knee function at the time of return to activity would have a higher rate of ACL reruptures at midterm follow-up. Additionally, it was hypothesized that most ACL reruptures would occur before age 20 years in the study population.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 65 skeletally immature patients (age <16 years) with ACL ruptures underwent reconstruction with a quadruple hamstring tendon graft between 2002 and 2016. Of these patients, 52 were available for the study. Patient characteristics, surgical details, Tegner and Lysholm scores, and ACL reconstruction outcomes were recorded. Patients were analyzed and compared according to ACL rerupture occurrence.

Results: Of the 52 patients, 18 (34.6%) experienced an ACL rerupture after reconstruction. The majority of reruptures (77.8%) occurred before age 20 years. There were 2 patients who sustained ACL reruptures during the rehabilitation period before they returned to activity. The majority of reruptures occurred after 12 months (83.2%), with 66.6% occurring after 24 months. Upon returning to activity between 6 and 9 months postoperatively, patients who ended up with intact ACL grafts reported 69% higher mean Tegner scores ($P = .006$) and 64% higher mean Lysholm scores than patients who sustained ACL reruptures ($P < .001$). Within the limits of this study, we could identify no statistical relationship between the rate of ACL reruptures and different sport types, surgical techniques, or associated injuries ($P > .05$).

Conclusion: Skeletally immature patients who underwent ACL reconstruction and sustained ACL reruptures had lower Tegner and Lysholm scores upon returning to activity than patients without ACL reruptures. In addition, most ACL reruptures occurred in patients younger than 20 years (77.8%) and after 24 months postoperatively (66.6%).

Keywords: anterior cruciate ligament; ACL; ACL reconstruction; skeletally immature; return to activity; ACL rerupture; pediatric patients

Several studies have reported up to a 3 times higher rate of graft failure in skeletally immature patients than in adults.^{3,7,22,26} The specific reason why an anterior cruciate

ligament (ACL) rerupture is more common in this population has not been totally elucidated yet.²⁸

Given the scarcity of guidelines and universal protocols for optimal rehabilitation after ACL reconstruction in the pediatric population, validating functional measures in this population, such as Tegner and Lysholm scores, may be essential to calculate the inherent risks of returning to physical activity and minimizing the risk of reruptures.^{15,16,23}

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Therefore, the purpose of this study was to analyze preoperative, intraoperative, and postoperative characteristics of pediatric patients who underwent ACL reconstruction and to determine the relationship of these factors to an ACL rerupture. It was hypothesized that patients with low knee function scores after returning to activity would have a higher rate of ACL reruptures. Additionally, it was hypothesized that most ACL reruptures would occur before age 20 years.

METHODS

This was a retrospective, longitudinal cohort study based on prospectively collected data, which was approved by the ethics and research committee of our institution. All patients provided informed consent before their surgery.

A total of 65 skeletally immature patients who underwent ACL transphyseal reconstruction between 2002 and 2016 were considered for this study. The inclusion criteria were patients aged <16 years with ACL injuries and knee radiographs revealing open growth physes who underwent ACL reconstruction with hamstring tendon grafts. The exclusion criteria were previous surgery on the ipsilateral knee, concomitant ipsilateral ligament injuries that required a surgical intervention, tibial spine fractures, and surgery with a non-hamstring tendon graft. Patients who experienced graft failure had their scores, physical characteristics, and surgical technique analyzed and compared with patients who had intact grafts.

The diagnosis of an ACL tear was made clinically (positive Lachman, anterior drawer, and pivot-shift tests)¹² and via magnetic resonance imaging and was confirmed arthroscopically. Anteroposterior and lateral knee radiographs were obtained to evaluate growth stages and long-leg radiographs to determine lower limb alignment and length at the time of the injury.

At the time of presentation after the injury, the characteristics of patients were recorded (age, sex, and Tanner stage, activity). At the time of surgery, surgical characteristics were recorded, including a vertical or anatomic femoral tunnel, type of fixation, graft diameter size, and bone tunnel description. The main purpose of achieving a more vertical femoral tunnel is to decrease the area of injury to the physis. All patients were counseled about the risks of growth disturbances, and a new long-leg radiograph was obtained before returning to activity to evaluate leg-length discrepancies or subtle angular deformities. After surgery (transphyseal isometric or anatomic ACL reconstruction with a quadruple hamstring tendon graft), all patients were referred to

physical therapy at the same institution, undergoing the rehabilitation protocol for a period of 6 to 9 months (2-3 times/wk). After this period, patients were released to return to activity according to the following criteria: full knee range of motion, muscular or proprioceptive measurements, and absence of instability or apprehension while performing physical activity.

An author who had no involvement in the clinical care of the patients (E.L.B.C.) administered the Lysholm knee score¹⁹ and Tegner activity scale.²⁴ The Tegner score graded activity levels from both before the injury (assessed retrospectively, during the patients' first postinjury examination) and 4 weeks after returning to activity. The Lysholm score was administered after the injury and 4 weeks after returning to activity.

All patients were evaluated weekly during the first month, every 15 days in the second and third months, and monthly until the first year after surgery. During all evaluations, a physical examination was performed. Knee radiographs were obtained after 2 weeks and then at 3, 6, and 12 months postoperatively. Magnetic resonance imaging was performed at 6, 12, and 24 months postoperatively or after any possible injury of the operated knee. All data were collected as usual as part of the normal follow-up routine.

In all patients diagnosed with a graft failure, a traumatic episode occurred, and the new injury was diagnosed within 2 to 13 days. The new knee injury episode was considered to define a rerupture.

Statistical Analysis

The independent variables compared in this cohort study were intact ACL graft and ACL rerupture. The Student *t* test was used to analyze the characteristics of the femoral tunnel (vertical vs anatomic) and the femoral and tibial fixation methods. The Mann-Whitney test was used to evaluate age, follow-up, rehabilitation time, graft diameter size, Tanner stage, bone tunnels, and Tegner and Lysholm scores. The chi-square test was used to evaluate the relationship between ACL tear and type of sport activity. A significance level of 5% and 95% CIs were used.

RESULTS

Of 65 patients, 10 did not meet inclusion criteria, and 3 were lost to follow-up, for a total of 52 study patients. Of these patients, 34 had an intact ACL graft and 18 sustained an ACL rerupture (Figure 1).

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Ethical approval for this study was obtained from the Universidade Federal de São Paulo/Hospital São Paulo.

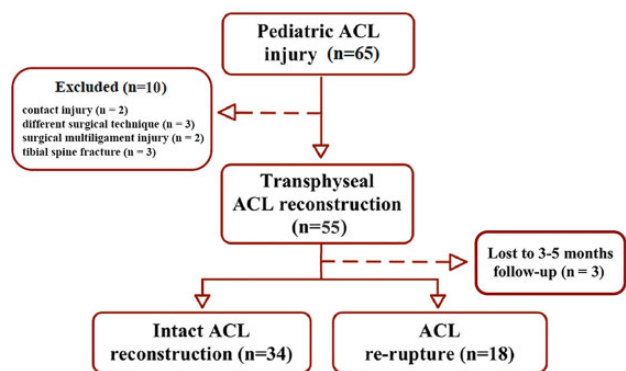


Figure 1. Flowchart of patient inclusion.

TABLE 1
Patient Data^a

	Intact ACL Graft (n = 34)	ACL Rerupture (n = 18)	P
Sex, n (%)			>.05
Male	16 (47)	13 (72)	
Female	18 (53)	5 (28)	
Age, y	13.6 ± 2.5	14.4 ± 1.9	>.05
Follow-up, y	7.4 ± 4.5	4.0 ± 2.8	>.05
Time to return to activity, mo	7.4 ± 1.0	7.5 ± 1.2	>.05
Tanner stage, n (%)			>.05
II	9 (26)	3 (17)	
III	11 (32)	8 (44)	
IV	14 (42)	7 (39)	

^aValues are presented as mean ± SD unless otherwise indicated. ACL, anterior cruciate ligament.

Table 1 shows the characteristics of the included patients. Most ACL reruptures (77.8%) occurred before the age of 20 years (mean, 18.2 ± 2.9 years [range, 14-24 years]). Among the patients who returned to activity, there was no difference in the time to return to activity (intact ACL graft: 7.4 ± 1.0 months [range, 6-9 months]; ACL rerupture: 7.5 ± 1.2 months [range, 6-9 months]). Only 2 patients had ACL reruptures during the rehabilitation period before they returned to activity (2 and 4 months after surgery, both resulting from return to sport before medical approval). Most ACL reruptures occurred after 12 months (83.2%); 66.6% occurred after 24 months (Figure 2).

At 4 weeks after returning to activity, patients with intact ACL grafts reported a mean Tegner score that was higher than patients with ACL reruptures (7.0 ± 0.8 vs 4.9 ± 1.3, respectively; *P* = .006) (Table 2). Only 5.6% of the patients with ACL reruptures regained preinjury levels of activity after 6 to 9 months of rehabilitation. Among patients who did not sustain ACL reruptures, 46.2% increased their activity level after the surgical procedure, 46.2% returned to their preinjury level of activity, and 7.6% returned to a lower level of activity than that before the ACL injury. After returning to activity, patients with

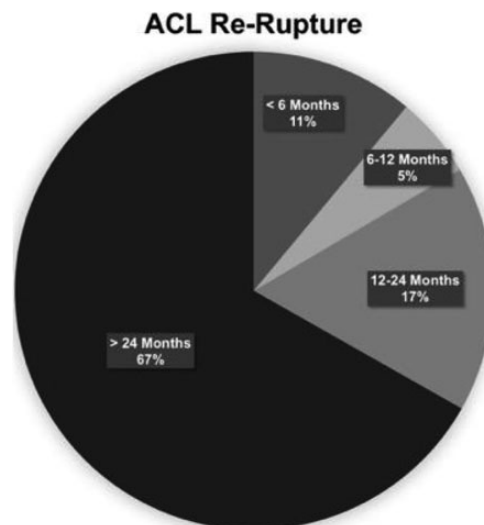


Figure 2. Anterior cruciate ligament (ACL) rerupture rate according to time postoperatively.

TABLE 2
Tegner and Lysholm Scores^a

	Intact ACL Graft (n = 34)	ACL Rerupture (n = 18)	P
Tegner score			
Before injury	7.2 ± 1.0	8.2 ± 1.1	>.05
4 wk after return to activity	7.0 ± 0.8	4.9 ± 1.3	.006
Lysholm score			
After injury	56.3 ± 15.0	57.6 ± 8.5	>.05
4 wk after return to activity	90.6 ± 6.1	58.8 ± 6.7	<.001

^aValues are presented as mean ± SD. ACL, anterior cruciate ligament.

intact ACL grafts reported a mean Lysholm score that was higher than that for patients who sustained ACL reruptures (90.6 ± 6.1 vs 58.8 ± 6.7, respectively; *P* < .001) (Table 2).

A medial meniscal tear was the most common concomitant injury. There was no significant difference in the incidence of meniscal injuries between patients with and without ACL reruptures (52.9% vs 33.3%, respectively). The most common sport practiced by the patients was soccer (34.6%), followed by basketball and skiing (5.8% each). An ACL injury unrelated to sport activity was common (23%). There was no statistical relationship between the kind of sport and the rate of ACL reruptures (*P* > .05).

Vertical femoral tunnel reconstruction was the most common primary surgical technique compared with anatomic ACL reconstruction in patients with or without ACL reruptures (79.4% vs 88.8%, respectively; *P* > .05). Further details of surgical techniques are shown in Table 3. No growth disturbances or angular deformities were diagnosed during the evaluation.

TABLE 3
ACL Reconstruction Techniques Used^a

	Intact ACL Graft (n = 34)	ACL Rupture (n = 18)	P
Femoral fixation, n (%)			
Transfix	24 (71)	9 (50)	>.05
Button	8 (23)	6 (33)	>.05
Interference screw	2 (6)	3 (17)	>.05
Tibial fixation, n (%)			
Interference screw	31 (91)	18 (100)	>.05
Button	3 (9)	0 (0)	>.05
Graft size diameter, mm	7.6 ± 0.7	7.3 ± 0.8	>.05
Femoral tunnel size diameter, mm	7.6 ± 0.7	7.7 ± 1.2	>.05
Tibial tunnel size diameter, mm	7.7 ± 0.9	7.8 ± 1.2	>.05

^aValues are presented as mean ± SD unless otherwise indicated. ACL, anterior cruciate ligament.

DISCUSSION

The main finding of this study was that skeletally immature patients who underwent ACL reconstruction and sustained reruptures had lower Lysholm and Tegner scores when returning to activity than patients who did not sustain ACL reruptures. Low Tegner and Lysholm scores after rehabilitation in patients with reruptures may be caused by a number of factors. One possible factor is the delayed return of quadriceps and hamstring strength, which leads to ineffective muscle control at the expense of a significant muscle deficit that has been shown to last for more than a year.^{8,10,14} Exposure of the reconstructed knee to biomechanical conditions in excess of its functional capacity may result in poor clinical outcomes and graft failure.^{7,11,21} Besides that, 6 to 9 months of rehabilitation could be insufficient for this population to return safely to sport. Probably, these children have been out of competition for a while and have to re-enter at a significantly higher level while most often not being physically and mentally 100% ready for this with their knee.^{13,27}

Another important finding of this study was that ACL reruptures occurred predominantly in patients younger than 20 years (77.8%), in agreement with previous studies that observed that skeletally immature and young adult patients have a 2.5 to 3.5 times increased risk of failure after ACL reconstruction when compared with adult patients.^{1,2,7,9,17,25}

Biological and biomechanical characteristics of the graft, such as small diameter, fatigue, and elongation due to functional adaptation, should be evaluated as factors associated with a higher rate of reruptures in the pediatric population.^{3,5} Kay et al¹⁸ reported that a predisposition to ACL injuries with high-risk activities (soccer, basketball, football)^{10,20} experienced by these patients may be more predictive of reruptures than the intrinsic reconstructed ligament strength, demonstrating that adherence to activity restriction during rehabilitation is critical. In our study, we did not identify a significant relationship between the

technique used, graft characteristics, or rehabilitation time and whether an ACL rerupture occurred.

In this study, ACL reruptures occurred predominantly after 24 months of follow-up and may be related to the period of corporal and behavioral transition of patients in this age group.¹⁸ During the same time period postoperatively, the graft is more integrated to the bone, but it may not yet have matured enough to withstand the stress demanded by a more developed musculoskeletal structure and a higher level of sport competition.^{3,4} In another study with patients aged 16 to 18 years, Dekker et al⁷ found similar results to the present study, with an average time of 26.5 months between primary ACL reconstruction and an ACL rerupture.

An ACL tear is frequently the first major injury in patients younger than 16 years. The reported rate of return to sport in the pediatric population is higher than reported rates in the adult population, which vary between 60% and 75%.^{6,8,18,22} One of the reasons for the difference in the rates of return to sport when compared with the adult population may be that adults often choose to forgo further sport participation out of fear of reinjuries and prioritization of work activity.

In the present study, during postoperative follow-up, 34.6% of the patients sustained ACL reruptures, and 77% of these injuries occurred during sport practice. Astur et al³ found a 24.6% rate of ACL reruptures in patients younger than 16 years. When including patients between the ages of 16 and 18 years, the incidence decreased to 21.2%.³ In the studies of Dekker et al⁷ (age <19 years) and Ho et al¹⁴ (age <18 years), the rerupture rate was 32% and 34%, respectively. In a meta-analysis with patients younger than 19 years, Kay et al¹⁸ found an incidence of reruptures of 13%.

The present study is unique in the literature because, to our knowledge, it is the only study that analyzed patients with ACL reruptures who are younger than 16 years and with open physes on radiographs at the time of primary ACL reconstruction. In addition, this study presents a midterm (mean, 7.4 years) follow-up to evaluate the outcomes of skeletally immature patients who underwent ACL reconstruction.

The main limitation of this study is the relatively small sample size, even considering that it is not usual to find a big sample size with ACL reruptures. In addition, it is not possible to ensure that patients with intact ACL grafts at the time of evaluation will avoid an ACL rerupture in the long term.

CONCLUSION

Skeletally immature patients who sustained ACL reruptures at midterm follow-up had lower Tegner and Lysholm scores at 6 to 9 months than patients who did not sustain ACL reruptures. In addition, 77.8% of ACL reruptures occurred in patients younger than 20 years, and 66.6% of ACL reruptures occurred more than 24 months after primary ACL reconstruction.

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