Anterior cruciate ligament re-rupture in pediatric population is related to lower functional scores at return to activity: a prospective, mid-term follow-up study

Abstract

Purpose: The objective of this study was to analyze pre-, intra- and postoperative characteristics of pediatric patients undergoing ACL reconstruction and determine the relationship of these factors to ACL re-rupture in the mid-term follow-up.

Methods: Sixty-five skeletally immature, under 16 years old patients with ACL rupture underwent reconstruction with quadruple hamstring graft between 2012 and 2016. Patient demographics, surgical details, Tegner and Lysholm scores and ACL reconstruction outcomes were recorded. Patients were analyzed and compared according to ACL re-rupture occurrence.

Results: Eighteen patients evaluated with ACL re-rupture after reconstruction. The majority of re-ruptures (77.8%) occurred before age 20. Two patients sustained ACL re-rupture during the rehabilitation period, before they returned to activity. The majority of re-ruptures occurred after 12 months (83.2%), with 66.6% occurring after 24 months. After returning to sports (6-9 months), patients that ended up with intact ACL reconstructions reported 69% higher mean Tegner scores (p = 0.006) and 64% higher mean Lysholm scores than patients sustained ACL re-ruptures (p <0.001). There was no statistical relationship between sports modality, surgical technique details, associated injuries and the rate of ACL re-rupture (n.s.)

Conclusions: Skeletally immature patients who underwent ACL reconstruction and sustained ACL re-rupture had lower Tegner and Lysholm scores after returning to activity than patients without ACL re-rupture. In addition, most ACL ruptures (77.8%) occurred in patients under age 20 and after 24 months postoperatively (66.6%).

Level of Evidence: Level IV Cohort study (prospective and longitudinal)

Keywords: anterior cruciate ligament (ACL); ACL reconstruction; skeletally immature; return to activity; ACL re-rupture; pediatric patients

Introduction

Factors influencing graft survival after an anterior cruciate ligament (ACL) reconstruction in the pediatric population include surgical technique, graft demands, musculoskeletal development, activity level participation, and even behavioral factors that may influence the greater occurrence of re-rupture.3,7,12,22
Several studies report up to three times higher rate of graft failure in skeletally immature patients than in adults. The specific reason why the ACL re-rupture is more common in this population was not totally elucidated yet. Given the scarcity of guidelines and universal protocols for optimal rehabilitation after ACLR in the pediatric population, validating functional scores in this population, such as Tegner and Lysholm, may be essential to measure the inherent risks of returning to physical activity, and minimizing the risk of re-ruptures. Therefore, the objective of this study was to analyze pre-, intra- and postoperative characteristics of pediatric patients who underwent ACL reconstruction and to determine the relationship of these factors to ACL re-rupture in the mid-term follow-up. It was hypothesized that patients with low knee function scores after returning to activity would have a higher rate of ACL re-rupture in the mid-term follow-up. Additionally, it was hypothesized that most ACL re-ruptures would occur before age 20.

**Material and methods**

This was a prospective and longitudinal cohort study evaluated and approved by the ethics and research committee of the author’s institution. All patients consent to this study before the surgery. Sixty-five skeletally immature patients who underwent ACL transphyseal reconstruction between 2012 and 2016 were included in this study. The inclusion criteria were: patients under 16 years with knee radiographic images revealing open growth physis; ACL injury; ACL reconstruction with hamstring graft. The non-inclusion criteria were: previous surgery on the ipsilateral knee, or concomitant, ipsilateral ligament injuries that required surgical intervention, or tibial spine fracture. Patients were excluded if they refused to participate, different surgical technique was chosen, or were lost to follow-up. Included patients who evaluated with graft failure during mid-term follow-up had their scores, physical characteristics, and surgical technique analyzed. (Figure 1)

![Flow-chart of patient inclusion](image)

*Figure 1: Flow-chart of patient inclusion. Characteristics of patients were evaluated and compared according to the outcome of the surgery performed. Patients who sustained re-rupture were compared to those with intact grafts throughout the follow-up and rehabilitation period, and did not present signs or symptoms suggestive of re-rupture.*
The diagnosis of ACL tear was clinical (positive Lachman, anterior drawer, pivot shift tests) and radiologic (Magnetic Resonance Imaging), and 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 presentation after injury, characteristics of patients were recorded (age, gender, injury laterality, Tanner stage, activity). At the time of surgery, the reconstruction technique used was recorded, including the type of fixation, graft characteristics and bone tunnel description. All patients were counseled about the risks of growth disturbances, and a new long leg radiographs was done before returning to activities to evaluate leg-length discrepancies or subtle angular deformity. After surgery (transphyseal isometric or anatomic ACL reconstruction with quadruple hamstring tendon graft), all patients were referred to physiotherapy at the same institution, performing the rehabilitation protocol for a period of 6 to 9 months (2-3 times /week). After this period, patients were released to return to activities according to the following criteria: full knee range of motion, muscular or proprioceptive measurement, and absence of instability or apprehension while performing physical activity.

One author, who had no involvement in the clinical care of the patients, administered a 2 questionnaire survey consisting of the Lysholm 19 and Tegner 24 scores. The Tegner score assessed both pre-injury (activity level by Tegner retrospectively, during their first assessment) and post-return to sport activity levels (6-9 months) to evaluate whether return to pre-injury activity level was obtained. The Lysholm score assessed both after injury and post return to activities (6-9 months). All patients were evaluated weekly during the first month; every 15 days in the second and third months, monthly until the ninth month after surgery. All data were collected as usual part of the normal follow-up.

**Statistical analysis**

The Student \( t \) test was used to analyze injury laterality, Tanner stage, surgical technique, graft type, and femoral and tibial fixation method. The Mann-Whitney test was used to evaluate age, follow-up, rehabilitation time, graft size and bone tunnels, as well as the Tegner and Lysholm scores, comparing patients with and without ACLR re-rupture. Chi-square test was used to evaluate the relationship between ACL tear and type of sport activity. A significance level of 5% and a 95% confidence interval were used.

**Results**

Table 1 shows the characteristics of the included patients. Most ACL re-ruptures (77.8%) occurred before the age of 20 (18.2 +/- 2.9 years, min: 14, max: 24 years). Among the patients who returned to activities, there was no difference in the time of rehabilitation (intact ACL reconstruction: 7.4 +/- 1.0 months, min: 6 - max: 9 months, ACL revision surgery patients: 7.5 +/- 1.2 months; min: 6 -max: 9
months) (n.s.). Only two patients had ACL re-rupture during the rehabilitation period, before they returned to activities (2 and 4 months of surgery, both resulted from return to sports prior to medical orientation) Most ACL re-ruptures occurred after 12 months (83.2%), and 66.6% after 24 months (Figure 2).

Table 1: Patient Data

<table>
<thead>
<tr>
<th></th>
<th>Intact ACL reconstruction (n=34)</th>
<th>ACL re-rupture (n=18)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male 16 (47)</td>
<td>13 (72)</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Female 18 (53)</td>
<td>5 (28)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>13.6 +/- 2.5</td>
<td>14.4 +/- 1.9</td>
<td>n.s.</td>
</tr>
<tr>
<td>Follow-up (yr)</td>
<td>7.4 +/- 4.5</td>
<td>4.0 +/- 2.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>Tanner stage</td>
<td>Tanner II 9 (26)</td>
<td>3 (17)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tanner III 11 (32)</td>
<td>8 (44)</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Tanner IV 14 (42)</td>
<td>7 (39)</td>
<td></td>
</tr>
</tbody>
</table>

aValues are presented as n (%) or mean +/- SD, ACL, anterior cruciate ligament.

After returning to activities, patients with intact ACLR reported a mean Tegner score that was 69% higher than patients with ACL re-rupture (7.0 +/- 0.8 vs. 4.9 +/- 1.3 respectively; p = 0.006) (Table 2). Only 5.6% of the patients with ACL re-rupture regained pre-injury level of activity after 6 to 9 months of rehabilitation (7.0; graft fail after 4.8 years). Among patients who did not sustain ACL re-rupture, 46.2% of patients increased their activity level after the surgical procedure, 46.2% returned to their...
pre-injury level of activity, and only 15.3% were held to a lower level of activity than that before ACL injury.

After returning to activity, patients with intact ACLR reported a mean Lysholm score 64% higher than patients who sustained ACLR re-rupture (90.6 +/- 6.1 vs. 58.8 +/- 6.7 respectively; p <0.001) (Table 2).

Table 2: Tegner and Lysholm scores<sup>a</sup>

<table>
<thead>
<tr>
<th></th>
<th>Intact ACL Reconstruction (n=34)</th>
<th>ACL re-rupture (n=18)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tegner before injury</td>
<td>7.2 +/- 1.0</td>
<td>8.2 +/- 1.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Tegner at return to activity</td>
<td>7.0 +/- 0.8</td>
<td>4.9 +/- 1.3</td>
<td>0.006</td>
</tr>
<tr>
<td>Lysholm after injury</td>
<td>56.3 +/- 15.0</td>
<td>57.6 +/- 8.5</td>
<td>n.s.</td>
</tr>
<tr>
<td>Lysholm at return to activity</td>
<td>90.6 +/- 6.1</td>
<td>58.8 +/- 6.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<sup>a</sup>Values are presented as mean +/-SD, ACL, anterior cruciate ligament

Medial meniscus tear was the most common concomitant injury. There was no difference in the incidence of meniscal injury between patients with and without ACL re-rupture (52.9% vs 33.3%, respectively; n.s.). The most common sport practiced by patients was soccer (34.6%), followed by basketball and skiing (5.8% each)- pivoting sports. ACL injury unrelated to sport activity was common (23%). There was no statistical relationship between the kind of sport and the rate of ACL re-rupture (n.s.). Vertical femoral tunnel reconstruction (to decrease the area of injury to tibial physis) was the most common primary surgical technique compared to the anatomic ACLR in patients with or without ACL re-rupture. (79.4% vs 88.8%, respectively, n.s.) Further details of surgical technique are shown in Table 3. No growth disturbances or angular deformities were diagnosed during evaluation.

Table 3: Anterior Cruciate Ligament reconstruction techniques<sup>a</sup>

<table>
<thead>
<tr>
<th>Surgical Technique</th>
<th>Intact ACL Reconstruction (n=34)(%)</th>
<th>ACL re-rupture (n=18)(%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral fixation</td>
<td>Transfix</td>
<td>24 (71)</td>
<td>9 (50)</td>
</tr>
<tr>
<td></td>
<td>Button</td>
<td>8 (23)</td>
<td>6 (33.3)</td>
</tr>
<tr>
<td></td>
<td>Interference Screw</td>
<td>2 (6)</td>
<td>3 (16.7)</td>
</tr>
<tr>
<td>Tibial fixation</td>
<td>Interference Screw</td>
<td>31 (91.2)</td>
<td>18 (100)</td>
</tr>
<tr>
<td></td>
<td>Button</td>
<td>3 (8.8)</td>
<td>0</td>
</tr>
<tr>
<td>Graft size diameter</td>
<td></td>
<td>7.6 +/- 0.7</td>
<td>7.3 +/- 0.8</td>
</tr>
<tr>
<td>Femoral Tunnel size diameter</td>
<td></td>
<td>7.6 +/- 0.7</td>
<td>7.7 +/- 1.2</td>
</tr>
</tbody>
</table>
Discussion

The main finding of this study was that skeletally immature patients who underwent ACLR and sustained re-rupture had lower Lysholm and Tegner scores when returning to activities than patients who did not sustain ACL re-rupture. Low Tegner and Lysholm scores after rehabilitation in patients with re-rupture may be due to 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 to return to sports could be not enough for this population to get back safe. The graft is more mature after two or more years, but that 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

In an attempt to maximize sports performance, young athletes tend to participate in higher intensity training and physical activity, correlating with better Tegner and Lysholm scores.13 This fact requires appreciation of psycho-behavioral factors of this age group, since they are not able to anticipate consequences of ligament injury, increasing the risk for re-rupture of the ACL.7

Another important finding of this study was that ACL re-ruptures occurred predominantly in patients younger than 20 years (78%), in agreement with previous studies that observed that skeletally immature patients have a 2.5 – 3.5x increased risk of failure after ACLR when compared to skeletally mature patients1,2,7,9,17,25

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 re-rupture in the pediatric population.3,5 Kay et al18 reported predisposition to ACL injury with high-risk activities (soccer, basketball, football)10,20 experienced by these patients may be more predictive of re-rupture than the intrinsic reconstructed ligament strength, demonstrating that adherence to activity restriction during rehab is critical. Furthermore, in the present study, no significant difference was observed between patients who did or did not sustain ACL re-rupture regarding technique used, graft characteristics nor rehabilitation time.

In this study, ACL re-rupture 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.16 During the same time

| Tibial Tunnel size diameter | 7.7 +/- 0.9 | 7.8 +/- 1.2 | n.s. |

*a*Values are presented as an n (%) or mean +/- SD, ACL, anterior cruciate ligament

*T*-student test *Mann-Whitney test
period postoperatively, the graft is more integrated to the bone, but it may not yet be matured enough to withstand the stress demanded by a more developed musculoskeletal structure, and a higher level of sports competition.\textsuperscript{3,4} In another study with patients aged 16-18 years, Dekker et al.\textsuperscript{7} found similar results to the present study, with an average time of 26.5 months between the primary ACLR and ACL re-rupture.

Besides, the rates of return to sport after ACLR among patients who later sustained ACL re-rupture were similar among studies, varying from 91 to 96.2\% of the patients. The reported rate of return to sport in pediatric population is higher than reported rates in the adult population, which varies between 60 and 75\%.\textsuperscript{5,8,18,22} An ACL tear is frequently the first major injury in patients younger than 16 years of age. This may be one of the reasons for the difference in the rate of return to sport when compared to the adult population, since adults often choose to forgo further sport participation for fear of re-injury and prioritization of work activity.

In the present study, during postoperative follow-up, 34.6\% of the patients sustained ACL re-rupture, and 77.8\% of these injuries occurred during sports practice. Astur et al.\textsuperscript{1} found a 24.6\% rate of ACL re-rupture in patients younger than 16 years. When including patients between the ages of 16 and 18, the incidence decreased to 21.2\%. In the studies of Dekker et al.\textsuperscript{10} (under 19 years) and Ho et al.\textsuperscript{14} (under 18 years) the re-rupture rate was 32 and 34\%, respectively. In a meta-analysis with patients younger than 19 years, Kay et al.\textsuperscript{18} found an incidence of re-rupture of 13\%. Although rates vary according to study and age of evaluated patients, in all studies with pediatric population the incidence is higher than that found in adult patients (2 to 10\%).\textsuperscript{1,6}

The present study is unique in the literature because, to the author’s knowledge, it is the only study that analyzes patients with ACL re-rupture under 16 years of age and with open physis in radiographic images at the time of primary ACLR. In addition, this study presents a mid-term (mean 7.4 years) follow-up to evaluate the outcomes of patients undergoing ACLR.

The limitations of this study are the relatively small sample size (but it is common with this sort of groups) and whether patients with intact ACLR at the time of evaluation will sustain an ACL re-rupture in the long-term is unknown. Furthermore, the data in this paper are all descriptional. There is no comparison available, therefore differences in the two groups cannot be considered causational. Finally, the return to play at 6-9 months likely reflects a poorer ACL result than truly being causational for the failure group.

**Conclusion**

Skeletally immature patients who sustained ACL re-rupture at mid-term follow-up had lower Tegner and Lysholm scores at 6-9 months than patients who did not sustain ACL re-rupture. In addition, 77.8\%
of ACL re-ruptures occurred in patients under 20 years of age and 66.6% of ACL re-ruptures occurred after 24 months of primary ACLR.

Compliance with ethical standards

Conflict of interest
All authors declare no conflict of interest

Funding
There was no funding for this study

Ethical approval
This cohort study was performed and approved by the institutional research ethics committee, protocol

References


