Are There Uniform Rehabilitation Protocols for Pediatric Anterior Cruciate Ligament Tears?

A 5 year Systematic Review

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Introduction

• In the pediatric patient population, as overall sports participation, early sport specialization, high-intensity training, and improved injury recognition continue to rise, treatment of sports-related injuries have consequently risen as well.

• Studies have shown knee injuries account for approximately 50-60% of high school related surgeries, with anterior cruciate ligament (ACL) tears and ACL reconstruction (ACLR) becoming increasingly prevalent.

• While ACL rehabilitation is an essential component of recovery following injury and reconstruction, there are few published reports describing specific pediatric ACL rehabilitation protocols in the context of varying treatment interventions.

• **Aim:** to systematically review the literature over the last 5 years for rehabilitation following ACL ligament tears in children in order to identify common principles among different treatment options and areas of future research.
Methods

• Study design: Systematic Review of Pubmed, EMBASE, and Cochrane*

• Inclusion criteria:
  1. Pediatric patient population (<18 years-old)
  2. ACL tear rehabilitation protocol directly mentioned (in meta-analyses, randomized controlled studies, prospective cohort studies, retrospective case-control and cohort studies, case reports, and review articles)

• Exclusion criteria:
  1. Full article not available in English language
  2. Full article not available online
  3. Article was published >5 years from search date
  4. Article limited to patients with closed physes

*Search terms used: (ACL OR "Anterior_Cruciate_ligament") AND (pediatric OR child*OR preadolescent OR juvenile OR "skeletally_immature") AND (rehab*OR management)
Records identified through PubMed (n=124), Embase (n=139), Cochrane (n=2)

Records after duplicates removed (n=202)

Title Search (n=202)

Full-text articles assessed for eligibility (n=131)

Total references retained (n=25)

Added from manual search (n=2)
Total studies included in qualitative synthesis (n=27)

Excluded:
Records excluded: unrelated to ACL injury, reconstruction, technique, management, recovery, or rehabilitation (n=89)

Full-text articles excluded:
- Rehab protocol not mentioned (n=86)
- Outside of appropriate age range (n=11)
- Full article not available online (n=18)
- Not available in English (n=1)
- Injury other than ACL tear (n=3)
- Referenced already identified article (n=2)
- Guidelines based primarily in adult literature (n=1)
Results

27 Articles Met Inclusion Criteria*:
• 1 Level II article
• 2 Level III articles
• 12 Level IV articles
• 3 Level V articles
• 9 Review articles

Interventions Discussed:
• 3 articles solely addressed non-operative treatment
• 10 discussed transphyseal ACLR
• 4 addressed all-epiphyseal ACLR
• 1 discussed extra-physeal ACLR
• 1 addressed partial transphyseal approach
• 8 articles discussed multiple techniques

*Included articles found on Reference slide
## Rehabilitation Technique Compilation** (1)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>“Prehab”</th>
<th>Bracing</th>
<th>Weight Bearing Restrictions</th>
<th>ROM Restrictions</th>
<th>Modalities</th>
<th>Strength</th>
<th>Proprioception &amp; Plyometrics</th>
<th>RTS Criteria</th>
<th>Prevention Program</th>
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<tbody>
<tr>
<td>Nonoperative Management</td>
<td>N/A</td>
<td>8 weeks⁴</td>
<td>TTBW for 8 wks⁵; PWB guided by pain⁵</td>
<td>Wk 0-8: 0°-90⁶⁴; Gradual increase between wk 6-12⁶</td>
<td>None described</td>
<td>Closed-chain isometric muscle ex. within 2 mos⁷</td>
<td>Wk 6-12 proprioceptive ex.⁸; &gt; wk 6: cycling &amp; swimming⁹; &gt; wk 12: running⁴</td>
<td>Mo 3-6 if sufficient muscle rehab⁸; &gt;12 mo: return to pivoting sports with brace⁴</td>
<td>Functional ACL brace to be worn for all sports after full rehab, &lt; Mo 6: No contact sports⁸; Inform patient about secondary intraarticular risk and need for regular medical consultation⁴</td>
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<td>(Reference 6 provides milestone-based rehabilitation protocol)</td>
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<td>Transphyseal Reconstruction</td>
<td>None described</td>
<td>4 wks with 0-90° ROM¹⁰⁵; 6 wks⁴,¹⁰,¹²,¹³,¹⁴; 8 wks¹⁵; 12 wks¹⁶</td>
<td>NBA for 3 wks followed by PWB for 2 wks¹⁷; TTBW for 2 wks¹⁰,¹²; 4 wks³, or until full return of quadriceps function¹⁰; Immediate WBAT²,¹⁴,¹⁵,¹⁹</td>
<td>Immediate passive ROM¹³,¹⁵,¹⁶,¹⁵,¹⁹,²⁰ with CPM device¹²,¹³,¹⁵; Limit to 0-90° for 2 wks¹² or 4 wks⁴,¹⁷; Full knee ext by wk 2² Early patellar mobilization¹⁰,¹⁴</td>
<td>Electrical stimulation¹⁰,¹⁴ ⁴, ¹⁵</td>
<td>Closed-chain ex.²,⁴,¹⁰,¹⁴,¹⁵,¹⁹,²⁰ for quadriceps and hamstrings within 3 mos¹⁰,¹⁵</td>
<td>Proprioceptive training within 3 mos²,¹⁴ &gt;mo 3: plyometrics, straight line jogging¹⁰,¹⁴ &gt; wk 8: cycling &amp; swimming⁴ &gt; wk 16: running⁴</td>
<td>&gt;6 mo: Full RTS¹⁰,¹²,¹⁴,¹⁶,¹⁷; &lt;9-12mo: Avoidance of cutting/pivoting sports⁴,¹⁵; Passing functional tests (“sports test,” hop-tests)²,¹⁰ – results in RTS between 6-12 mos</td>
<td>Functional ACL brace for 1-2 yrs⁴,¹⁰,¹²,¹⁴; Formal ACL injury prevention program²⁰</td>
</tr>
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</table>

Abbreviations: “Prehab,” Prehabilitation (exercises conducted and goals prior to surgery); ROM, range of motion; RTS, return to sport; Wk, week; Mo, month; Yr, year; TTBW, toe-touch weight bearing; PWB, partial weight bearing; WBAT, weight bearing as tolerated; NWB, non-weight bearing; CPM, continuous passive motion; Ex., exercises; ITB, iliobial band reconstruction; HEP, home exercise program; SLR, straight leg raise; SL, single leg; Ext, extension; Flex, flexion; PACU, Post-Anesthesia Care Unit

**Of the 27 articles included in the systematic review, articles were only featured in the compilation table if they specifically mentioned at least 1 of the above 9 rehabilitation categories
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<td><strong>Physeal-Sparing Reconstruction</strong></td>
<td>All-epiphyseal</td>
<td>ITB: 6 wks&lt;sup&gt;10,12&lt;/sup&gt; All-epiphyseal: 4 wks: locked in full ext&lt;sup&gt;1,23&lt;/sup&gt; Wk 4-6: unlock brace if: 1. SLR x10 without ext lag 2. Active knee flex &gt; angle of brace&lt;sup&gt;41&lt;/sup&gt;, &gt;Wk 6: discontinue brace if: 1. ROM &gt;100° 2. SL squat of 30° with good knee control&lt;sup&gt;23&lt;/sup&gt; ITB: TTWB for 6 wks&lt;sup&gt;10,12&lt;/sup&gt; All-epiphyseal: TTWB for 1 wk WBAT for wks 2-4&lt;sup&gt;23&lt;/sup&gt;; PWB for 4 wks&lt;sup&gt;1&lt;/sup&gt; Early patellar mobilization&lt;sup&gt;10,22&lt;/sup&gt;,&lt;sup&gt;24&lt;/sup&gt; ITB: 0-90° for 6 wks&lt;sup&gt;12&lt;/sup&gt; All-epiphyseal: CPM use encouraged&lt;sup&gt;1,23&lt;/sup&gt; 90° flex by end of wk 2 120° flex by end of wk 4 – can use stationary bike&lt;sup&gt;23&lt;/sup&gt;; 90° flex by end wk 4 125° flex by end wk 8&lt;sup&gt;24&lt;/sup&gt; Cryotherapy in PACU&lt;sup&gt;2&lt;/sup&gt;; Electrical stimulation during wk 1&lt;sup&gt;22&lt;/sup&gt;; Underwater treadmill if patient apprehensive about weight bearing&lt;sup&gt;4&lt;/sup&gt; ITB: Closed-chain ex. for quadriceps and hamstrings within 3 mos&lt;sup&gt;10&lt;/sup&gt;; All-epiphyseal&lt;sup&gt;21,24&lt;/sup&gt;: Wk 1: quadriceps activation, SLR, begin HEP Wk 2-4: resisted leg press, step-ups, mini squats, squastimmune, hip abduction, core, independence with HEP Wk 4-16: SL stance with neuromuscular control, squat to 90°, SL squats, retro-treadmill, core, continued HEP Wk 12: may add open-chain ext Wk 16-20: maximize strength ITB: &gt;mo 3: Straight line jogging, plyometrics&lt;sup&gt;10&lt;/sup&gt; All-epiphyseal&lt;sup&gt;21,24&lt;/sup&gt;: Wk 2-16: balance, proprioception Wk 16-24: athletic ready position stance, straight ahead running, double-leg hopping if criteria met Dynamic control with jumping &amp; landing Wk 24-36: SL plyometrics, cutting/pivoting drills if criteria met ITB: &gt;6 mo: Full RTS&lt;sup&gt;10,12&lt;/sup&gt; All-epiphyseal: 1. 90% on functional testing 2. &gt;90% isokinetic testing at 180°/sec and 360°/sec 3. Full knee ROM 4. &gt;9 mos post-op&lt;sup&gt;25&lt;/sup&gt; 1. Dynamic control with sport-specific movement 2. Hop test &gt;85% of unaffected limb 3. Lack of apprehension with sport-specific movement&lt;sup&gt;24&lt;/sup&gt; Treatment: Functional ACL brace for 1-2 yrs&lt;sup&gt;10,12&lt;/sup&gt; All-epiphyseal: Wk 16-20: ACL injury prevention assessment Wk 28: evaluate for functional bracing compliance&lt;sup&gt;24&lt;/sup&gt;</td>
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<td><strong>Concomitant Meniscal Repair</strong></td>
<td>Transphyseal: TTWB for 2-6 wks depending on severity&lt;sup&gt;12&lt;/sup&gt;; All-epiphyseal: PWB for 4 wks&lt;sup&gt;12&lt;/sup&gt; Transphyseal: “Restricted ROM depending on severity”&lt;sup&gt;12&lt;/sup&gt; All-epiphyseal: Wk 0-4: 0-90° limit&lt;sup&gt;22&lt;/sup&gt; All-epiphyseal: &lt;Wk 6: Avoid squats below 60° and isolated hamstring strengthening&lt;sup&gt;22&lt;/sup&gt;</td>
<td>Transphyseal: TTWB for 2-6 wks depending on severity&lt;sup&gt;12&lt;/sup&gt;; All-epiphyseal: PWB for 4 wks&lt;sup&gt;12&lt;/sup&gt;</td>
<td><strong>Transphyseal:</strong> TTWB for 2-6 wks depending on severity&lt;sup&gt;12&lt;/sup&gt;; All-epiphyseal: PWB for 4 wks&lt;sup&gt;12&lt;/sup&gt;</td>
<td><strong>Transphyseal:</strong> “Restricted ROM depending on severity”&lt;sup&gt;12&lt;/sup&gt; All-epiphyseal: Wk 0-4: 0-90° limit&lt;sup&gt;22&lt;/sup&gt; All-epiphyseal: &lt;Wk 6: Avoid squats below 60° and isolated hamstring strengthening&lt;sup&gt;22&lt;/sup&gt;</td>
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Conclusion

• ACL tear rehabilitation following injury and treatment is a fundamental component in the effort of a patient to regain pre-surgical functional ability.

• Currently, few youth-specific rehabilitation protocols have been described, with the majority based on a combination of adult literature and clinical expertise.

• Many current protocols are based on timeframe alone rather than functional milestones.
  – As evident in the preceding table, of the 16 articles that addressed return-to-sport criteria, 10 were based on temporal progression, while 6 also involved achievement of physical milestones.

• Two of the 10 articles that mentioned a future ACL prevention plan described a formal prevention program.

• Further studies should be conducted to prospectively evaluate rehabilitation protocols and return-to-sport criteria for young athletes while keeping in mind both physical and psychosocial differences between children and adults.
References Included in Sysytematic Review


