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CASE REPORT

REHABILITATION CONSIDERATIONS FOR ALL EPIPHYSEAL ACL RECONSTRUCTION

Elliot M. Greenberg, PT, DPT, OCS, CSCS[1]
Jeffrey Albaugh, PT, MS, ATC[1]
Theodore J. Ganley, MD[1,2,3]
J. Todd R. Lawrence, MD, PhD[1,2,3]

ABSTRACT

Background: The management of the pediatric patient with an Anterior Cruciate Ligament (ACL) rupture is evolving towards earlier reconstruction. The rehabilitation progression and outcomes for skeletally immature individuals undergoing ACL reconstruction (ACL-R) are not well described in the literature. Differences in surgical procedure, age related physiology, and emotional maturity may have a significant impact on recovery and return to sports. The purpose of this case report is to present the rehabilitation and outcome of a skeletally immature patient that underwent an all-epiphyseal ACL-R, highlight important considerations in the rehabilitation process and present topics for future research.

Case Description: Single subject case report of an 8 year-old boy who underwent all epiphyseal ACL-R after complete ACL rupture.

Outcomes: The patient was able to achieve at least 90% strength symmetry and pass all necessary functional criteria to return to sports by 9 months post surgery. Two year follow up data indicated that the patient was able to make a full return to previous level of athletic activity, as well as maintain lower extremity strength and power over time.

Discussion: Objective outcome measures, rehabilitation protocols and time frame for return to sports for skeletally immature patients following physeal sparing or all epiphyseal ACL-R are not well described in the literature. This case report outlines objective measures of strength and functional recovery in a patient from this unique population. As ACL-R in the skeletally immature patient is studied more, new information on rehabilitation progression and outcomes may alter the rehabilitation program and timeline for return to unrestricted activity.

Key words: Anterior cruciate ligament, pediatric, rehabilitation, return to sports

Level of Evidence: 4, Case Report

[1] Sports Medicine and Performance Center at The Children's Hospital of Philadelphia, Philadelphia, PA, USA
[2] Division of Orthopaedic Surgery, The Children's Hospital of Philadelphia, Philadelphia, PA, USA
[3] Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA, USA

Conflict of interest statement:
The authors have no financial or commercial affiliations related to the performance or outcome of this manuscript.

CORRESPONDING AUTHOR

J. Todd R. Lawrence, MD, PhD
The Children's Hospital of Philadelphia
Assistant Professor of Orthopaedic Surgery, University of Pennsylvania School of Medicine
Attending Physician Division of Orthopaedics
The Children's Hospital of Philadelphia
Wood Building, 2nd floor
34th Street and Civic Center Blvd.
Philadelphia, PA 19104-4399
Phone: 215-590-1527
Fax: 215-590-1501
Email: lawrencej@email.chop.edu

BACKGROUND

Intrasubstance Anterior Cruciate Ligament (ACL) tears are being reported with increasing frequency in the pediatric skeletally immature population.[1-2] Although there is no consensus regarding non-operative versus operative treatment, delaying treatment until closer to skeletal maturity has been associated with chronic instability leading to chondral and meniscal injuries.[3-8] Traditional adult ACL reconstruction (ACL-R) techniques are not advisable in this population due to the possible risk of growth disturbance via disruption of the physis, commonly referred to as the growth plate.[9] The physes of the distal femur and proximal tibia display extremely rapid growth during the adolescent growth spurt; with the distal femur contributing 40% and proximal tibia contributing 27% of the overall growth of the lower extremity.[10-11] The femoral attachment of the ACL is only a few millimeters from the distal femoral physis and traditional tunnels used for ACL reconstruction in adults cross the physis obliquely and eccentrically.[12-13] The tibial physis, while more distant from the tibial attachment, is also often crossed with the tunnels used in most standard adult ACL-R techniques. Tensioned grafts, rigid graft fixation, bone blocks that cross the physis and large drill holes in the physis have all been shown to increase the risk of causing a disturbance in the growth of the physis. This could lead to angular limb deformity or length disparity.[1-2]

Multiple techniques for surgical stabilization of the skeletally immature ACL deficient knee have been described.[1-2] Recently an all epiphyseal ACL-R technique was described, that completely avoids the growth plates while still placing the ACL graft in the anatomical footprint of both the tibial and femoral attachments.[9] This approach theoretically minimizes the risk of any growth abnormality due to surgery.

It is well recognized that the rate of ACL injury in the skeletally immature population is rising and with advancing surgical techniques there is a resulting increased need for post-operative physical therapy in this population.[2-3] Physical rehabilitation from ACL-R in the adult population is well studied. Numerous authors have reported on successful outcomes and have identified objective performance data for rehabilitation progression and return to sports participation timeframe.[14-16] However, research studying the outcomes of the skeletally immature patient after ACL-R is sparse and it remains unclear if these same recommendations and outcomes for the skeletally mature population apply in the pediatric population.[3]

Due to several key differences in the operative technique and age related tissue healing characteristics, modifications to the accepted evidence based rehabilitation scheme for adults are often utilized.[17] Furthermore, cognitive, emotional and behavioral factors specific to the pediatric patient must be considered and can have a significant impact on the decision making process to elect surgical management and the rehabilitation program afterward.

The purpose of this case report is to present the rehabilitation and outcomes for an 8 year-old boy that underwent an all epiphyseal ACL-R. His experience will be used to highlight important considerations in the rehabilitation of these patients, to provide practical tips in approach, and introduce concepts for discussion and possible future research.

CASE DESCRIPTION

Participant and History

The patient was an 8 year-old boy (height 144 cm; weight 42 kg; Body Mass Index 21 kg/m^2) who injured his right knee while attempting to land from a jump in the terrain park while skiing. Upon landing, the patient remembers his right leg twisting, feeling a "pop" and immediate pain in his knee. Physical examination and subsequent magnetic resonance imaging (MRI) confirmed the diagnosis of a complete tear of the ACL. Since he was having a recurrent sense of instability following the injury and wished to continue with an active lifestyle, after considerable thought and discussion regarding the risks and benefits of operative versus non-operative management, the patient and his family elected he undergo surgical reconstruction.

Pre-operative physical therapy

The patient was referred to physical therapy prior to surgery for gait training, post-operative education, and assessment of motivation, maturity level and ability to comply with post-operative restrictions. The patient underwent gait training utilizing bilateral axillary crutches and was educated on toe touch weight bearing (TTWB) precautions, to be used immediately

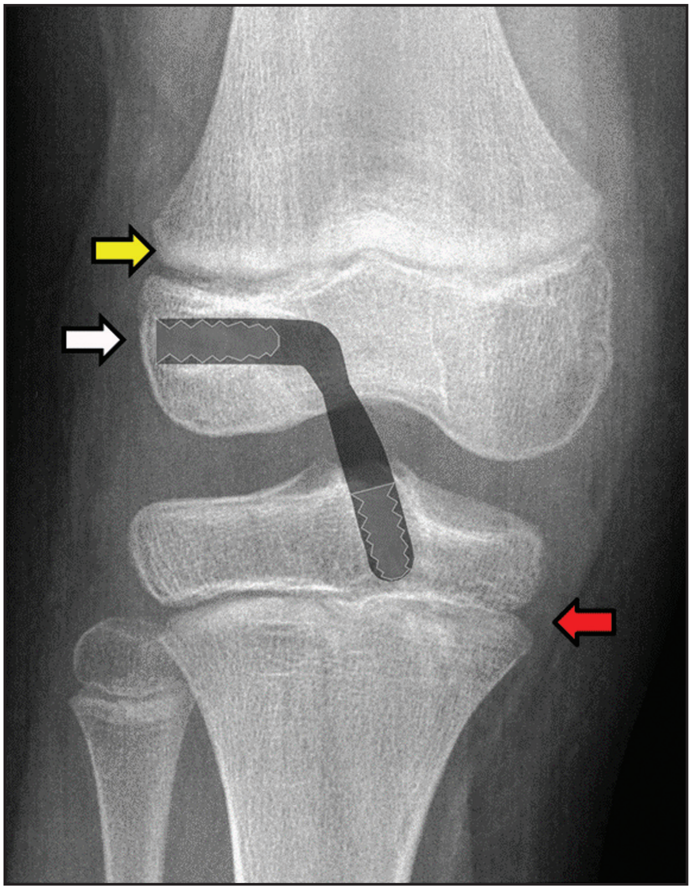

Figure 1. *Schematic representation of All Epiphyseal ACL Reconstruction. Post-operative x-ray image with schematic representation of the graft and interference screw fixation. The tunnels are drilled to the center of the femoral and tibial ACL footprints (white arrow). The tunnels, the graft material and graft fixation are contained entirely within the epiphysis. No large drill holes are made in the tibial (red arrow) or femoral (yellow arrow) physes, no fixation crosses the physis and the graft is not tensioned across the physis.*

after surgery. The parents and patient were also educated in proper techniques for post-operative pain management, swelling reduction techniques and an initial exercise program. During this session, he displayed a good cognitive and physical understanding of his injury and the importance of the post-operative rehabilitation involved. He took directions well, had no problems with activity restrictions and easily learned the exercises. The authors have found that these are important characteristics that help to determine if the patient is an appropriate rehabilitation candidate in order to ensure good surgical outcomes.

The patient required one pre-operative treatment session as he had already met all the following pre-operative goals: no effusion, at least 4/5 quadriceps strength with manual muscle testing, full knee extension range of motion, at least 120° of active knee flexion range of motion, independence with gait maintaining weight bearing precautions, and independence with immediate post-operative exercise instructions.

Surgical Procedure

Approximately two months after initial injury, a fellowship trained pediatric and sports medicine orthopedic surgeon performed an all-epiphyseal ACL-R with a quadrupled autologous hamstring graft, using a newly described technique.[9] This technique adheres to the generally accepted principles of ACL-R by placing the graft in the center of the native footprint of the ACL, but theoretically minimizes the risk to the growing physes by avoiding any fixation, large drill holes, or tensioning of the graft across the physes (Figure 1). During the procedure, an intra-operative computed tomography scan with 3-dimensional reconstruction is utilized to ensure safe and accurate placement of tunnels in the distal femoral and proximal tibial epiphyses avoiding the physes and the articular surfaces.

Postoperative Intervention

After surgery the patient was placed in a hinged post-operative knee brace locked in slight hyperextension. He was instructed to remain in the brace at all times, with the exception of while bathing or in physical therapy. Specific care was taken to make sure the patient understood he needed to wear the brace while sleeping. He used a continuous passive motion (CPM) machine for up to 6 hours per day. The range of motion was initially set from 0°-30° and he was instructed to progress his movement by 5°-10° of flexion per day as his pain permitted. The patient was restricted to TTWB utilizing bilateral axillary crutches as he had been instructed prior to surgery. An inpatient physical therapist reviewed gait training and ensured the patient was adherent to weight bearing restrictions and safe with ambulation prior to discharge.

Formal outpatient physical therapy was initiated on post-operative day 11 and treatment was progressed based upon our all epiphyseal ACL-R post-operative protocol (Appendix 1). Our current protocol is based upon the integration of known ACL healing characteristics in the adult population and surgeon expertise. The protocol utilizes both time and criteria based

Table 1. *Sequence of brace management and gait progression.*

Post-op Week	Brace Status	Weight Bearing
Week 0-3	Locked at 0°	Toe-Touch
Week 4	Open 0°-50°	Partial Weight Bearing (PWB)
Week 5	No Brace (at home) Open 0°-90°	FWB FWB
Week 6	No Brace	FWB

benchmarks for progression through the phases of rehabilitation.

The patient's pain was assessed utilizing a visual analog scale where a score of 0 represents "no pain" and a score of 10 representing "worst pain imaginable". The patient rated his pain 0/10 at the initial visit, with the worst pain being 6/10 since surgery. A moderate joint effusion was present with a difference of 0.8 cm side to side in circumference measurement. Active knee extension-flexion range of motion (ROM) was 0°-65° and passive range of motion was 0°-85°. Trace quadriceps activation was present on the involved leg and he was unable to perform a straight leg raise (SLR) without an extensor lag. The patient was started on a basic program consisting of active and passive ROM exercises, quadriceps sets and straight leg raises with the brace locked in extension. The patient was fitted with a knee compression sleeve and educated in effusion management. The patient was given specific instructions to elevate his leg for 15 minutes every hour while in school. A note was issued to his teacher detailing this program.

By the end of post-operative week 3, the patient had achieved 0-90° of passive knee ROM. He went on to recover full passive ROM of 0-150° by week 7. Quadriceps function returned quickly and the patient was able to perform a SLR with no lag during the 2nd post-operative visit. As quadriceps strength improved, the patient was able to ambulate without knee buckling or hyperextension in stance phase. At this point, the patient had achieved sufficient muscular control of the knee to unlock his post-operative brace and begin weaning off crutches. Table 1 details the timeline for gait and brace weaning progression used for this patient. By post-operative week 5, the patient had met the proposed functional criteria of knee ROM greater than 0-100° and ability to perform a single limb squat to at least 30° of knee flexion, which would allow him to discontinue use of his hinged knee brace. However, according to the protocol, the patient is not permitted to discontinue brace usage until 6 weeks post-operative. Adherence to the use of bracing was causing the patient to become frustrated and his parents reported this was leading to some behavioral difficulties. As a compromise, the patient was allowed to ambulate without the brace at home, but was still advised to continue to wear the hinged brace when in public and at school.

Open kinetic chain knee extension and flexion exercises were held until after post-operative week 10. After that, the remainder of the progression followed the protocol of accelerated rehabilitation based on established guidelines for strengthening and dynamic stabilization training derived from guidelines following adult ACL-R.

According to the protocol, the following criteria were used for advancement to running and dynamic activity: 1) The patient should be tolerating all rehab progression with no adverse reactions 2) satisfactory

Table 2. *Functional Hop Test Results at 6 months post-surgical follow up.*

Functional Hop Test	Involved leg	Uninvolved Leg	Involved / Uninvolved	Percentage Deficit
Single Leg Jump	109 cm	101 cm	1.07	+7%
Single Leg Triple Jump	300 cm	295 cm	1.02	+2%
Single Leg Vertical Jump	16.5 cm	18.3 cm	.90	-10%
Single Leg Timed side to side Jump*	15 ground contacts	17 ground contacts	.88	-12%

*The patient is instructed to jump side to side as fast as they can over two lines 12" apart for a period of 20 seconds. The number of successful ground contacts the patient has on each leg within 20 seconds is counted.

physician clinical and radiograph exam 3) less than 25% peak torque quad deficit with isokinetic testing at 180° and 300° per second and 4) less than 3 mm translation with KT-1000 (MEDmetric® Corporation, San Diego, CA) knee arthrometer testing. Formal evaluation for advancement was performed at 14 weeks post-operatively. Due to the patient's physical size, the KT-1000 unit would not fit appropriately and therefore did not yield a reliable measurement. Thus, this criterion for advancement could not contribute to clinical decision making. Utilizing the unaffected limb as a control, isokinetic testing revealed a peak torque quadriceps deficit of 6.3% and 10.9% at 180 and 300 degrees per second respectively. The patient had been tolerating all rehabilitation exercises without complication and satisfied all physical therapy clinical testing criteria for advancement. Physician follow-up examination for progression was not scheduled until post-operative week 16. Formal physical therapy was temporarily discontinued and the patient continued performing his established home exercise program supervised by his parents. After a satisfactory physician examination, he was cleared for advancement by the physician.

The patient was progressed through running and agility exercises beginning in straight planes with double leg activities and progressing to multidirectional drills. Plyometric training began at 19 weeks post-operatively with low-level bilateral training. The therapist focused instruction of technique emphasizing limiting ground impact forces and limiting any dynamic knee valgus at takeoff or landing. As the patient demonstrated proper mechanics, the demand of plyometric training was increased from bilateral to unilateral tasks and finally to multiplanar jumps. At this point in time, the patient was fitted with a DonJoy™ Full Force functional ACL brace (DJO Global, LLC, Vista, CA). The recommendation by the surgeon is that the brace be worn with all sports activity for at least 2 years following surgery.

Progression to sports specific rehabilitation activities is typically allowed between weeks 24-36 and is dependent upon the patient satisfying the following criteria: 1) pain free with all activity thus far 2) quadriceps peak torque deficit less than 10% 3) functional hop test scores of less than 10% deficit 4) satisfactory lower extremity control and alignment during jumping task. The patient was tested at 6 months post surgery. Isokinetic testing results demonstrated a 9.3% peak torque quadriceps deficit at 180° and a 3.1% strength advantage on his operated leg at 300° per second. Functional hop testing consisted of a single leg hop, single leg triple hop, single leg vertical jump and single leg side-to-side jump. As outlined in Table 2, the patient was able to achieve at least 90% symmetry with all functional hop tests, with the exception of timed side to side hop, which was 88% symmetrical. He demonstrated excellent landing form with no valgus movement of the knee upon landing or take off, ability to cushion impact descending into approximately 20-30° hip and knee flexion upon landing and stable balance with landing.

Table 3. *Functional Hop Test Results at 2 year post-surgical follow up.*				
Functional Hop Test	Involved leg (cm)	Uninvolved Leg (cm)	Involved / Uninvolved	Percentage Deficit
Single Leg Jump	117 cm	117 cm	1.00	0%
Single Leg Triple Jump	363 cm	401 cm	0.91	-9%
Single Leg Vertical Jump	17 cm	17.5 cm	0.97	-3%
Single Leg Timed side to side Jump*	22 ground contacts	21 ground contacts	1.05	+5%

*The patient is instructed to jump side to side as fast as they can over two lines 12" apart for a period of 20 seconds. The number of successful ground contacts the patient has on each leg within 20 seconds is counted.

Outcomes

The patient had achieved all clinical criteria necessary to return to sports within 6 months of ACL-R, however as outlined in the protocol unrestricted return to competitive sports was held until the patient is 9 months post-op. The patient had already been performing a home program that consisted of running, agility and plyometric training. He was discharged from physical therapy and advised to continue this program until his 9-month follow up with his surgeon. In the interim, he was allowed to participate in modified gym class and recess activity that did not involve any contact, as long he wore his functional ACL brace. He was advised to refrain from high-risk activities such as jumping on trampolines, skateboarding, and wrestling with his brothers.

The patient returned for long term follow-up at approximately 2 years post surgery. He had returned to all recreational activities including competitive baseball and skiing. He reported no feelings of knee instability with any activity. Upon isokinetic testing patient demonstrated a strength advantage of 19.3% and 12.5% for peak torque extension force at 180 and 300 degrees per second respectively. Functional hop testing revealed the patient was able to maintain criteria of at least 90% symmetry between limbs over time. Please see Table 3 for more specific details of hop testing data.

DISCUSSION

Numerous authors have reported on successful rehabilitation after adult ACL-R and functional testing programs have been developed to help guide rehabilitation and determine readiness for return to sports participation.[16] However, few authors have reported on similar outcomes in the pediatric population.[3] Most outcome studies focus primarily on determination of any adverse effects on skeletal growth and define functional success based mostly on self report scales.[4,18] Bonnard et al reported on 57 cases of physeal sparing ACL-R with mean age at surgery of 12.2 years and a minimum of 2 year follow-up. They found that mean time for return to sport was 11 months (range 6-18 months) and that 90% had excellent or good results based on subjective assessment using the International Knee Disability Classification (IKDC) score. The IKDC is a knee specific patient reported outcome measurement tool that has demonstrated adequate psychometric properties for use in the adult population, however it has not been validated for use in children or adolescents.[19] Thus, the use of this scale as the primary outcome measure for this population may not yield the most reliable outcome data. Furthermore Bonnard et al do not report on specific objective outcome measures in order to demonstrate functional return of strength, power and physical ability. The case presented here demonstrates successful achievement of all return to sports criteria within 6 months of surgery and presents specific objective data about strength and functional performance throughout the recovery timeline in an 8 year old patient. This patient was able to return to sports participation at 9 months post surgery.

Although this case demonstrates a successful outcome, there are many questions regarding rehabilitation in this population that remain unanswered.

Due to the unique nature of this procedure, tissue healing characteristics are not well studied in the pediatric patient after ACL-R. Physiological healing differences may account for variations seen in rehabilitation and return to activity timelines between physeal sparing and adult ACL reconstruction.[16] Early weight bearing is typically advocated following adult ACL reconstruction, however many surgeons advise a period of limited weight bearing for physeal sparing procedures.[10] The recommendation for limited weight bearing in our protocol is largely based on surgeon expertise, mostly respecting the behavioral challenges that accompany this population but also acknowledging possible stress concentration across the physis, due to the location of the femoral tunnel. The pediatric patient may not possess the patience and self-control necessary to ambulate WBAT with proper gait mechanics. In such a child, excessive early weight bearing and poor gait mechanics could risk the health of the graft tissue, cause increased joint effusion and pain, and lead to lasting gait abnormalities or arthrofibrosis. Femoral tunnel placement within a few millimeters of the growth plate, while not directly disturbing the physis, may nonetheless cause stress concentration in other areas of the physis. For these reasons, it may be more beneficial to restrict weight bearing in this population in order to avoid these possible complications. The therapist familiar with this population will be able to use experience and clinical milestones such as quadriceps strength, knee stability in closed chain tasks and effusion level, to properly progress the patient's weight bearing and gait status. These recommendations may change as physeal stress reactions and mechanisms of healing are studied further.

The physiology of strength development in the prepubescent child must also be considered during the rehab process. Prepubescent children lack circulating androgens and strength gains seen in this population are not always associated with muscle hypertrophy, as in the adult population.[20] Neural adaptations, such as increased motor unit activation and improved motor unit coordination, are primarily responsible for strength gains in children.[21-22] Quadriceps atrophy is common after ACL reconstruction and return of muscle function and strength is an essential component of rehabilitation. Although the mechanism for strength increase in children may be different, this case demonstrates full return of quadriceps strength was achieved within 6 months of surgery. This is consistent with findings of prior studies within a teenage population,[23] however future research is needed to determine if the rate and magnitude of strength return is the same for the pediatric population.

Several emotional and behavioral factors make the rehabilitation of pediatric or adolescent patients following physeal sparing ACL reconstruction challenging to physical therapists responsible for their successful outcomes.[3,9] Although pediatric specialists are well aware of these factors and well versed in coping with them, the authors have found that many children who receive physeal sparing ACL-R are being rehabilitated in classically adult physical therapy settings. Therefore the therapist treating this population, unfamiliar with these factors, may need additional guidance and assistance.

The level of emotional maturity in pediatric patients undergoing physeal sparing ACL-R must be considered as a factor during the decision making process of choosing surgical versus nonsurgical management. The parents, surgeon, and therapist must work together with the patient, to decide if the patient is mature enough to comply safely with the post-operative restrictions and motivated enough to work toward a successful outcome. Currently, this is a highly subjective process and the authors are not aware of any objective measures available to guide this decision making process. The authors currently utilize a team approach that encompasses parental opinion and observational opinion from different practitioners during physician office visits and pre-operative therapy education training. This way the team can judge in different environments and at different snapshots in time, whether the child possesses the proper level of maturity to achieve successful rehabilitation.

Maturity level also impacts rehabilitation for this population during the decision making process to discontinue use of the post-operative brace. In adult ACL-R rehabilitation the decision to discontinue the use of a brace is based solely upon physiological characteristics such as graft integrity, quadriceps function, range of motion, and gait characteristics. In the rehabilitation of the child with ACL-R, the therapist must also consider other extrinsic factors as well. In this case, the patient was allowed to discontinue use of the post-operative brace earlier at home, but he was required to continue with use at school and while in public. This was done for safety considerations. It was felt that keeping the brace on in school would decrease the chances of injury from patient participation in horseplay or careless behavior on the part of his classmates. His classmates may not have remembered that the patient just had surgery without the reminder of him wearing the brace. In this way, the maturity level of not only the patient, but his peers as well, has an impact on the overall rehabilitation scheme.

ACL-R rehabilitation requires a level of dedication and commitment that can prove challenging for even the most dedicated and mature athletes. Pediatric patients participating in rehabilitation after physeal sparing ACL-R will require the therapist to be dynamic and flexible in their approach to treatment. It is important to keep the patient actively engaged in all activities while ensuring that the activity remains fresh and fun. Maintaining motivation over time can be important in enabling them to maximize their physical potential.[3]

Parental post-operative education is one aspect of complete care that cannot be neglected. Parents must be educated in realistic expectations of the rehabilitation process in order to prevent unnecessary patient directed stress during recovery. At the author's facility, we have occasionally seen issues arise when parents base their expectation of rehabilitation on what they see in the media about professional athletes and recovery from ACL-R. Parents can sometimes place undue pressure on the child to recover or perform. This could lead to poor outcomes or actually delayed recovery. Being aware of this possibility and addressing parent questions early is a key factor to avoiding this scenario.

While the physical therapist and parent must be knowledgeable about activity restrictions after ACL-R, it is also very important to understand what type of activities are permissible. It is important for children to have an outlet for energy, creativity, and play. Post-operative restrictions can impact many aspects of the child's life and restoring some type of activity balance is essential for emotional and psychological wellbeing. Birthday parties, school recess, family vacations and amusement parks are some situations commonly faced by the pediatric sports medicine specialist. Parents and patients rely on the expertise of the physical therapist for recommendations that will allow the child the satisfaction of participation, but at the same time limiting risk of injury or rehabilitation complications.

CONCLUSION

The management of skeletally immature children with knee instability due to ACL rupture is evolving towards earlier ACL reconstruction.[4] There are adverse effects associated with delaying surgical reconstruction until the patient is skeletally mature and advances in surgical techniques allow for anatomical ACL-R in the skeletally immature athlete while minimizing the risk of premature physeal closure.[4-7,17,24] The rehabilitation progression in this population has some differences from traditional ACL rehabilitation programs for adults due to behavioral and physiological characteristics. Due to the lack of rehabilitation based outcome studies in the literature, the current timeline of rehabilitation progression is largely based upon integration of known ACL healing characteristics in the adult population and surgeon expertise. Future research is needed to identify the time line and magnitude of strength return, if functional performance measures used in adult ACL-R are appropriate in the skeletally immature and if so, what is the normal performance in this population. Additionally, long term objective outcome studies are necessary to determine percentage of patients that achieve successful outcomes over time.

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APPENDIX 1

Physeal Sparing Anterior Cruciate Ligament Reconstruction Protocol

The following protocol utilizes a blend of both criteria <u>and</u> timeframes as the determinants of advancement. It is recognized that many athletes will feel good relatively early in their rehabilitation and want to advance to higher level activities as a result. In spite of rapid functional progress, it is important to respect the biological component of recovery and limit advancement if the timeframe for a given healing stage has not been completed. Overall, this protocol targets return to full unrestricted activity <u>at 9 months</u> if all other criteria are also met. If the criteria are met sooner, the patient must restrict his/her activity level until the end of the 9th post-op month.

<u>Week 1:</u> (Visit #1 scheduled to begin one week post –op)

Goals:

1) Ambulation/Brace Use: **<u>Toe-Touch Weight Bearing</u>**
   Post-op brace locked in full extension for ambulation
   Sleep with brace locked in full extension
2) Maintain Full Knee Extension
3) Minimize Pain and Effusion – Compression wrap, elevation, ice
4) Good quad activation
5) Patient Education:
   - ❑ What to expect, how to maintain extension
   - ❑ CPM review (if applicable)
   - ❑ Crutches, wt bearing status
   - ❑ Hinged post-op brace education

Exercises:

- CPM Machine – start at 0 – 30 degrees. Increase <u>about</u> 10 degrees per day.
- PROM
  a. Wall Slides Seated Active Assistive Knee Flexion
  b. Prone Dangle
  c. Passive resting extension with heel prop
- Patellar Mobilizations
- Quad muscle Activation (Functional E-Stim w/ Quad setting and/or Biofeedback)
- SLR x3 (Flexion, Adduction, Abduction)
- Hamstring/Calf Stretches
- Ankle Pumps
- Gait Training
- Home Exercise Program (2-3 times per day)

<u>Week 2 to 4:</u>

Goals:

1) Ambulation/Brace Use: -Continue crutch use, **<u>PWB brace locked in full extension</u>**

****In Physical Therapy <u>only</u>, WBAT without brace for ROM, strength, & gait training****
****Continue to sleep with brace locked in full extension until end of week 4****

2) Maintain Full Knee Extension
3) Minimize Effusion and pain

4) Promote Knee Flexion:
    - 90° by end of week 2
    - 120° by end of week 4
5) Good patellar mobility
6) Fair proprioception, involved leg
7) Independent with home exercises

Exercises:

- As previous
- Scar Mobilization/Massage
- Proprioceptive Neuromuscular Facilitation, Progressive Resistive Exercises
- Manual/Machine resisted leg press
- Balance/Proprioception
- Isometric Knee extension 90-60º
- Stationary Bike for ROM
- Mini-Squats progress up to 90º
- Step ups
- Retro Treadmill/Stairmaster
- Core
- Hip abduction/external rotation
- Review HEP

<u>Weeks 4 to 16:</u>

Goals:

1) Discontinue crutch use **at 4 weeks**
2) Ambulation/Brace Use:

    -**After 4 weeks,** unlock post-op brace for ambulation (90º – progress to open) if following criteria are met:

    a. SLR without quadriceps lag (10 repetitions)
    b. Active knee flexion range to greater than angle of brace

    -**After 6 weeks**, wean and discontinue post-op brace if criteria met

    a. ROM $\geq$100º
    b. Single Leg Squat 30º with good knee control

4) Normalize Gait Pattern
5) Full ROM
6) Enhance Strength
7) Enhance Proprioception/Balance
8) Improve Local Muscular Endurance
9) Initiate Cardiovascular training

Exercises:

As above

Functional Strengthening

- Proprioceptive Neuromuscular Facilitation, Progressive Resistive Exercises
- Manual/Machine resisted leg press
- Balance/Proprioception
- Squats to 90 degrees
- Single leg squats

    - Step ups
    - Retro Treadmill/Stairmaster
- Review Home Exercise Program (2 times per day)

12 weeks:

- May add open chain knee extension through full range

Weeks 16 to 24:

Goals:

1) Criteria to begin straight ahead running, double-leg hopping:
   Isokinetic Test - Quad Peak Torque Deficit ≤ 25% at 180º/sec and 300º/sec .
2) KT 1000 test: 15#, 20#, Quad Active, Manual Maximum (if available)

Exercises:

- Continue strength, endurance, proprioception progression
- Begin double-leg hopping, jogging, agility drills as able and if passed Isokinetic Test
- Initiate sport specific activities and double-leg plyometrics as able and if passed Isokinetic Test

Weeks 24 to 36:

Goals:

1) Gradual Return to unrestricted sports if Criteria met
   a. Pain-free running
   b. Functional Tests (>90%) and Pain free
   c. Isokinetic test
      Quadriceps Peak Torque Deficit ≤10%
      Total Work ≤ 10%
   d. KT 1000 test: 15#, 20#, Quad Active, Manual Maximum (if available)
   e. Cardiovascular endurance to subjective pre-morbid level

Exercises:

- Single-leg plyometrics
- Cutting/pivoting drills with stutter step pattern
- High intensity aerobic/anaerobic sport specific training
- Advanced lower extremity strengthening

RETURN TO SPORTS CRITERIA

1) 90% Functional tests
2) ≥ 90 % Isokinetic Test at 180º/sec, and 300º/sec
3) Full knee ROM
4) 9 months post-op

Recommended Functional Hop Test:

- Triple Hop for distance
- Single Hop for distance
- Lateral Hop (12"x12" squares separated by 12"- # of hops IN BOX in 20 seconds)
- Unilateral Vertical Jump