Pediatric ACL Injury: Guiding a family from Pre-Surgery to Full Recovery

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Course Learning Objectives:
1. Identify risks associated with operative and non-operative management of ACL tears in the skeletally immature patient.
2. Describe the various factors of a typical adult ACL reconstruction procedure that relate to poor outcomes within this specialized population.
3. Understand various surgical options and rehabilitation implications of the various procedures performed within this population.
4. Accurately assess functional ability within this population using valid, evidence based performance outcome measures.
5. Provide an inclusive return to sport/activity program for home based, late phase rehabilitation.
6. Recognize the importance of continuous injury prevention screening and training in this population.
7. Understand the complex implications for working with the younger athlete as it relates to cognitive and psychosocial maturity and how it will impact surgical and rehabilitation plans and associated outcomes.
8. Describe and differentiate the normal developmental sequence for athletic skill acquisition, between young males and females and apply this knowledge to rehabilitation and injury prevention strategies.
9. Identify areas of future research necessary for safely returning this population back to full activity.
Treatment Considerations Specific to Pediatric Anterior Cruciate Ligament Injury - EG

1. Frequency of ACL injuries in pediatric athlete
   a. Two mechanisms of ACL injury in peds
      i. Tibial Spine avulsion fracture
      ii. Intrasubstance ACL tear
   b. Intra-substance tear rate rising
      i. Lawrence et al AJSM 2011
         1. Retrospective review of cases 1999-2011
         2. Found substantial increase in mid-substance ACL tears
            (11.35 per year) while tibial spine avulsion remained flat
            (1.07 per year)
      ii. Beck & Lawrence American Academy of Pediatrics Annual
          Meeting Oct-Nov 2015
         1. Retrospective review of billing data from large
            metropolitan insurance company for 20 years (Jan 1994-Dec 2013)
            a. Ages 6-18 years-old
         2. Overall incidence of ACL tears increased 2.3% per year
            a. Males increased 2.2% per year
               i. Peak incidence age 17
            b. Females increased 2.5% per year
               i. Peak incidence age 16
            c. Why?
               i. Increased participation = increased exposure
                  to injury
                  1. Taxi Cab effect
               ii. Sports Specialization
                  1. Not well rounded athletes
                  iii. Increased awareness

2. Female versus Male in pediatric injuries
   a. Are females more at risk?
      i. Stracciolini et al Sports Health 2014

3. Treatment of Pediatric ACL injuries
   a. Surgery versus non-surgery
      i. Non-operative management
         1. Are there pediatric copers?
               i. Retrospective review ACL injury <12 years-old

2
1. Functional testing battery to try and identify copers
   ii. 50% of those identified as copers able to return to prior level of play

1. Suggests functional testing battery may be possible

b. Moksnes *JOSPT* 2012
   i. Clinical commentary detailing non-operative treatment approach

2. Conclusions of non-operative protocol perspective – Delayed reconstruction until skeletally mature
   a. Especially for those interested in Level I sports
   b. View out of concern for iatrogenic injury of leg length or angular limb deformity with surgical reconstruction
      i. Position of growth plates relative to reconstruction procedure tunnels
      ii. Frosch et al *Arthroscopy* 2010
         1. Meta-analysis – risk of growth disturbance 1.8% (CI95 0%, 3.9%)
      iii. Vavken and Murray – Systematic Review *Arthroscopy* 2011
         1. .01% prevalence
      iv. Conclusion – Growth abnormality risk is low

3. Risks with delayed reconstruction
   a. Is there harm in delaying reconstruction
      i. Lawrence et al *AJSM* 2011
      ii. Anderson & Anderson *AJSM* 2015
      iii. Newman et al *AJSM* 2015
         1. Symptomatic mm tears more prevalent in non-op or delayed reconstruction groups
   v. Conclusions – current consensus is favoring earlier surgical reconstruction using specialized procedures

b. Unique surgical approaches developed for pediatric ACL reconstruction
   i. Absolute restrictions –
1. No hardware across physis
2. No bone plugs across physis

ii. Caution
1. Avoid large tunnels
2. Tension graft across growth plates with caution
   a. Fabricant et al *JBJS* 2013
   b. Ludwig & Atanda *Phys Sportsmed* 2015
   c. Gausden et al *Curr Opin Peds* 2015

4. Summary - Risks associated with both choices of treatment
   a. Risks of surgical treatment
      i. Growth abnormalities in lower limb
         1. Leg length & Angular deformity
      ii. General surgical risks
      iii. Graft failure
      iv. Arthrofibrosis
      v. Early onset OA
      vi. Prolonged rehabilitation required
   b. Risks of non-surgical management
      i. Chronic knee instability
      ii. Increased risk of damage to secondary structures
         1. Meniscus, articular cartilage
      iii. Decreased activity levels
         1. Limited sports participation choices
         2. Decreased quality of life
      iv. Early onset OA

*Considerations for Return to Sport and Functional Testing for the Pediatric Athlete - ML*

**Injury Risk in Children and adolescents**
- Increased due to rapid growth and high levels of activity
- Previous injury can be greatest risk factor for injury
- Proper education to patient and family regarding expectations for length and intensity of rehabilitation, strict guidelines for progression, and risk of re-injury with return to sport should be reviewed with family to assist with decision making.

**Second ACL injuries**
- Younger patients (<20) have an increased risk for both graft failures and contralateral injuries – *(Fauno 2014, Kaeding 2011, Webster 2014)*
• Allograft is worse than autograft in the younger population (<25 y/o)- (Wasserstein 2015, Kaeding 2011)

• What increases that risk?
  o Webster et al 2014 –
    ▪ Return to cutting/pivoting sports increased odds
    ▪ Positive family history
  o Paterno 2012
    ▪ Biomechanical and neuromuscular risk factors
    ▪ Quad weakness, altered postural stability and altered movement patterns
  o Laboute et al
    ▪ Greater risk returning ≤ 7 months

• Rates of revision and contralateral injury vary between studies. Limited data on patients in the 8-13 y/o age group

With those odds of reinjury, how do these kids stand a chance? How can we safely put them back on the field? What criteria should be used?

Functional Testing – what is it and why use it?
• Provide information relative to the functional level of performance necessary in sports competition (Draovitch 2012)
• Mimic demands of sport (Draovitch 2012)
• Developed to track rehabilitation and determine return to play criteria (Caffrey 2009)
• Unbiased means of measuring functional ability (Caffrey 2009)

Functional Testing – is anyone using it now?
• Barber-Westin and Noyes completed systematic review including 264 studies
  o 105 (40%) failed to provide any criteria for return to sports after ACL reconstruction.
  o 84 studies (32%) the amount of time postoperatively was the only criterion provided.
  o 40 studies (15%) the amount of time along with subjective criteria were given.
  o 35 studies (13%) noted objective criteria required for return to athletics.
    ▪ muscle strength or thigh circumference (28 studies)
    ▪ general knee examination (15 studies)
    ▪ single-leg hop tests (10 studies)
    ▪ Lachman rating (1 study)
    ▪ Validated questionnaires (1 study).

• Myer at al (2012)
  o Young athletes assessed after medical release and RTS activity demonstrate measurable functional deficits after ACLR that are independent of time from surgery
The exclusive use of temporal guidelines by clinicians may be an inaccurate scale to measure readiness to safely RTS
Study emphasizes the use of objective tools that are sensitive to limb-to-limb deficits
Need to develop rehab protocols that are targeted to eliminate limb asymmetries

Proposed Functional Testing – Rehabilitation Progression

Early Stage Rehabilitation
- Isokinetic strength test (MMT or HHD if isokinetic not available)
- Lateral step down test
- Y-balance

Mid Stage Rehabilitation
- Isokinetic strength test
- Lateral step down
- Y-balance
- Single leg hop
- Drop Vertical Jump
- Tuck Jump

Late stage Rehabilitation
- Isokinetic strength test
- Single leg hop
- Drop Vertical Jump
- Tuck jump
- Cutting

Strength testing
- Active stabilization of the knee joint depends largely on co-activation and force generation of the adjacent musculature (DiStasi et al, 2013)
- Quadriceps strength is strongly related to measurements of knee function and control after ACL injury
- Hamstrings activation may be an important component in NM control of the reconstructed knee
- Deficits in strength correlate to decreased limb control & increased risk of repeat injury
- When there is a delay in co-activation of the quadriceps and hamstrings muscles, active restraint is absent or insufficient and the joint will rely primarily on passive restraints (Hashemi et al, 2010)
- Greenberg et al – significant strength and functional deficits may be present >1 year after all epiphyseal ACLR in 8-15 y/o
  - 7 months - only 9/16 patients were able to achieve 90% LSI
  - 12 months - only 6/16 subjects were able to achieve 90% LSI on all functional hop tests
  - 15 months - only 4/16 subjects able to achieve LSI >/= 90% on all testing parameters
• Wells et al – teenagers (around 16 y/o) only 59% able to achieve 85% LSI in less than 6 months

Manual muscle testing
• MMT most widely used clinical method of strength assessment
• Examiner’s subjective assessment of the amount of resistance applied is inherent in the grading criteria for strengths in the Good to Normal range (Wadsworth et al, 1987)
• PT using MMT unable to identify up to 50% loss of knee extensor strength (Beasley 1961)

Hand held dynamometry
• More objective than MMT
• Examiner’s own strength may affect his/her ability to use a dynamometer appropriately with stronger subjects

Isokinetic strength test
• High test re-test reliability for peak torque, peak torque/body weight, total work and average power (60 and 180°/second)
• Allows for assessment of quad dominance
• Deficits in the hamstring-quadriceps torque production ratio, key variable in the primary ACL injury risk model

Isokinetic strength test set up
• Seating position is standardized so that the hip and knee are both at 90°
• Patient is allowed to perform 5-10 practice repetitions prior to testing
• Testing performed on the uninvolved limb first
• Currently testing at 180° and 300° per second, though there is some evidence for testing at 60 °/sec
• Isokinetic strength test: Passing criteria

Goals for strength testing:
3 Months:  LSI ≥75% for Peak Torque Quads, Hams and Total Work
6 Months:  LSI ≥ 85% for Peak Torque Quads, Hams and Total Work
9 Months:  LSI ≥ 90% for Peak Torque Quads, Hams and Total Work
Hamstring / Quadriceps Ratio of > 65%

Lateral step down
• Takes into account: position of the trunk, pelvis, knee and ankle
• Aberrant patterns are commonly seen up to 2 years after ACLR and may explain the high rate of second ACL injury
• Rabin et al found a link between decreased ankle dorsiflexion range of motion and medial displacement of the knee during lateral step down
• Aberrant motions of the pelvis & trunk can affect moments at the knee (Powers, 2010)
• Assess amount of medial displacement of the knee which is thought to increase the lateral vector of the quadriceps muscle, represented by the Q-angle (Rabin, Kozol 2010)
• Increase in the Q-angle potentially pre-disposes to mal-tracking of the patella in the femoral groove and increase in patella-femoral contact pressure

Lateral step down test
• Patient stands with their foot close to the edge of a 6-8” height step.
• Uninvolved leg should be off the side of the step
• Instructed to keep both hands on their waist and bend their knee until the heel of uninvolved leg lightly touches the floor, then immediately return to the starting position.
• Lateral step down: Passing criteria
• Scoring:
  • 0-1 good
  • 2-3 moderate
  • 4-6 poor
• Goals:
  • 3 month post-operative ACLR <3
  • 6 month post-operative ACLR <1

Y balance
• To assess the athlete’s dynamic balance/postural control, and measure the extent of remaining deficits in proprioception, dynamic balance, and postural control.
• Studies have reported the ability of the test to differentiate performance in those with pathology, primarily chronic ankle instability, ACL deficiency and patellofemoral pain syndrome
  • Plisky et al
  • Clagg et al
  • Garrison et al 2015
• Y balance: testing procedure
  • 3 practice trials per limb measure 4th
  • Patient instructed to stand in single limb stance with the most distal aspect of their great toe on the line of the stance plate (if using FMS tool) or center of the grid (if using tape on the floor)
  • Patient instructed to perform maximum reach by pushing behind the reach indicator and should avoid kicking the indicator
  • Patients are not allowed to touch down after moving the indicator, they must return to the start position after reach in each direction
• Passing score:
  • ≥ 90% composite score
  • Reach distance ≤ 4 cm difference between limbs
• if patient does not pass at 6 months, they can still advance to 9 month training as long as strength test, lateral step down and hop tests goals have been achieved
• **Goals:** 9 month post-operative ACLR
  • Composite score and limb symmetry ≥ 90%
  • Reach distance ≤ 4 cm difference between limbs

**Single leg Hop test**
• Designed to challenge the athlete’s dynamic stability and neuromuscular control (Fitzgerald 2001)
• It has been proven to help identify or confirm abnormal limb symmetry and limitations in an ACL deficient knee (Noyes 1991)
• **How to perform** - Athlete completes jump maintaining single limb stance upon landing.
  • Single
  • Triple
  • Crossover
  • Timed
• Average of 3 trials per leg
• Calculate Limb symmetry index
  • Involved/uninvolved x100 for distance jumps
  • Uninvolved/involved x100 for timed hop
• **PASSING CRITERIA**
  • Mid Stage Rehabilitation: 85% limb symmetry index (Noyes 1991, Fitzgerald 2001)
    • Acceptable for cutting and non-contact drills
  • Late stage Rehabilitation: 90% or better (Myer 2011)
    • Acceptable to begin return to sport progression
• **GOOD ALIGNMENT AND SYMMETRICAL QUALITY OF MOVEMENT**
  Common errors include:
  • Dynamic knee valgus
  • Femoral adduction and internal rotation
  • Contralateral pelvic drop
  • Lateral trunk lean
  • Decreased knee flexion

**Drop-Jump Screening Test**
• Reliable assessment tool to capture faulty movement patterns, such as increased dynamic genu valgus, that may identify athletes are risk for ACL tear (Hewett 2005)
• **Drop-Jump Screening Test- How to perform**
• Set-up
  • 12” box
  • Reflective markers placed at greater trochanter and lateral malleolus of both legs
• Velcro circles on center of each patella
• Complete jump-land sequence – 3 trials
  • Jump off box
  • Land on both feet
  • Max vertical jump
• **Drop-Jump Screening Test** - Scoring
  Following images can be captured
  • Pre-land
  • Land
  • Takeoff

Normalized Knee Separation Distance:
*Distance between knees in cm*
*Distance between hips in cm*
• **Drop Vertical Jump - PASSING CRITERIA**
  Scores as follows (Noyes 2005):
  • ≤ 60% poor
  • 61-80% fair
  • ≥ 81% good

**Drop Vertical Jump- Landing Error Scoring System (LESS)**
• **Purpose:**
  • Detect movement pattern errors during a drop jump task that place athletes at risk for noncontact ACL injury (Padua 2009)
  • The LESS is a valid and reliable tool for identifying potentially high risk movement patterns during a jump landing
• **Drop Vertical Jump - Landing Error Scoring System (LESS)**
  • Prospective studies on-going to determine effectiveness as screening tool (Padua 2015, Smith 2012)
  • Poor landing mechanics increased likelihood of stress fracture in a group of subjects from a US service academy by 2.33-2.5. (Cameron 2014)

flat-footed or heel-to-toe
asymmetric landing at initial contact
• **Drop Vertical Jump - LESS**
  • Uses 2 video camera to capture both frontal and sagittal plane mechanics
  • Test Performance:
    • Athlete jumps forward off a 30-cm high box 50% of their height away from the box
    • Immediately rebounds for a maximal vertical jump on landing
(Padua 2009 – JUMP ACL study)
• **Drop Vertical Jump – LESS Scoring (Padua)**
  • LESS – Scoring on 3 trials
    • Lower scores = fewer errors = better technique
    • Scoring 0=No/1=Yes for criteria 1-15
    • Joint displacement and overall impression 0/1/2
  • Scores as follows:
• <4 Excellent (Low risk)
• 4-5 Good
• >6 Poor (High risk)

Drop Vertical Jump - REAL TIME ASSESSMENT (Padua 2011) - LESS - RT
• Limitation of LESS is that it cannot be assessed in real time and requires video cameras.
• Includes 10 jump-landing characteristics and is scored over 4 trials of the jump-landing task.
  • Sagittal – decreased knee, hip and trunk flexion, heel/toe landing
  • Frontal Plane – knee valgus, hip IR/ADD, Tibial IR/ER, stance width, trunk lateral flexion
• No cut-offs or passing criteria established yet.

Drop Vertical Jump - iLESS (Cortes 2013) - iLess
• Purpose: identify individuals with faulty movement patterns in large scale injury screenings
• Single drop-landing - Frontal plane video only
• iLESS – dichotomous classification
  • 0=good movement, no risk
  • 1= poor movement, high risk

Tuck Jump
• Identify asymmetrical and at risk movement patterns in the high level athlete
• Assessment and direct treatment for high risk athletes (Meyer 2008)
• Minimal research on validity or predictive capabilities

How to perform
• Patients stand with feet shoulder width apart on strips of tape placed 35cm apart
• Perform 10 seconds of repeated tuck jump
• Video anterior and lateral view
• Clinician will check off boxes for impairments observed

Scoring
• 10 points maximum (see scoring sheet)
• ≥ 6 suggests that the athlete would benefit from technique training.
• Area of focus: (Meyer 2008)
  • lower extremity valgus at landing
  • equalization of side-to-side differences

Cutting Assessment
Minimal to no clinical evidence regarding formal testing
• Limited information on most appropriate, most efficient or safest cutting mechanics (Havens 2014)
• Reduce dynamic valgus, place the foot closer to the center of mass and land on toes (Kristianslund 2014)
• Whole body technique training - foot placement close to midline, neutral foot alignment, upright torso and torso facing direction of travel (Dempsey 2009)
• Symmetrical performance of power movements with sufficient hip and knee flexion angles with decreased knee abduction (Myer 2006)

**Patient self-reporting**
- Use reliable and valid tools (FAAM, LEFS, IKDC, KOS, PEDI-IKDC, HSS-Pedi-FABS)
- Results of patient subjective measures may not be accurate. Parents will often fill out questionnaire with or without child’s assistance.

**Functional outcome measures**
- Evidence showing that fear of re-injury negatively influences RTS outcomes after ACLR has grown over the past decade

Your patient asks, “When can I…????”
- Full and symmetrical strength: dynamometry, isokinetic strength
- Balance and neuromuscular control: Y balance, lateral step down
- Dynamic stability: Y balance, single leg hop, tuck jump, drop jump, cutting
- Symmetrical power production: single leg hop, tuck jump, cutting
- Muscular and Cardio Endurance: isokinetic strength, tuck jump, cutting
- Confidence: psychological readiness
- Subjective reporting: use of FOM

**Take Home Points**
- Use a battery of functional tests throughout rehabilitation
- Assess both quantity AND QUALITY of movement
- Ensure mental, psychological and emotional readiness
- Gradual return to sport progression
- ON-GOING injury prevention.

**Late Stage Rehabilitation Considerations for the Young Athlete-KK**
- Following ACLR & Rehabilitation
  - Deficits up to 4 yrs post-op
    - Strength
    - Balance
    - Proprioception
    - Postural Control
    - Asymmetries in lower extremity
      - Force generation
      - Force attenuation
      - Altered movement patterns
- Following ACLR & Rehabilitation
  - Neuromuscular Asymmetries highly predictive of 2nd injury (Hewett, AJSM 2013)
• Hip rotational control deficits
• Excessive Frontal Plane knee mechanics
• Knee flexor deficits
• Postural Control Deficits

• Long Term Goals of ACLR
  • Safe Return to Unrestricted Activity
    • Emphasis on Sport(s)/Position(s)
  • Prevent Re-injury

• Significant Pressure to return to…
  • When can I ride a bike?
  • When can I play dodge ball?
  • Can I go on a trampoline?
  • Is a moon bounce OK?
  • When can I play?

• The Pediatric Athlete
  • “A Body in Flux”
    • Growth-related considerations
    • Sensorimotor function considerations
    • Psychosocial Considerations

• Growth-related considerations
  • Prepubescent thru puberty
  • Growth spurt
    • Peak height velocity
      • Females ~ 12 yrs
      • Males ~ 14 yrs
    • Bony growth can exceed soft tissue accommodation affecting…
      • Flexibility
      • Postural control
      • Coordination

• Sensorimotor function considerations
  • Developing /delayed
    • Pre-pubescent running and jumping/cutting
      • Increased knee frontal plane moments
      • Increased GRF
    • Sensorimotor regression
• Puberty
  • Neuromuscular control
  • Postural stability
  • Intersegmental/interlimb coordination

• Psychosocial Considerations
  • Perceptions of pain
  • Difficulty with Sustained focus/attention span
  • Ability to self-assess and self-correct
  • Decreased Information retention
  • Concrete thinking
  • Sports as social outlet and self-concept
  • Weight gain/ Muscle loss

• Early Phase: Pediatric vs Adult ACLR rehab
  • Protected weight bearing
  • ROM restrictions
  • Knee immobilization
  • Strength training

• Intermediate & Advanced Phases
  • Address impairments
    • Strength & Muscle performance
    • Neuromuscular training
    • Plyometrics
  • Injury Prevention
  • Progressive return to sport
    • Sport/position specific drills

• Strength & Muscle Performance
  • Muscle demand
    • Intensity
    • Frequency
    • Duration
  • Power generation

• Neuromuscular training
  • Train movements not muscles
  • Known before unknown
  • Simple before complex
  • Stable before unstable
• Appropriate progressive speeds

• Plyometrics
  • Power generation
  • Force attenuation
  • Activities related to Sport/Position
  • Proper technique bilaterally

• Single leg progression
  • Step, squat & hold
  • DL jump, SL land & hold
  • SL hop, contralateral land & hold
  • SL hop, land & hold
  • SL repeated hop

• Modify variables
  • SL ↔ DL transitions
  • Direction
  • Surface
  • Intensity (reps, time, force)
  • Part task → Sequential → Simultaneous
  • Distraction

• Breaking it down
  • Clinical decision making
    • When can I ride a bike?
    • When can I play dodge ball?
    • Can I go on a trampoline?
    • Is a moon bounce OK?
    • When can I play?

• Criterion for Return to Sport Phase
  • No Pain or Joint effusion
  • Full AROM
  • Quad/hams Strength ≥ 90%
    • Relevant musculature
  • Functional Limb symmetry ≥ 90%
    • Quantitative measures
    • Qualitative measures
  • Pedi-IKDC ≥ 85%
• Injury Prevention Program
  • Endurance
    • Aerobic and muscular
  • Flexibility
  • Strengthening
  • Neuromuscular
    • Dynamic stabilization
    • Plyometrics
  • Specificity training
    • Agility & Speed

Return to Sport Progression
• Level 1:
  • Organized practice
  • Warm-up, Stretching, skills/drills
  • NO contact, possession, scrimmage
  • Progress time for Endurance deficits
  • 10 Practices minimum
• Level 2:
  • Level 1 +
  • Contact & Possession skills/drills
  • 10 Practices minimum
• Level 3:
  • Level 1+2 +
  • Team-only Scrimmage
  • NO “Friendly” scrimmage
  • 10 min continuous play MAX
  • 20 min total playing time
  • Increase playing time per practice
  • 5 Practices minimum
• Level 4:
  • Level 1-3 +
  • Game/Competition
  • 1 day only
  • 10 min continuous play MAX
  • 20 min total playing time
  • Increase playing time per day
  • 5 Games minimum
• Level 5:
  • Multiple Games/day
• Attention to endurance
• Limit time per game

• Summary
• With ACLR rehab for the pediatric athlete it is important to consider developmental issues which may have a profound effect on the rehab process
• Stress the importance of Injury prevention early and often throughout rehab
• Use sound clinical judgment and qualitative, as well as quantitative criterion for progression, and advancement to sport-specific activities and return to sports
• Be an advocate for your patient to protect them from themselves, parents, coaches, and the pressure of returning too early

<p>| Literature Review on graft type and failure rates in young active adults and children |
|---------------------------------|------------------|-----------------|------------------|-------------------|
| Author                          | Study Design                  | Age of subjects | Graft failures  | Contralateral injury | Results/Discussion                                                                 |
| Brophy et al 2012               | Prospective from MOON group - 100 soccer players questions on RTP status | Mean age 24.2 (11-53) | 3% (3)          | 9% (9)             | ACLR on Non-dominant limb had a higher future rate of contralateral ACL reconstruction (16%) than dominant limb (3.5%) 20% reinjury rate women 5.5% injury rate men |
| Cruz et al 103 patients         | 21 month mean follow up       | 6-15 years old  | 11 re-ruptures (10.7%) | 2 (1.9%)          | Higher rates due to increased activity levels |
| Fauno et al 2014                | Using Danish Knee Ligament Reconstruction Register identified 14,806 | &lt;13 to &gt;20 | 4 age groups: A &lt;13 – small sample size, unable to determine risk |                   | Revision rate in 13-20 y/o ACLR patient up to 3.5 times greater compared to adult (&gt;20) |</p>
<table>
<thead>
<tr>
<th>Kaeding et al 2015</th>
<th>Data from 2002-2008 cohort database used to identify risk factors for ACL reretear 2 year follow up</th>
<th>Mean age 27 – 2488 participants</th>
<th>109 graft tears (4.4%) Allograft 5.2x greater risk No significant difference between HS and BPTB Odds increased with a decrease in age Odds increased with increase in Marx score 88 contralateral (3.5%) Lower age and higher activity level risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaeding et al 2011</td>
<td>Purpose - evaluate influence of graft choice (allograft vs autograft) on risk of tearing ACLR graft Cohort study 2002</td>
<td>Patients aged 10-19 highest percentage of graft failures (8.2%) Odds of graft rupture with allograft 4x higher than autograft</td>
<td>For each 10 year decrease in age, odds of graft rupture increases 2.3 times (see charts)</td>
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<tr>
<td>Study</td>
<td>Methodology</td>
<td>Mean age (range)</td>
<td>Outcome</td>
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<tr>
<td>Koch et al 2014</td>
<td>Determine risk of complication in 12 patients who underwent all epiphyseal ACL R from 2006-2010</td>
<td>10-13 years</td>
<td>2/12 graft failure requiring second surgery</td>
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<tr>
<td>Laboute et al 2010</td>
<td>298 respondees who underwent ACLR in 2003-04</td>
<td></td>
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<tr>
<td>Paterno et al (March 2012)</td>
<td>63 ACLR ready for RTS 39 control</td>
<td>Ages 10-25</td>
<td>4/16 (25%)</td>
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<tr>
<td>Paterno et al 2014</td>
<td>125 participants - 78 athletes underwent ACLR, 47 healthy controls, follow up 24 months</td>
<td>10-25 years</td>
<td>7/23 graft tears</td>
</tr>
<tr>
<td>Wasserstein et al 2015</td>
<td>compared autograft and allograft use in young active patients</td>
<td>&lt;25 y/o</td>
<td>pooled failure was 9.6% for autografts and 25% for allografts</td>
</tr>
<tr>
<td>Webster et al 2014</td>
<td>561 patient responses,</td>
<td>25 patients (4.5%)</td>
<td>42 patients (7.5%)</td>
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<tr>
<td>Study</td>
<td>Minimum 3 Year Follow Up</td>
<td>Subsequent Injury to Either Knee</td>
<td>Prospective MOON Cohort Study</td>
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<tr>
<td>Wright et al 2011</td>
<td>Systematic review 6 studies 5 year follow up</td>
<td>1.8%-10.4% (5.8%)</td>
<td>Of 273 patients, 235 data collected</td>
</tr>
<tr>
<td>Wright et al – 2007 Prospective MOON Cohort study</td>
<td>2 year follow up</td>
<td>8.2% to 16.0% (11.8%)</td>
<td>Average age 24</td>
</tr>
</tbody>
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**REFERENCES:**

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