

Unique Considerations for the Pediatric Athlete During Rehabilitation and Return to Sport After Anterior Cruciate Ligament Reconstruction



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Abstract: Anterior cruciate ligament (ACL) injuries and surgical intervention in the pediatric population have increased in the recent years. Although surgical techniques have advanced, evidence-based rehabilitation guidelines that consider all aspects of the youth athlete are currently lacking. The purpose of this commentary is to review the current evidence on unique considerations for the pediatric and adolescent population during rehabilitation and return to sport after ACL reconstruction (ACLR), with a focus on children under 18 years of age. This review revealed that returning a youth athlete to sport after ACLR requires knowledge and appreciation of various aspects of the growing athlete different from adults. In addition to postoperative precautions that contribute to a slow rehabilitation process, young athletes need additional time for strength gains. Address risk of reinjury and for contralateral injury by using neuromuscular training and rigorous return-to-sport training programs. Consider return to sport after 9 months because the reinjury rate is high in this population. A combination of time and objective measures, both quantitative and qualitative criteria, and psychological readiness should be used to assess readiness to return to sport and decrease risk of future injury. Healthcare providers should be aware of the psychosocial impact of injury on the youth athletes and refer to sport psychology when necessary.

Level of Evidence: Level V.

Over the last 2 decades, anterior cruciate ligament (ACL) injuries and surgical intervention in children and adolescents have been increasing.¹⁻⁷ This increase is often attributed to increased participation in competitive organized sports,⁸ early sports specialization,⁹ and year-round training and competition.¹⁰ Furthermore, advancements in surgical techniques allow for early reconstruction of the ACL in the

skeletally immature patient, restoring knee stability, decreasing risk of subsequent injury to the knee, improving rate of return to play, and providing favorable long-term outcomes.¹¹⁻¹⁴

Although pediatric athletes return to sports at a high rate after ACL reconstruction (ACLR),¹⁵ subsequent ACL injuries to the ipsilateral or contralateral leg are reported to be as high as 32%.^{16,17} Recent studies of revision ACLR in pediatric and adolescent populations have reported lower functional outcomes, lower return to sport rates, significant risk of contralateral ACL injury, and high rates of revision graft injury^{18,19} compared to primary ACLR. Revision ACLR has also been associated with more meniscal and cartilage abnormalities,¹⁸⁻²⁰ which increases concern for long-term knee and general health.

Youth are undergoing changes both physiologically and psychologically which warrant consideration. As such, protocols and recommendations created for adults cannot merely be extrapolated to children and adolescents with ACL injuries. Physiologically, pediatric athletes have slower strength recovery, decreased neuromuscular control, poor rates of passing return-to-sport (RTS) criteria, and higher reinjury rates than adults, suggesting that RTS testing criteria and timeline

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to RTS created for adults may not be appropriate. Sports also offers many psychosocial benefits for the youth including socialization, building teamwork and leadership skills, and improving self-esteem.²¹ Not being able to play has significant impact on the youth athlete physically, mentally, and socially. Therefore healthcare providers must not only ensure full recovery and RTS but also minimize the risk of reinjury. The purpose of this commentary is to review the current evidence on unique considerations for the pediatric and adolescent population during rehabilitation and RTS after ACL reconstruction (ACLR), with a focus on children under 18 years of age.

ACL Injuries in Children and Adolescents

The number of ACL injuries have been increasing across all age groups, even in children as young as 5 to 10 years of age.^{2-4,6,22} In children younger than 12, a higher ACL injury rate is reported in boys.^{1,2,23-25} Increased rates in female athletes begin around puberty,^{1,24} at around age 12. In both sexes, the rate of ACL injuries increase as they progress through puberty.^{1,2,4,24} The overall injury rate is highest in late adolescence for both sexes (15-18 years).¹⁻⁴

Periods of rapid growth and development may contribute to ACL injury risk. The femur and tibia grow at a fast rate, which creates a longer lever and increases torque at the knee.²⁶ Increases in height and body weight raise the center of mass, and greater muscle forces are required to control its movement during sports activities leading to increased muscular and neuromuscular demand.²⁶ After maturity, decreased biomechanical and neuromuscular control of the knee, such as greater knee abduction angles and moments, higher ground reaction forces during landing, and decreased active knee joint stiffness are observed in females compared to males.²⁷⁻³⁰

In addition to physical growth, sensorimotor mechanisms such as visual, somatosensory, vestibular, postural control, and coordination continue to develop during childhood and adolescence. Some adolescents may experience delays or regression in some aspects of sensorimotor function, which may affect motor control and contribute to awkward movement patterns. However, there is no consensus on how it may affect injury risk.³¹ These physical, biomechanical, neuromuscular, and sensorimotor factors may also contribute to a challenging rehabilitation compared to the adult population.

Nonoperative or delayed surgical treatment was once the standard of care for the skeletally immature patient with ACL tear due to concerns of physeal injury and subsequent deformity. Current practice has evolved to favor early surgery with good functional outcomes, decreased meniscal and articular cartilage injuries, and improved rate of return to sports with minimal risk of

growth disturbance.^{11,14,32-35} Surgical treatment for the skeletally immature includes physeal sparing, partial transphyseal, and transphyseal techniques.^{10,12} Despite these advancements in surgical treatment, there is currently a lack of evidence-based rehabilitation protocols after ACLR specific to the youth athlete.³⁶

Psychosocial Considerations for the Youth Athlete

Adolescence is a time for identity development, social skill acquisition, and developing independence.³⁷ Professionals caring for the adolescent athlete must appreciate the impact of injury beyond physical symptoms and functional limitations. Lower quality-of-life (QOL) scores are reported in adolescent athletes with knee injuries^{38,39} with greater impairments in season-ending injuries such as ACL tears.⁴⁰ A strong correlation between knee function and the social and emotional domains of QOL in pediatric and adolescent patients with ACL injuries has been found both before and after surgery.⁴¹ In addition to physical limitations, ACL-injured athletes may experience emotional reactions such as loss, denial, frustration, and anger,⁴²⁻⁴⁴ decreased academic performance,⁴⁵ and loss of identity and loneliness.^{40,43,46} Although higher levels of athletic identity are associated with positive health benefits, self-esteem, and improved social relationships, they are also associated with depressive symptoms after injury.⁴⁷ Moreover, Padaki et al.⁴⁸ reported that many adolescent athletes experienced symptoms consistent with post-traumatic stress disorder after an ACL rupture, suggesting that the level of psychological trauma experienced by these athletes may be greater than is recognized. Healthcare professionals must appreciate the unique psychosocial factors that impact injured youth athletes and should prioritize their psychological and emotional well-being when caring for their physical health. To maintain social aspects, young athletes may be encouraged to attend and participate in their team training sessions as their surgical precautions allow.⁴⁹ Although depressive symptoms may decrease over time,^{44,50} psychological response after an injury varies among individuals⁴⁴; therefore referral to sport psychology may be warranted for the struggling athlete for successful rehabilitation.

Psychological factors must also be considered during recovery after ACLR. Factors such as anxiety may affect recovery in children. High levels of preoperative anxiety in children and adolescents are related to higher postoperative pain intensity.⁵¹ Perioperative parental anxiety and pain catastrophizing also relate to child anxiety and postoperative pain,⁵²⁻⁵⁴ highlighting the influence of parents on the child, unique to this population. Anxiety and pain can negatively affect rehabilitation because patients may not tolerate

weightbearing loads and range of motion progressions and may find it difficult to adhere to home exercise programs or to be motivated. Youth athletes, especially prepubescents, cannot perform unsupervised exercises independently with correct technique.⁴⁹ Successful rehabilitation and adherence to home programs often require collaboration with parents or family members, even in the adolescent population.

The healthcare team plays an important role for youth during their recovery. Disanti reported psychological and social barriers were just as prevalent as physical symptoms for returning to physical activity. Positive factors that help with recovery include having detailed knowledge of their recovery process, trusting relationships with the physical therapist (PT), individualized goals, and incorporating sport-specific activities. Negative factors include lack of attention from the medical team and receiving a generalized approach to treatment.⁴² Paterno et al.⁵⁵ identified PT/patient relationship quality as an essential factor that young patients and their parents perceive to impact ACLR outcomes. PTs are identified as a guide throughout the recovery process, motivator, confidence booster, and care coordinator.⁵⁵

Based on the information, the healthcare team may provide athletes with thorough education on the overall recovery process in easily understandable ways, create and discuss individualized treatment plans and goals with the patient, and ensure one-on-one attention during their sessions. Postoperative rehabilitation can be frustrating and mentally challenging for the ordinarily active young athlete, especially in the early stages when the athlete performs relatively basic exercises. Incorporating sport-specific exercises throughout the recovery process and providing the athlete with challenging workouts with aerobic conditioning, involving the upper extremities or the uninjured leg within safe constraints can help motivate and keep them engaged. Providing the athlete with concrete short-term goals (e.g., 1 session or 1 week) and assessing them with the patient may also help them navigate the uncertainty they may have about their progress and motivate them for the next goal. Although it is common for youth athletes and rehabilitation specialists to become impatient and frustrated with the slow progress, adhering to both time- and criterion-based progression is advocated.³⁶

Rehabilitation is Slower in the Youth Athlete

Recovery for the youth athlete after ACLR is typically slower than that of an adult because of postsurgical precautions, slower strength gains, and psychological factors. Physseal-respecting surgeries frequently have weightbearing and range of motion restrictions,^{10,36}

contributing to a longer rehabilitation duration. Concomitant procedures to the meniscus or the articular cartilage can further prolong this process.

Quadriceps strength deficit is related to altered knee mechanics, greater limb asymmetry, altered landing patterns,⁵⁶ and decreased function⁵⁷ after ACLR. Delayed strength recovery is reported in all age groups in the pediatric population. In preadolescent athletes who underwent all-epiphyseal physseal-sparing ACLR, only 56% of athletes achieved 90% quad strength symmetry at 7 months after ACLR whereas 94% of athletes achieved adequate hamstring strength.⁵⁸ In contrast, a separate study of pediatric athletes who underwent the same surgery reported that 69% of athletes met 90% limb symmetry for quadriceps strength, whereas only 38% met the cutoff for hamstring strength.⁵⁹ Difficulty regaining strength is also reported in adolescents, with only 59% of athletes (mean age 15) achieving $\geq 85\%$ quadriceps symmetry within 6 months.⁶⁰ Additionally, in older adolescents (mean age 17) who were cleared for unrestricted sports, only 43.5% to 56% met the cutoff of 85% to 90% quadriceps strength symmetry.^{56,57,61}

Although the cause of this delay in strength recovery is unclear, it is thought that physiological and psychological factors contribute. Training-induced strength improvements can be achieved in prepubescent children.^{62,63} However, strength gain is likely related to improved motor unit recruitment and neural adaptations rather than muscle hypertrophy^{64,65} because they lack androgenic hormones.^{66,67} Thus, in this age group, dynamic multijoint neuromuscular control should be the primary focus in rehabilitation.⁴⁹ In adolescence, there is an increase in circulating androgens⁶⁶; therefore rehabilitation can more closely resemble that of an adult.⁴⁹

As discussed previously, increased postoperative pain and anxiety may contribute to slow recovery of strength and functional progression. Furthermore, psychological readiness is increasingly recognized as influencing RTS after ACLR.⁶⁸⁻⁷² Paterno et al.⁷³ reported those with greater self-reported fear, using the Tampa Scale of Kinesiophobia, demonstrated decreased single-leg hop performance, isometric quadriceps strength, and had an increased risk of ipsilateral reinjury in the 24 months after ACLR. McPherson et al.⁷⁴ reported those with minor improvement in psychological readiness from preoperative to the 12-month mark, as measured by ACL-Return to Sport after Injury (ACL-RSI), were associated with a second ACL injury in younger patients. Although the specific recommendations of psychological interventions is beyond the scope of this article and can be found elsewhere,⁷⁵ it is important for clinicians to address psychological factors throughout the rehabilitation process.

Return to Sport Testing for the Youth

Most agree on using a battery of tests to assess RTS readiness, including muscle strength tests, functional tests such as hop tests, movement quality, and patient-reported outcome measures (PROMs).⁷⁶⁻⁷⁸ Limb symmetry index $\geq 90\%$ is a frequently reported criterion for strength and functional tests. Still, only 13% to 25% meet the passing combined criteria in this population after ACLR.^{58,61} Interestingly, Greenberg et al.⁷⁹ reported that although a high proportion of uninjured youth athletes achieved passing performance on isolated hop tests, only 45% achieved $\geq 90\%$ limb symmetry index across all four hop tests. These studies suggest that hop tests should be used with caution in this population.

The use of the uninvolved limb as a reference standard for symmetry presents its own problem. It does not reflect preinjury levels and may overestimate knee function after ACLR,⁸⁰ because of contralateral leg detraining, or the leg was weaker to begin with. The contralateral leg may be best tested before surgery for a more accurate benchmark.⁸¹

In addition to quantitative measures, quality of movement should be assessed as part of the RTS decision-making process. Decreased neuromuscular control has been related to ACL injury, reinjury, and decreased knee function.⁸²⁻⁸⁴ Movements such as squat, step down, single leg squat, drop vertical jump, tuck jump, deceleration, shuffle, single leg hop, and cutting are commonly used to assess kinematics and loading symmetry.^{85,86} There is currently no standardized testing procedure for the pediatric athlete, and protocols created for the adult may lead to inaccurate results. Children may require verbal and visual demonstrations of the tasks, repeated several times, as well as specific instructions so that they clearly understand what they are asked to do. Different testing criteria and testing procedure may be necessary for the youth athlete.

Physical tests alone do not provide a complete picture of an athlete's readiness to RTS. PROMs offer insight into patient's perception of recovery and are an integral component of information in addition to objective clinical data throughout the recovery process. Phillips reported PROMs are underused and misused in the pediatric orthopaedic literature.⁸⁷ Fabricant found the use of PROMs to evaluate pediatric ACLR is neither standardized nor validated for the population.⁸⁸ The Lysholm, International Knee Documentation Committee Subjective Knee form (IKDC), Tegner Activity Scale, and Knee Injury and Osteoarthritis Outcome Score (KOOS) are frequently reported PROMs in the pediatric ACL literature,^{88,89} but none are designed for nor validated in the pediatric population. The use of adult PROMs in children has been shown to cause comprehensibility problems and should be avoided.⁹⁰

Therefore, whenever possible, the use of pediatric PROMs is recommended, such as the Pedi-IKDC^{91,92} or KOOS-Child⁹³ to assess self-reported knee function, and the Hospital for Special Surgery Pediatric Functional Activity Brief Scale (HSS Pedi-FABS)⁹⁴ to assess self-reported activity level. The Child Health Questionnaire,⁹⁵ Peds QL,⁹⁶ or the Pediatric PROMIS⁹⁷ may be used to assess QOL.

Incorporating psychological readiness and kinesiophobia assessment into a battery of RTS tests can further assist clinicians in RTS decision-making. The ACL-RSI assesses emotion, confidence, and risk appraisal and has been related to decision to RTS.⁹⁸ Additionally, a cutoff score of 76.7 points was 90% sensitive to identify younger patients who suffered a second ACL injury.⁹⁹ ACL-RSI is valid from 16 years of age.⁹⁸ The Tampa Scale of Kinesiophobia assesses pain-related fear or movement or reinjury and has been used in previous studies after ACLR.^{73,100} However, it is important to note that the instrument has not been validated for children after ACLR.

Reinjury Rate is High in the Youth

Testing both physical and psychological readiness is important before RTS because reinjury rate is high. More than 90% of pediatric athletes return to sport after ACLR, with up to 81% returning to competitive-level sport at the preinjury level.^{15,101} However, the rate of a second ACL injury in this population is as high as 32%.^{17,102-104} The risk is highest within the first 2 years after ACLR.^{17,105} Unfortunately, the contralateral injury rate in this population is also increased, at 7% to 20.5%.^{16,17,103,106-108} Reasons for a second ACL injury to either knee is multifactorial. Non-modifiable factors include graft type,^{20,109,110} age younger than 15 to 16,^{106,111} female sex,¹⁰⁶ and anatomic factors.¹¹²⁻¹¹⁴ Modifiable factors include returning to high-risk sports¹¹⁵ and biomechanical and neuromuscular factors.⁸³ Decreased net hip muscle external rotation torque, increased dynamic valgus during landing, asymmetries in internal knee extensor moment at initial contact, and decreased single-leg postural stability at the time of RTS predicts second ACL injury to either knee.⁸³ These neuromuscular deficits are similar to primary ACL injury risk.²⁹

Neuromuscular training (NMT) effectively improves landing mechanics and performance and has shown to reduce ACL injury rate in healthy adolescents.¹¹⁶⁻¹²¹ Therefore NMT program should be an important component of rehabilitation after ACLR to reduce the risk of a second injury to the ipsilateral leg and to the contralateral leg. NMT effectiveness on preventing ACL injury has been shown to be dose-dependent and should be performed longer than 20 minutes in duration, more than 2 times per week.¹²² Incorporating

various types of exercises such as plyometrics, balance training, trunk stabilization, and posterior chain strengthening exercises optimize the effects of NMT.¹²²

Clinic-based rehabilitation may not represent the same conditions athletes experience on the field or court during sports. Therefore youth athletes may benefit from a more performance-based, sports-specific RTS training before unrestricted sports participation. On-field rehabilitation and RTS training programs have been shown to successfully improve muscle strength and knee function and reduce the risk of reinjury after ACLR.¹²³⁻¹²⁵ Important elements include restoring movement quality, physical conditioning, sport-specific skills, and load management.¹²⁶ This may be best performed working with a performance specialist or team coach. Communication of all key stakeholders (athlete, coach, parents/guardians, healthcare providers) is crucial to monitor the progress of the program and assist the athlete's safe RTS. A more rigorous RTS training program that bridges the gap between rehabilitation and unrestricted sports may improve outcomes after ACLR in the youth.

Time to Return to Sport is Later in Youth Athletes

Many young athletes expect to RTS much sooner than the expected timeline.¹²⁷ There are considerable differences in the literature regarding time to RTS in this population, and the appropriate time to return to play is currently unknown. Earlier RTS has been shown to be predictive of a second ACL injury in youth athletes.¹⁶ ACL reinjury rate was reduced by 51% for each month RTS was delayed until 9 months after surgery.¹²⁸ Additionally, young athletes who returned to sport earlier than nine months had a 7-fold higher rate of second ACL injury than those who returned to sport after 9 months.¹²⁹ The International Olympic Committee recommends youth athletes delay returning to pivoting sport until at least 12 months,⁴⁹ and Nagelli and Hewitt¹³⁰ proposed that young athletes delay RTS for two years based on biological healing, resolution of symptoms, and functional recovery. Based on the present information, RTS may be considered beginning at 9 months and can be as late as 2 years, along with satisfactory objective clinical data, movement quality, and psychological readiness. Healthcare providers should educate the athlete and their families regarding realistic expectations for time to RTS and risks of returning to sport too soon in a manner that is easily understandable before surgery.

It is important to note that many articles on pediatric and adolescent ACL injuries are of level IV evidence. Moreover, most are published after 2000 with short-term follow-up. Therefore the long-term functional outcome and QOL are largely unknown.

Conclusion

Successfully returning a youth athlete to sport after ACLR requires knowledge and appreciation of various aspects of the growing athlete different from adults. In addition to postoperative precautions that contribute to a slow rehabilitation process, young athletes need additional time for strength gains. Address risk of reinjury and for contralateral injury by using neuromuscular training and rigorous return to sport training programs. Consider return to sport after 9 months as reinjury rate is high in this population. A combination of time and objective measures, both quantitative and qualitative criteria, and psychological readiness should be used to assess readiness to return to sport and decrease risk of future injury. Healthcare providers should be aware of the psychosocial impact of injury on the youth athletes and refer to sport psychology when necessary.

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