Improved Patient-reported Outcomes in Patients Aged 16 and Younger at Two Years After Anterior Cruciate Ligament Reconstruction Despite Relatively High Rates of Reinjury and Repeat Surgery

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Background: Anterior cruciate ligament reconstruction (ACLR) in adolescent patients, particularly those aged 16 and under, are increasingly common procedure that lacks robust clinical and patient-reported outcome (PRO) data. The purpose of this study was to report 2-year PROs of patients receiving ACLR aged 16 or younger using the single assessment numerical evaluation (SANE) and knee injury and osteoarthritis outcome score (KOOS). Secondary aims included characterizing treatment characteristics, return to sport (RTS), and clinical outcomes.

Methods: The institutional PRO database was queried for patients receiving ACLR from 2009 to 2020. Patients aged older than 16, revision procedures, concomitant ligament repairs/reconstructions, and patients without full outcome data at 2 years were excluded. Outcomes over 2 years after ACLR included SANE, KOOS, reinjuries, reoperations, and time to RTS.

Results: A total of 98 patients were included with an average age of 15.0 years. Most patients were females (77.6%). Bone-tendon-bone autograft (69.4%) was the most used. Average RTS was 8.7 months (range: 4.8 to 24.0 mo), with 90% of patients eventually returning to sport. A total of 23 patients (23.5%) experienced a reinjury and 24.5% (n = 24) underwent reoperation. Timing to RTS was not associated with reinjury, but patients who returned between 9.5 and 13.7 months did not sustain reinjuries. Mean KOOS and SANE scores at 2 years were 87.1 and 89.1, respectively, with an average improvement of +18.4 and +22.9, respectively. Change in KOOS was negatively impacted by reinjury to the anterior cruciate ligament graft and reoperation (anterior cruciate ligament failure: +10.0 vs 19.3, $P = 0.081$, respectively; reoperation: +13.2 vs +20.1, $P = 0.051$, respectively), though these did not reach statistical significance.

Conclusion: Patients experienced improved SANE and KOOS scores after ACLR. Rates of reinjury and reoperation were relatively high and negatively impacted PRO scores but were not associated with the timing of RTS. Adolescent patients should be counseled regarding the risk of subsequent ipsilateral and contralateral knee injury after ACLR.

Level of Evidence: Level IV—case series.

Key Words: pediatric anterior cruciate ligament reconstruction, patient-reported outcomes, KOOS, SANE, return to sport

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Anterior cruciate ligament reconstruction (ACLR) in adolescent patients, particularly those aged 16 and under, is an increasingly common procedure. Recently, pediatric ACLR has increased by almost three times compared with other orthopaedic procedures, with anterior cruciate ligament (ACL) injuries in the pediatric population reaching a rate of 12 per 10,000 patient-years.[1–3] This increase in pediatric ACL injuries and ACLR may be in part due to the increase in sports participation, especially early sports specialization.[4] The natural history of ACL tears in the pediatric population is well-described with support for nonoperative treatment in patients who are able to comply with significant activity restrictions.[5] However, active patients who undergo nonoperative management see higher rates of instability episodes, cartilage injury, premature degenerative changes, and meniscal injuries even in the setting of physical therapy and bracing.[5] As more pediatric patients undergo ACLR, there is an increasing need to evaluate the efficacy of surgical and non-surgical treatment.

Literature regarding patient-reported outcome (PRO) data after ACLR for pediatric patients, particularly aged 16 and younger, is limited, with many of the most recent studies addressing only transphyseal techniques.[2] Common PROs used in ACLR include the International Knee Documentation Committee, knee

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injury and osteoarthritis outcome score (KOOS), Tegner scores, and the Lysholm scoring scale.[2,6–8] Only one study has utilized the single assessment numeric evaluation (SANE) score for patients with ACLR, and this was in a small number of pediatric patients.[9]

ACL reruptures have been shown to be associated with low PRO scores, low rates of return to sport (RTS), and high rates of revision ACLR, particularly for patients aged 16 and younger.[10,11] Pediatric patients are typically more active and involved in some form of regular physical activity compared with older patients, accentuating the significance of RTS. Although up to a 90% RTS rate has been shown, the prevalence of a second ACL injury (retearing of the graft or the contralateral ACL) can occur in ~30% of pediatric patients.[12] Appropriate postoperative physical therapy, RTS timing, and level of restrictions play an important role in minimizing reinjury. There is no consensus on the appropriate time or metrics to utilize to clear patients to RTS in this high reinjury-risk population.

There is currently a paucity of information surrounding ACLR outcomes in pediatric patients despite the increasing frequency of ACLR in this group. This study reports 2-year PROs of patients receiving ACLR aged 16 or younger using the single assessment numerical evaluation (SANE) and KOOS, as well as rates and timing of RTS. It was hypothesized that patients would see improvement in their outcome scores after primary ACLR and those with a longer time before returning to sport would have a lower incidence of reinjury. Secondary aims included characterizing patient demographics, treatment characteristics, and other clinical outcomes such as reinjuries and reoperations in this population.

METHODS

After approval by the Institutional Review Board, a retrospective review of the institutional PRO database was conducted for patients who underwent ACLR from 2009 to 2020. Patients aged older than 16, revision procedures, concomitant ligament repairs/reconstructions, and patients without full outcome data at baseline and 2 years were excluded. Patient demographic information, injury characteristics, surgical technique, and clinical outcomes were obtained through a review of the patient's electronic medical record. Bone age was determined by a blinded review of patient injury magnetic resonance imaging (MRI) by a senior author as described by Pennock et al.[13] All operations were performed at an ambulatory surgery center by a total of 15 sports medicine fellowship-trained orthopaedic surgeons. Outcomes collected over 2 years after ACLR included SANE, KOOS, reinjuries (eg, ipsilateral ACL graft tear, contralateral ACL tear, meniscus tear, cyclops lesion, etc), reoperations, and time until RTS.

SANE and KOOS scores at preoperative baseline and 2 years after index surgery were collected prospectively and stored in a The Health Insurance Portability and Accountability Act-compliant PRO database, REDCap, until being retrospectively reviewed for the purposes of this study. The SANE instrument consists of a single question that asks patients to rate their knee on a scale of 0 to 100, with 100 being normal.[14] The KOOS instrument has 5 distinct subscales: pain, other symptoms, function in daily life, function in sport and recreation, and knee-related quality of life.[15] Questions are scored 0 to 4 and then normalized for each subscale. The overall KOOS is scored from 0 to 100, with 100 indicating no knee-related difficulties and 0 indicating extreme knee-related difficulties. Questionnaires were completed with the assistance of the patient's parent or guardian.

Data were analyzed using Intellectus Statistics (Clearwater, FL). Pearson correlations were conducted to evaluate how KOOS and SANE scores were affected by age, Body Mass Index, and length of restrictions. Analysis of variance and χ^2 tests were performed for a subgroup analysis that was conducted to evaluate for differences between patients who experienced reinjury and those who did not. A similar analysis was performed for patients who underwent reoperation compared with those who did not. The level of statistical significance was set to $P = 0.05$.

RESULTS

A total of 98 patients were identified and met the criteria for analysis. Patients had an average age of 15.0 (range: 10 to 16) and most were females (n = 76, 77.6%). The average Body Mass Index was 22.8 ± 3.8. Bone age MRI determination revealed an average bone age of 14.7 ± 0.7. Male patients had a higher average bone age than their female counterparts (15.9 ± 1.2 y versus 15.3 ± 0.9; $P = 0.036$). Of the 78 female patients, 55 (70.5%) were postmenarchal, 2 patients (2.6%) were premenarchal, and the rest did not have any documentation of menarche (21, 26.9%).

The most common activity during which patients injured their ACL was playing soccer (n = 40, 40.8%), followed by basketball (n = 22, 232.4). Meniscal tears occurred in almost half of the patients (n = 46, 46.9%), with 73.9% (n = 34) of those patients having a simultaneous meniscal operation. Those who had meniscal tears but did not undergo meniscal operation were felt to have stable tears that did not require intervention. Most ACLs were reconstructed using the standard adult technique (72, 73.5%), with all but 4 of those receiving bone-tendon-bone (BTB) autograft. Of patients that underwent BTB ACLR, 53 (95%) of the females and 8 (72%) of the males had at least partial closure of both the femoral and tibial physes. The rest of the patients underwent transphyseal reconstruction with a hamstring autograft (4, 4.1%) or a femoral physeal-sparing technique with a hamstring autograft (22, 22.4%). There was a statistically significant difference in average bone age between those that underwent transphyseal and physeal-sparing procedures (15.6 ± 0.9 vs 14.9 ± 1.2 y for transphyseal and physeal-sparing, respectively; $P = 0.001$), as well as between those that received BTB and hamstring autografts (15.7 ± 0.8 y for BTB vs 14.8 ± 1.2 y for hamstring autograph patients, respectively; $P < 0.001$). Implants typically consisted of aperture fixation on the femur and tibia (n = 67, 68.4%

TABLE 1. Baseline Characteristics (N = 98)

Age	15.0 ± 1.2
Bone age*	15.4 ± 1.0
Sex	
Female	76 (77.6)
Male	22 (22.5)
BMI	22.8 ± 3.8
Activity during injury	
Soccer	40 (40.8)
Basketball	22 (22.5)
Football	7 (7.1)
Skiing	4 (4.1)
Other†	25 (25.5)
Meniscal tears	46 (46.9)
Meniscal operations	34 (34.7)
Repair	23 (23.5)
Debridement	11 (11.2)
Surgical technique	
Adult transphyseal	72 (73.5)
Physeal-sparing	26 (26.5)
Graft type	
BTB autograft	68 (69.4)
Hamstring autograft	30 (30.6)
Femoral implants	
Aperture	67 (68.4)
Suspensory	31 (31.6)
Tibial implants	
Aperture	80 (81.6)
Suspensory	18 (18.4)

Continuous data are reported as mean ± SD. Categorial data are reported as N/n (%).

*Determined through a blinded review of knee magnetic resonance imaging by a senior author as described by Pennock et al.

†Other sports included: baseball, cheerleading, hockey, track, rugby, softball, volleyball, lacrosse, tennis, gymnastics, dance, and skateboarding.

BMI indicates Body Mass Index; BTB, bone-tendon-bone.

and n = 80, 81.6%, respectively; Table 1). The average operative time was 111.0 ± 25.7 minutes.

After initial ACLR, a total of 23 patients (23.5%) experienced an injury requiring orthopaedic consultation and cessation of sports, including 9 retorn ACL grafts and 8 contralateral ACL injuries requiring surgery (17/23, 74% of total injuries; Table 2). Reinjuries happened at an average of 12 months postoperatively; however, they ranged from as early as 2 months to as late as 22 months postoperatively over the 2-year study period. Patients who sustained these reinjuries were not found to have any significantly different characteristics compared with those who did not experience reinjury (Table 3). The overall reoperation rate was 24.5% (n = 24). The average RTS time was 8.7 months (range: 4.8 to 24.0 mo), with 90% of patients achieving RTS during the 2-year study period. Of the 23 patients who were reinjured, the majority (16, 69.6%) returned to sport before 9 months postoperatively (Fig. 1). However, there was no significant difference in the RTS time between those who sustained reinjury and those who did not (P = 0.713). Similarly, there was no significant difference in reinjury status between those who returned to sports before 9 months and those who returned after 9 months (P = 0.395).

The overall average KOOS and SANE scores at 2 years were 87.1 and 89.1, respectively. The overall average 2-year change in KOOS and SANE scores were +18.4 and +22.9, respectively. Patients who retore their ACL graft and those who underwent any ipsilateral knee reoperation demonstrated a smaller change in their KOOS scores at 2 years compared with their counterparts who had > 2-year ACL survival and those with no reoperations (ACL failure: +10.0 vs 19.3, P = 0.081, respectively; reoperation: +13.2 vs +20.1, P = 0.051, respectively), though this did not reach statistical significance. Change in SANE score was not found to be significantly associated with rerupture or reoperation (P = 0.187, P = 0.658, respectively). There was no difference in change in PRO between groups that underwent physeal-sparing and transphyseal techniques (P = 0.350 and P = 0.569 for change in SANE and KOOS, respectively), nor did graft influence PRO increase (P = 0.350 and P = 0.655 for change in SANE and KOOS, respectively). Male patients who had a bone age of 16, as determined by MRI review, had the highest average increase in SANE and KOOS as compared with their counterparts (P = 0.136 and P = 0.036, respectively). Post hoc analyses revealed a significantly greater increase in KOOS in patients with an MRI bone age of 16 (mean delta KOOS = 45.8 ± 4.6) versus their counterparts with a bone age of 17 or 18 (14.5 ± 13.4 and 7.2 ± 11.2, respectively; P = 0.032 and P = 0.034, respectively). MRI bone age did not have a significant effect on PROs in the female cohort.

TABLE 2. ACLR Outcomes for Patients Aged 16 or Younger (N = 98)

Time to RTS (mo)	8.7 ± 3.4
Reinjuries	23 (23.5)
Ipsilateral ACL graft tear	9 (9.2)
Contralateral ACL tear	8 (8.2)
Other*	6 (6.1)
Ipsilateral knee reoperations†	24 (24.5)
Revision ACL	9 (9.2)
Meniscal debridement/repair	7 (7.1)
Cyclops lesion	5 (5.1)
Lysis of adhesions	7 (7.1)
KOOS‡	
Baseline	68.7 ± 13.8
Two years	87.1 ± 12.6
SANE‡	
Baseline	66.1 ± 23.3
Two years	89.1 ± 21.2

Continuous data are reported as mean ± SD. Categorial data are reported as N/n (%).

*Other injuries included meniscal tears (4), patellar fracture (1—on a hamstring autograft patient), and patellar tendonitis (1).

†Sum of reoperations does not equal the total number of patients with reoperation due to multiple operative indications for individual patients.

‡Statistically significant difference between baseline and follow-up scores upon analysis by paired t test (KOOS) and Wilcoxon signed-rank testing (SANE).

ACLR indicates anterior cruciate ligament reconstruction; KOOS, knee injury and osteoarthritis outcome score; RTS, return to sport; SANE, single assessment numeric evaluation.

DISCUSSION

With the number of primary pediatric ACLR surgeries increasing each year, an understanding of postoperative outcomes is important to help guide

TABLE 3. Characteristics of Patients Aged 16 or Younger Who Sustained Reinjuries After ACLR (N = 98)

	Injured (n = 23)	Noninjured (n = 75)	Univariate *P*
Age	15.0 ± 1.0	15.1 ± 1.2	0.934
Sex			0.217
Female	20 (87.0)	56 (74.7)	—
Male	3 (13.0)	19 (25.3)	—
BMI	22.3 ± 3.5	23.6 ± 3.9	0.369
Meniscal tears	8 (34.8)	38 (50.6)	0.182
Meniscal operations	6 (26.1)	28 (37.3)	0.322
Repair	3 (13.0)	20 (26.7)	—
Debridement	2 (8.7)	14 (18.7)	—
Surgical technique			0.628
Adult transphyseal	16 (69.6)	56 (74.7)	—
Physeal-sparing	7 (30.4)	19 (25.3)	—
Graft type			0.983
BTB autograft	16 (69.6)	52 (69.3)	—
Hamstring autograft	7 (30.4)	23 (30.7)	—
Femoral implants			0.710
Aperture	15 (65.2)	52 (69.3)	—
Suspensory	8 (34.8)	23 (30.7)	—
Tibial implants			0.552
Aperture	20 (87.0)	60 (80.0)	—
Suspensory	3 (13.0)	15 (20.0)	—

Continuous data are reported as mean ± SD. Categorial data are reported as N/n (%).

ACLR indicates anterior cruciate ligament reconstruction; BMI, Body Mass Index; BTB, bone-tendon-bone.

perioperative discussions and decision-making. Using KOOS and SANE, this study demonstrated that patients aged 16 or younger can obtain good 2-year outcomes for primary ACLR. The reoperation rate was high at 24%, indicating the need to provide proper surgical treatment, education, and rehabilitation for these patients. Retearing of the ACL graft, as well as reoperation, were found to negatively impact PROs further demonstrating the need to mitigate reinjury. Patients were mostly treated with transphyseal drilling techniques, and there was no difference in the technique distribution between patients experiencing reinjury after ACLR and those who did not. In terms of RTS, patients aged 16 years or younger who have ACLR surgery often RTS, but the rate of reinjuries requiring orthopaedic consultation and cessation of sports was noted to be 23%. While most patients returned to sports 6 to 9 months after surgery, none of these injuries occurred in patients returning to sports around the 10 to 13-month mark.

PROs are valuable tools that can be used to monitor the progress of patients and can potentially allow surgeons to peripherally follow their patients as they go through the recovery period. This study found ~18 and 23-point improvements in KOOS and SANE scores over the 2-year study period. The high scores found in this study suggest that young pediatric patients should expect to have a generally good outcome. Increasing age has been shown to be associated with decreasing PRO scores.[16] Previous literature that spans the pediatric and adult population has demonstrated that the largest difference lies between the age 16 and younger group, compared with the age 45 and older group (average SANE: 90 vs 80, respectively).[16] Even though the younger patients have overall good outcome scores, the high reinjury rate needs to be considered as patients with revision ACLR typically have comparatively worse outcomes, high reinjury rates, high complication rates, and decreased RTS rates.[11] This study demonstrated similar results with patients achieving smaller gains in KOOS scores after reinjury and reoperation compared with those who did not reinjure or undergo reoperation. These results further highlight the importance of patient education, as well as good adherence to postoperative rehabilitation, to mitigate poor outcomes and reinjury.

In the relatively few studies that exist concerning RTS in pediatric patients, rates of >90%[12,17] have been

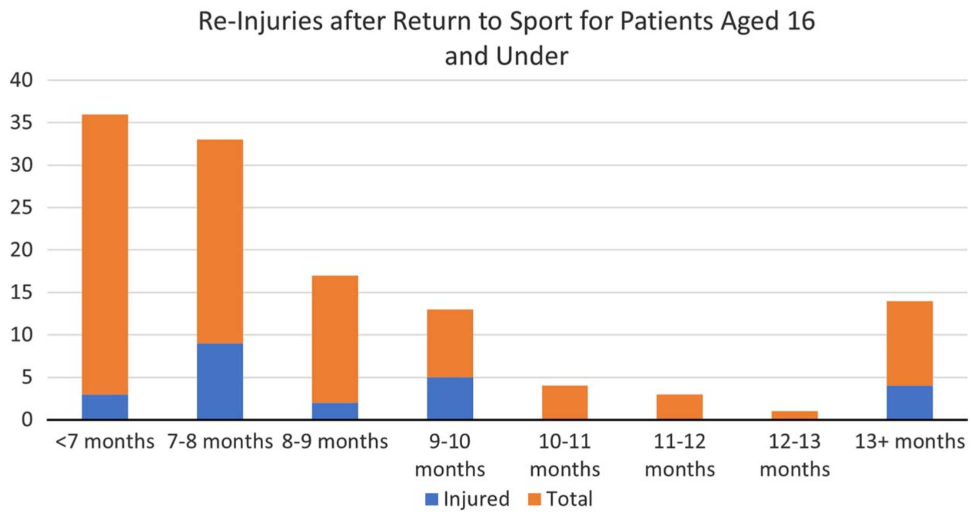

FIGURE 1. Reinjuries after return to sport (RTS) for patients aged 16 or younger. The frequency of reinjuries is stratified by month of clearance for RTS. full color online

reported in contrast to rates as low as 60% to 75% RTS rates[18] in skeletally mature individuals. The demonstrated average time to RTS in previous literature is ~9.6 months in pediatric patients who undergo ACLR.[6] The present study supports previous literature with a discovered RTS rate of 90% with patients returning to sport at 8.7 ± 3.4 months. Although RTS rates have been found to be higher in the pediatric population compared with the adult population, ACL reinjury rates have also been demonstrated to be higher with rates > 30%[12,19] in contrast to 2% to 5%[8,20,21] in adults. Comparable reinjury rates have been found in patients younger than 25, which may indicate that skeletal maturity is not the only factor influencing reinjury.[22] This study similarly found a reinjury rate of 23%, which may indicate that more focus needs to be placed on RTS restrictions, education, and rehabilitation programs to decrease the high pediatric reinjury rate.

Patients in this study who returned to play during the 10 to 13-month period did not experience reinjury or reoperation, which is similar to previous literature demonstrating earlier RTS being correlated with a second injury.[12] The cause for this is not clear, but it is possible that the patients in the group returning to sports between 10 and 13 months were better rehabilitated than those who returned earlier than 10 months. Another study found that almost half of the study patients' reinjuries occurred before the patient was cleared to RTS, and they determined this was due to pediatric patients' high activity levels and lack of adherence to sports restrictions.[23] In Europe, it has been suggested that in young children patients should not return to pivoting sports until 2 years post-ACLR.[24] Currently, there are no standard rehabilitation protocols or evaluations to determine clearance for sports.[25] A survey of 60 orthopaedic surgeons reported using a method of functional testing for RTS clearance, but the type of testing and progression criteria had significant variability.[26] The same study also found only 20% of surgeons reported using PRO measures with their patients.[26]

ACLR technique can vary between older and younger patients depending on skeletal maturity, with physeal-sparing techniques being used in younger, skeletally immature patients.[27] A recent review of 561 pediatric and adolescent ACLR cases found BTB autografts had the lowest failure rate of 6% compared with 13% with soft tissue allografts. The average time to failure was ~14 months and 8% sustained a contralateral ACL injury.[28] Patients in the current study were mostly treated with BTB autograft with 10% of those experiencing graft retear and 8% experiencing a contralateral ACL tear. Two-proportion z tests revealed no significant difference in the reported rates of failure of BTB autograft between the present study and the presented literature value. The current study demonstrates relatively good PROs and RTS for both physeal-sparing and nonphyseal-sparing ACLR surgical techniques.

This study has several strengths and weaknesses. One strength of this study is the use of prospectively collected, validated PRO measures that have been used in various ACL-related studies.[14,29–32] This is the largest study to analyze SANE scores in pediatric patients who underwent ACLR. Parent-proxy reporting for PROMs in the pediatric population is well-documented and is most in agreement with the child for physical outcomes in comparison with emotional/psychological domains.[33] In terms of weaknesses, due to the retrospective nature of this study, it is at risk of selection bias, and only associations can be identified by analysis. This study does not represent the entire spectrum of pediatric patient ages, and as such is not generalizable to the entire pediatric population. Though all surgeons involved in the procedures represented in the current study underwent fellowship training in the field of sports medicine, the retrospective nature of this study precluded the use of a standard operative protocol. This restricted the ability of the authors to share the indications for technical details, such as drilling techniques, autograft selection, and screw placement in aperture fixation. This study was unable to account for the varying rehabilitation protocols that may have been utilized which also can affect ACLR recovery, RTS, and reinjury rates, but does represent the typical scenario where even in a single surgeon's practice, patients are receiving care from a variety of physical therapy facilities and providers. This study did not include mental health diagnoses as a study variable which may influence the PRO results as well. The number of patients who experienced reinjury was small which may have affected the significance of the comparative analysis. Limb length alignment films were not routinely performed before ACLR, so varus/valgus deformities and growth disturbances resulting from ACLR could not be determined. Finally, this study was conducted at one institution within a large metropolitan area, which may impact the generalizability of these results.

CONCLUSION

This study found improved SANE and KOOS scores in the age 16 and younger population after ACLR that were negatively impacted by reinjury and reoperation. Patients were typically treated with transphyseal techniques with BTB autograft, and there was no difference in the technique used in reinjured and nonreinjured patients. For most patients in this group, ACLR can help them RTS and achieve improved outcomes, but a cautious approach should be taken as rates of reinjury and reoperation are relatively high. Future research should evaluate the appropriate time for RTS in this population to minimize adverse outcomes.

REFERENCES

1. Tepolt FA, Feldman L, Kocher MS. Trends in pediatric ACL reconstruction from the PHIS database. *J Pediatr Orthop*. 2018;38: e490–e494.
2. Buckle C, Wainwright A. A systematic review of long-term patient-reported outcomes for the treatment of anterior cruciate ligament injuries in the skeletally immature. *J Child Orthop*. 2018;12:251–261.
3. Beck NA, Lawrence JTR, Nordin JD, et al. ACL tears in school-aged children and adolescents over 20 years. *Pediatrics*. 2017;139:e20161877.
4. Fabricant PD, Lakomkin N, Sugimoto D, et al. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. *Phys Sportsmed*. 2016;44:257–262.

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5. Dingel A, Aoyama J, Ganley T, et al. Pediatric ACL tears: natural history. *J Pediatr Orthop*. 2019;39:S47–S49.
6. Group M, Wright RW, Huston LJ, et al. Predictors of patient-reported outcomes at 2 years after revision anterior cruciate ligament reconstruction. *Am J Sports Med*. 2019;47:2394–2401.
7. Nwachukwu BU, Sullivan SW, Rauck RC, et al. Patient-reported outcomes and factors associated with achieving the minimal clinically important difference after ACL reconstruction: results at a mean 7.7-year follow-up. *JBJS Open Access*. 2021;6:e21.00056.
8. Kaeding CC, Pedroza AD, Reinke EK, et al. Risk factors and predictors of subsequent ACL injury in either knee after ACL reconstruction: prospective analysis of 2488 primary ACL reconstructions from the MOON cohort. *Am J Sports Med*. 2015;43: 1583–1590.
9. Pennock AT, Johnson KP, Turk RD, et al. Transphyseal Anterior Cruciate Ligament Reconstruction in the Skeletally Immature: Quadriceps Tendon Autograft Versus Hamstring Tendon Autograft. *Orthop J Sports Med*. 2019;7:2325967119872450.
10. Cordasco FA, Black SR, Price M, et al. Return to sport and reoperation rates in patients under the age of 20 after primary anterior cruciate ligament reconstruction: risk profile comparing 3 patient groups predicated upon skeletal age. *Am J Sports Med*. 2019; 47:628–639.
11. Christino MA, Tepolt FA, Sugimoto D, et al. Revision ACL reconstruction in children and adolescents. *J Pediatr Orthop*. 2020; 40:129–134.
12. Dekker TJ, Godin JA, Dale KM, et al. Return to sport after pediatric anterior cruciate ligament reconstruction and its effect on subsequent anterior cruciate ligament injury. *J Bone Joint Surg Am*. 2017;99:897–904.
13. Pennock AT, Bomar JD, Manning JD. The creation and validation of a knee bone age atlas utilizing MRI. *J Bone Joint Surg Am*. 2018;100:e20.
14. Williams GN, Taylor DC, Gangel TJ, et al. Comparison of the single assessment numeric evaluation method and the Lysholm score. *Clin Orthop Relat Res (1976-2007)*. 2000;373:184–192.
15. Roos EM, Roos HP, Lohmander LS, et al. Knee injury and osteoarthritis outcome score (KOOS)—development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998; 28:88–96.
16. Webster KE, Feller JA. Younger patients and men achieve higher outcome scores than older patients and women after anterior cruciate ligament reconstruction. *Clin Orthop Relat Res*. 2017;475:2472–2480.
17. Chicorelli AM, Micheli LJ, Kelly M, et al. Return to sport after anterior cruciate ligament reconstruction in the skeletally immature athlete. *Clin J Sport Med*. 2016;26:266–271.
18. Ellman MB, Sherman SL, Forsythe B, et al. Return to play following anterior cruciate ligament reconstruction. *J Am Acad Orthop Surg*. 2015;23:283–296.
19. Shelbourne KD, Sullivan AN, Bohard K, et al. Return to basketball and soccer after anterior cruciate ligament reconstruction in competitive school-aged athletes. *Sports Health*. 2009;1:236–241.
20. Shelbourne KD, Gray T, Haro M. Incidence of subsequent injury to either knee within 5 years after anterior cruciate ligament reconstruction with patellar tendon autograft. *Am J Sports Med*. 2009;37: 246–251.
21. Andernord D, Desai N, Björnsson H, et al. Patient predictors of early revision surgery after anterior cruciate ligament reconstruction: a cohort study of 16,930 patients with 2-year follow-up. *Am J Sports Med*. 2015;43:121–127.
22. Zacharias AJ, Whitaker JR, Collofello BS, et al. Secondary injuries after pediatric anterior cruciate ligament reconstruction: a systematic review with quantitative analysis. *Am J Sports Med*. 2021;49:1086–1093.
23. DeFrancesco CJ, Storey EP, Flynn JM, et al. Pediatric ACL reconstruction and return to the operating room: revision is less than half of the story. *J Pediatr Orthop*. 2019;39:516–520.
24. Geffroy L, Lefevre N, Thevenin-Lemoine C, et al. Return to sport and re-tears after anterior cruciate ligament reconstruction in children and adolescents. *Orthop Traumatol Surg Res*. 2018;104: S183–S188.
25. Dietvorst M, Brzoskowski MH, van der Steen M, et al. Limited evidence for return to sport testing after ACL reconstruction in children and adolescents under 16 years: a scoping review. *J Exp Orthop*. 2020;7:83.
26. Greenberg EM, Greenberg ET, Albaugh J, et al. Anterior Cruciate Ligament Reconstruction Rehabilitation Clinical Practice Patterns: A Survey of the PRiSM Society. *Orthop J Sports Med*. 2019;7: 2325967119839041.
27. Pagliazzi G, Cuzzolin M, Pacchiarini L, et al. Physeal-sparing ACL reconstruction provides better knee laxity restoration but similar clinical outcomes to partial transphyseal and complete transphyseal approaches in the pediatric population: a systematic review and meta-analysis. *Knee Surg Sports Traumatol Arthrosc*. 2023;31:206–218.
28. Ho B, Edmonds EW, Chambers HG, et al. Risk factors for early ACL reconstruction failure in pediatric and adolescent patients: a review of 561 cases. *J Pediatr Orthop*. 2018;38:388–392.
29. Zhang JK, Barron J, Arvesen J, et al. Effect of patient resilience and the single assessment numeric evaluation (SANE) score on return to sport following anterior cruciate ligament reconstruction surgery. *Arch Bone Jt Surg*. 2021;9:512.
30. Taylor DC, Posner M, Curl WW, et al. Isolated tears of the anterior cruciate ligament: over 30-year follow-up of patients treated with arthrotomy and primary repair. *Am J Sports Med*. 2009;37:65–71.
31. Muller B, Yabroudi MA, Lynch A, et al. Defining thresholds for the patient acceptable symptom state for the IKDC subjective knee form and KOOS for patients who underwent ACL reconstruction. *Am J Sports Med*. 2016;44:2820–2826.
32. Magnitskaya N, Mouton C, Gokeler A, et al. Younger age and hamstring tendon graft are associated with higher IKDC 2000 and KOOS scores during the first year after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2020;28:823–832.
33. Narayanan UG. Outcomes in pediatric orthopedics. *Evidence-Based Orthopedics*. 2021;173:1017–1028.

