The Incidence of Second Anterior Cruciate Ligament Injury in Young Athletes is not Influenced by Time to Return to Sport[1]

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Introduction

The incidence of second anterior cruciate ligament (ACL) injury among the population of young, adolescent athletes is alarming, with recent studies reporting rates as high as 30%.[1-3] Research has shown that this incidence is highest within the first 2 years following return to sport (RTS) after primary ACL reconstruction (ACLR).[1, 4] Furthermore, within the first 12 months after RTS, the incidence rate of second ACL injury is 15 times higher for a young individual after ACLR compared to that of a young athlete without a history of ACL injury.[5] These high rates have called into question the timing of RTS among the population of young, adolescent athletes after primary ACLR.

Following early studies suggesting that a safe return to sport could occur within 3-4 months of ACLR,[6-8] the time point of 6 months has more recently been clinically and publically perceived as a safe amount of time for return to sports following ACLR.[9-11] In the most recent systematic review of published criteria for unrestricted RTS following ACLR, the amount of post-operative time was the only criteria used in 32% of the studies. Of the studies using post-operative time as criteria, 53% listed 6 months or greater as an acceptable time for unrestricted return to sport. Additionally, 15% of the studies in this review utilized the amount of post-operative time and subjective criteria, indicating the perceived importance of patient-reported function as return to sport criteria in addition to time from surgery.[12]

[1] This work was made possible due to the continuous support and guidance of co-authors, Dr. Laura Schmitt, PT, PhD, Staci Thomas, MS, and Dr. Mark Paterno, PT, PhD, ATC

Despite the notion of 6 months being a widely accepted time for safe RTS following ACLR, aggregated results from the current literature suggest the time range for RTS among young, adolescent athletes is between 5 and 12 months.[13-16] More recently, researchers have advocated for a delay in RTS following primary ACLR as a means of second ACL injury risk reduction. Grindem and colleagues found a reduced risk in knee injury of 51% for every month of delayed RTS up to nine months following primary ACLR in a population of adult athletes participating in pivoting sports.[17] Within a cohort of younger athletes, the majority of whom still had open physes, Dekker et al. found a longer time between ACLR and RTS to offer a protective effect, with each month of delay further reducing the risk of second ACL injury.[15] Furthermore, new literature suggests the achievement of baseline joint health and function after ACLR can take up to 24 months.[18] A lack of consensus regarding the effect of time from ACLR to RTS on the influence of second ACL injury among a population of young, adolescent athletes has yet to be identified. Additionally, the effect of patient-reported function at time of RTS on the incidence of second ACL injury has not been studied in this population.

Therefore, the purpose of this study was twofold; to investigate the effect of time from ACLR to return to sport on the incidence of 2nd ACL injury among a population of young, adolescent athletes, and to investigate the influence of patient-reported function at time of return to sport on the incidence of 2nd ACL injury. Our hypothesis was that incidence of 2nd ACL injury among a population of young, adolescent athletes would not be influenced by time to return to sport or patient-reported function following primary ACLR.

Methods

Participants

This study was conducted as part of the ACL Reconstruction Long-term outcomes in Adolescents and Young adults (ACL-RELAY) Study at Cincinnati Children's Hospital, which is an ongoing longitudinal study of outcomes following ACLR among young athletes. The cohort for this study included 184 young athletes (mean age=16.8±3.0 years) recruited from local orthopaedic practices and physical therapy clinics in the greater Cincinnati and Northern Kentucky areas from 2007 to 2016. All participants were recruited following primary ACLR and were enrolled in the study within 4 weeks of receiving medical clearance to return to unrestricted sports participation by their surgeon and rehabilitation specialist. Inclusion criteria for this study required that participants (1) be between the ages of 10 and 25, (2) with primary, unilateral ACLR, (3) have completed rehabilitation program after ACLR, (4) were cleared for unrestricted sports participation by a surgeon and treating rehabilitation specialist, and (5) planned to return to cutting and pivoting sports on a regular basis (50 hours or more per year). The decision to allow return-to-sport clearance, the criteria used in return-to-sport decision-making, and the rehabilitation program after ACLR were not monitored or controlled by the current study. All baseline data for this study were collected within 4 weeks of return-to-sport clearance. Participants with all grafts types (bone-patellar tendon-bone autograft, hamstring tendon autograft, allograft) as well as those with meniscus repair or partial meniscetomy at the time of ACLR were included in the study. Exclusion criteria consisted of (1) a history of low back pain requiring the care of a physician in the past year, (2) lower extremity injury or surgery (beyond primary ACL injury) requiring the care of a physician in the past year, (3) a concomitant ligament injury during the ACL injury (beyond grade 1 medial collateral ligament injury), and (4) skeletal immaturity, as identified by an ACL reconstruction procedure that was modified due to open epiphyseal plates in the tibia or femur. This study was approved by the Cincinnati

Children's Hospital Medical Center internal Institutional Review Board, and written formal consent and/or parental permission were obtained prior to testing from all participants and/or the parent/guardian, when required.

Demographic and anthropometric data (age, height, and weight) and patient-reported outcome scores were collected for all participants at time of RTS. Data collection occurred during single testing sessions within 4 weeks of the patient's medical clearance to RTS. At this time, patients were categorized into 3 groups according to time from ACLR to RTS; early RTS group (<6 months post-operative) (n=19), average RTS group (6-9 months post-operative) (n=106), and late RTS group (≥9 months post-operative) (n=63). All participants were then tracked for 24 months to record the incidence of a second ACL injury to either the involved limb or contralateral limb.

Patient-reported Function

At the time of RTS, each participant completed patient-reported outcome measures including the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC)[19] and the Knee Injury and Osteoarthritis Outcome Score (KOOS).[20] These patient-reported outcome measures, among others, are commonly utilized throughout rehabilitation after ACLR in order to evaluate improvement or deterioration of self-reports of knee function and also to aid in RTS decision-making.[21, 22]

The IKDC consists of 18 items with response types that include 5-point Likert scales, 11-point Likert scales, and dichotomous yes or no answers. Each item is weighted according to the number of response options. The difference between the raw score and the lowest possible score is divided by the range of possible scores multiplied by 100.[19] The total score is expressed as a single index, with higher scores representing higher knee function. The IKDC has been shown to

be valid, reliable, and responsive in a population of patients following ACLR.[19, 23, 24] This instrument is frequently used for patients following knee injury as an assessment of symptoms, function, and sport-related activity. In addition, this tool has been validated in a population of pediatric, adolescent, and young adult patients with a variety of knee pathologies.[25] The IKDC has been shown to demonstrate positive test-retest reliability, with ICC of 0.87-0.98, in addition to Cronbach's α values ranging from 0.77 to 0.97, which indicated positive internal consistency.[26]

The KOOS is a knee-specific patient-reported outcome measure that was also validated for patients following ACLR.[20] Commonly administered to patients with ACL injury, meniscus injury, or post-traumatic osteoarthritis, the KOOS was developed as a measure of self-reported knee function to be used in research studies, with the intent to conduct long-term follow-up.[21] The KOOS contains 42 items within separately scored subscales used to assess different health dimensions: Pain (nine items), Symptoms (seven items), Activities of Daily Life Function (seventeen items), Sport and Recreation Function (five items), and Knee-related Quality of Life (four items). All items are scored 0-4, and the five subscale scores are transformed to a 0-100 scale, with higher scores representing higher knee function within each dimension. All subscales of the KOOS demonstrate positive test-retest reliability (ICC = 0.75-0.93) and internal consistency (Cronbach's α = 0.74-0.96).[27]

Statistical Analysis

One-way ANOVAs were used to identify differences in age, height, and weight between groups. One-way ANOVAs were also used to determine between group differences in IKDC and KOOS scores. Crude incidence of 2nd ACL injury was identified within each group and chi-squared analyses were used to determine the difference in proportion of 2nd ACL injuries

between groups. For the participants who suffered a 2nd ACL injury, a one-way ANOVA was utilized to detect differences in time from date of RTS to date of 2nd ACL injury between groups. Statistical significance for all comparisons was determined a priori as $P<.05$. All statistical analyses were performed using IBM SPSS (version 23.0) software.

Results

No significant differences in age ($p=0.40$), height ($p=0.65$), or weight (0.92) existed among the early RTS, average RTS, and late RTS groups at baseline testing (Table 1). Additionally, no differences between groups were seen in patient-reported function on the IKDC and all KOOS subscales, or between those who sustained 2nd ACL injury versus those who did not within each group at time of RTS (Table 2). With respect to 2nd ACL injury, there were no group differences ($p=0.716$) in the proportion of participants within each group who suffered a 2nd ACL injury within 24 months of RTS date (Table 3). Among those participants, an analysis of time between RTS and date of 2nd ACL injury also revealed no differences ($p=0.246$) (Table 4).

Table 1. Demographic Data

	Early RTS (n=19)	Average RTS (n=105)	Late RTS (n=60)	p-value
Age (yr)	17.1 ± 2.6	16.5 ±2.6	16.6 ± 2.6	0.57
Height (cm)	169.6 ± 10.2	168.0 ± 11.9	166.7 ± 9.5	0.56
Weight (kg)	68.2 ± 15.6	67.8 ± 16.8	66.2 ± 15.2	0.80

Demographic data reported as mean ± standard deviation. RTS, return to sport; yr, years; cm, centimeters; kg, kilograms

Table 2. Patient-reported Outcome Scores at the Time of RTS

Patient-reported Outcome Measure	Early RTS Group			Average RTS Group			Late RTS Group		
	2nd ACL (n=5)	No 2nd ACL (n=14)	p-value	2nd ACL (n=20)	No 2nd ACL (n=86)	p-value	2nd ACL (n=13)	No 2nd ACL (n=50)	p-value
IKDC	88.8 ±10.8	83.6 ±12.3	0.37	93.3±6.1	89.8 ±10.1	0.14	90.4±7.1	88.3 ±11.7	0.55
KOOS pain	91.2 ±5.8	90.8±7.7	0.91	95.8±4.2	93.2±8.7	0.21	93.8±7.9	92.4±8.7	0.62
KOOS Symptom	77.2 ±15.7	81.7 ±15.3	0.58	90.3±9.6	86.8 ±12.8	0.26	91.6±7.1	85.2 ±15.2	0.14
KOOS ADL	98.0±1.4	97.1±5.1	0.72	98.6±2.3	98.0±5.0	0.57	96.3 ±10.1	97.1±4.6	0.67
KOOS Sports	82.0 ±11.5	79.6 ±12.6	0.72	92.5±8.2	87.2 ±13.9	0.11	86.5 ±13.0	84.4 ±16.9	0.67
KOOS QOL	66.4±7.2	68.8±22.7	0.82	80.1±17.8	72.2±19.9	0.11	81.6±14.3	73.2 ±19.0	0.14

Data reported as mean score ± standard deviation. RTS, Return to Sport; 2nd ACL, 2nd ACL injury; IKDC, International Knee Documentation Committee Survey; KOOS, Knee Injury and Osteoarthritis Outcome Score; ADLs, Activities of Daily Living

Table 3. Incidence of 2nd ACL injury

Group	2nd ACL Injury	Proportion
Early RTS	5/19	26.3%
Average RTS	20/105	19.0%
Late RTS	13/60	21.7%

Table 4. Time from RTS to date of 2nd ACL Injury

Group	Time from RTS to 2nd Injury (months)	p-value
Early RTS (n=5)	4.6 (±4.3)	P=0.24
Average RTS (n=20)	8.1 (±5.7)	
Late RTS (n=13)	5.3 (±4.8)	

Discussion

The purpose of this study was twofold; to investigate the effect of time from ACLR to return to sport on the incidence of 2nd ACL injury among a population of young, adolescent

athletes, and to investigate the influence of patient-reported function at time of return to sport on the incidence of 2nd ACL injury. In accordance with our hypothesis, neither time to RTS nor patient-reported function influenced the incidence of second ACL injury in this population. Furthermore, no differences in time between RTS and date of second injury were found among participants in the early, average, and late RTS groups who suffered a second ACL injury.

Time between ACLR and RTS

For the young, athletic participants in this study, time between primary ACLR and RTS did not influence the incidence of second ACL injury. Despite returning to sport at varying time points after surgery, the proportion of athletes that suffered a second ACL injury was 26.3%, 18.9%, and 22.2% for the early, average, and late RTS groups, respectively. These high rates that are similar to those reported in previous studies of young athletes participating in pivoting sports,[1-3] the population at highest risk of subsequent injury for either the ipsilateral or contralateral ACL.[2, 3, 28-31] This finding calls into question the belief that time from surgery to RTS is the most important variable, in relation to other variables, related to the incidence of second ACL injury, particularly among young athletes. Specifically, non-temporal related factors specific to the patient, such as altered movement patterns and deficits in postural stability may play a greater role in 2nd ACL injury risk.[32]

This study result is contrary to a recent report that suggests a delay in time to RTS may be protective against second ACL injury in other populations. Utilizing a cohort of pediatric patients after primary ACLR, with a wide time to RTS range of 2-24 months, Dekker and colleagues found a 32% incidence rate of second ACL injury, which is similar to that found in this study and in previous research on young athletes.[1-3] Interestingly, the authors also reported an increased protective effect against second ACL injury for every month of delayed RTS. While

this finding may suggest that a delayed return to sport may be protective of a second ACL injury in young athletes, several factors were present in these data which may have influenced the results. Specifically, this study included a relatively small sample of participants, the majority of whom had open physes, and some of whom were not medically cleared for sports participation at time of RTS. This premature RTS by some athletes may have inflated second injury rates for those returning to sports early, prior to medical clearance. Furthermore, the RTS timeframes used for analysis relied on retrospective patient report instead of prospective, clinician documentation in real time, potentially inducing a recall bias not present in our study. In the present study, young athletes were not enrolled unless they had been cleared for full participation in sports by both a surgeon and a rehabilitation specialist. Additionally, the prospective study design of our work, as compared to the retrospective review performed by Dekker et al., allowed for real-time capture of clearance to RTS, patient-reported function, and incidence of second injury.

In a population of older athletes returning to pivoting sports following primary ACLR, Grindem et al. found a 51% reduction in subsequent injury for every one month delay in RTS, up to nine months.[17] However, this protective effect of time was not specific to second ACL injury, but inclusive of all knee injuries to the ipsilateral limb only, limiting the applicability of this finding to our study question. The inclusion of athletes up to 60 years of age, and those who participated in pivoting sports at the non-competitive level may have contributed to the differences in second ACL injury rates. Participants in our study had all intended to return to Level I/II pivoting or cutting sports after ACLR, likely increasing the amount of athletic exposures after RTS compared to older, less active patients. Additionally, the mean time to RTS in this cohort was similar to that of our cohort at 8.1±5.7 months post-operatively, however, the

authors also controlled for both preoperative and postoperative rehabilitation programs, which may not be generalizable to the wider population of young athletes after ACLR.

Patient-reported function at time of RTS

Patient-reported function at time of RTS was similar among the three groups, regardless of time between ACLR and RTS, demonstrating no influence on the high incidence of second ACL injury among young athletes. Additionally, patient-reported function did not differ between athletes who sustained a second ACL injury versus those who did not within each of the three groups. The effect of patient-reported function on the incidence of second ACL injury incidence has not been studied extensively in the literature, however, associations between patient-reported function and performance on other commonly utilized RTS criteria have been made. In previous work from the ACL-RELAY Study, an algorithm was developed to identify young athletes at high risk of second ACL injury by way of standard clinical measures. In conjunction with high functional performance, these authors found high self-reported confidence, as measured by question 3 of the KOOS quality of life subscale, to be a risk factor of second ACL injury among young, athletic females.[33] Patients from the same database with higher self-reported fear at time of RTS were found to be 13 times more likely to suffer a second ACL injury within 24 months after RTS.[34] This research group has also demonstrated that young, athletic patients with higher IKDC scores demonstrate increased strength and functional performance compared to those with lower scores.[35]

In spite of this relationship between patient reports on the IKDC and patient strength and performance, the current study found no differences in patient-reported function on the IKDC among the early, average, and late RTS groups, similar to findings reported in previous studies that have investigated patient-reported function at time of RTS.[13, 17, 36] In their analysis of older,

pivoting athletes after primary ACLR, Grindem and colleagues found no differences in patient-reported function scores among those who reinjured the involved knee compared to those who did not despite differences between groups in the achievement of RTS criteria at time of RTS.[17] In a study that compared outcomes between adolescent and adult athletes returning to sport following ACLR, no differences in mean KOOS scores were found between groups at both 8 and 12 months after ACLR. Interestingly, these authors also reported the presence of muscle function deficits at time of RTS in the majority of the participants despite similar self-reports of function.[36] While patient-reported function alone may not influence the incidence of second ACL injury among young athletes, the emerging literature would suggest it should be an essential consideration in the RTS decision-making process.

Time Between RTS and Second Injury

For the young athletes in this study who sustained a second ACL injury, the amount of time between RTS and second injury did not differ between the early, average, and late RTS groups. The majority of these second injuries occurred within the first 12 months after RTS, which reflects the incidence rates for this population reported in the literature.[1, 5] This finding further emphasizes that factors aside from time to RTS may be contributing factors to the high incidence of second ACL injury within the first year following RTS. Previous studies have reported such factors to include young age,[37] graft type,[37] return to competitive sports,[14, 37] altered biomechanics,[32, 38] strength deficits,[39] patient-reported function,[33, 34] and functional performance.[33, 39] Furthermore, recent work has suggested that the complete achievement of RTS criteria may have a protective effect against second ACL injury, regardless of the time taken to achieve all criteria.[13, 14, 39]

Contributors of High Incidence of Second ACL Injury

The results of this study and others suggest that factors aside from time may play a strong role in the high incidence of second ACL injury among young athletes. If time alone is to be used as criteria for safe RTS, recent literature would suggest young athletes need to delay RTS for up to two years in order to achieve baseline joint health and function.[18] Our study results demonstrate no difference in second ACL injury rates with respect to time after ACLR, however, the majority of the second ACL injuries occur within the first 12 months after RTS, regardless of when a young athlete returns to sport within the first year after ACLR. In response to the high incidence of second ACL injury seen within these first 12 months, other researchers have called for the enhancement and adherence to strict RTS criteria, as most young athletes are unable to meet recommended criteria at time of RTS, yet return to full competition nonetheless.[13] Fortunately, similar to RTS criteria, the time between ACLR and RTS is a modifiable factor that warrants further investigation, particularly beyond the 12-month postoperative time point. Nonetheless, further research on modifiable factors aside from time, such as functional performance, movement patterns, psychological readiness, and achievement of RTS testing may require more attention for prevention of 2nd ACL injury.

Limitations

This study is not without limitations. The cohort was comprised of young, athletic individuals participating in pivoting sports, a larger proportion of whom were female. While the results from this sample of patients may not be representative of the wider population of individuals who undergo ACLR, the sample itself is representative of a population at high risk of sustaining a second ACL injury,[1, 5] therefore the investigation is highly warranted. Future research should look to expand this sample in order to determine if similar results would be

found among a heterogeneous sample that includes a similar number of young male participants. Furthermore, according to the RTS timeframes reported in the literature, a larger sample size would allow for a more in-depth investigation of participants that return prior to 6 months postoperatively and after 9 months postoperatively, the two groups of lower size in this study. This cohort did not include any participants that returned beyond the 18-month postoperative time point, which is representative of current clinical practice. However, the inclusion of these participants may provide additional insight to outcomes for individuals that delay RTS past the first year after ACLR. Finally, while all participants were cleared for unrestricted sports participation by a surgeon and rehabilitation specialist, the number and type of exposures after RTS was not controlled for. Future research on sports exposure following varying time points of RTS may provide further understanding of risk factors for second ACL injury among young athletes.

Conclusion

In summary, the length of time between ACLR and RTS had no influence on the incidence of second ACL injury among a population of young athletes who were cleared to RTS after ACLR. Furthermore, patient-reported function at time of RTS was similar among groups, regardless of time between ACLR and RTS. For the participants in each group that suffered a second injury, the time between RTS and second injury did not differ. Therefore, in the months between primary ACLR and RTS, factors aside from time, such as functional performance, movement patterns, psychological readiness, and achievement of RTS criteria may be more predictive of risk of second ACL injury. Particularly among young athletes, further research is

necessary in order to determine the optimization of this time in order to address the high incidence of second ACL injury.

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