IJSPT
INTERNATIONAL JOURNAL OF SPORTS PHYSICAL THERAPY

Weaver A, Ness B, Roman D, Giampetruzzi N, Cleland J. Short-Term Clinical Outcomes After Anterior Cruciate Ligament Reconstruction In Adolescents During The COVID-19 Pandemic. *IJSPT*. 2022;17(4):585-592.

Original Research

Short-Term Clinical Outcomes After Anterior Cruciate Ligament Reconstruction In Adolescents During The COVID-19 Pandemic

Adam Weaver[1] [a], Brandon Ness[2], Dylan Roman[1], Nicholas Giampetruzzi[1], Joshua Cleland[2]

[1] Sports Physical Therapy, Connecticut Children's, [2] Doctor of Physical Therapy Program, Tufts University School of Medicine

Keywords: Adolescent, Anterior Cruciate Ligament Reconstruction, COVID, Strength, Rehabilitation

https://doi.org/10.26603/001c.35668

International Journal of Sports Physical Therapy

Vol. 17, Issue 4, 2022

Background/Purpose

The COVID-19 pandemic has impacted adolescents across multiple areas of health. While many factors influence outcomes following anterior cruciate ligament reconstruction (ACLR), the impact of the COVID-19 pandemic on early patient outcomes after ACLR is currently unknown in an adolescent population. The purpose of this study was to determine if short-term clinical outcomes were different in adolescents after ACLR for those who underwent surgery pre-COVID versus during the COVID-19 pandemic timeframe.

Design

Retrospective cohort

Methods

A retrospective review of records occurred for patients who underwent ACLR with a quadriceps tendon autograft. Two separate review timeframes were defined according to date of surgery (control: September 2017 - October 2019; COVID: March 2020 - May 2021). Patients were classified into pre-COVID (control) and COVID groups by surgical date and were then age- and sex-matched. Three-month postoperative outcomes were included for analysis, including normalized isometric quadriceps and hamstring peak torque, Anterior Cruciate Ligament – Return to Sport after Injury (ACL-RSI), and the Pedi International Knee Documentation Committee Form (Pedi-IKDC) scores.

Results

Sixty patients met the inclusion criteria (34 females, 56.7%). Follow-up testing occurred at 3.2 months (98.13 ± 14.91 days) postoperative. A significant difference was found between groups for normalized quadriceps peak torque on the uninvolved limb, with the control group (2.03 ± 0.47 Nm/kg) demonstrating decreased peak torque compared to the COVID group (2.49 ± 0.61 Nm/kg) ($p = 0.002$, effect size (d) = 0.84). For the involved limb, no difference in normalized quadriceps peak torque was observed between the control group (1.25 ± 0.33 Nm/kg) and those who underwent surgery during the COVID-19 pandemic (1.49 ± 0.70 Nm/kg) ($p = 0.09$). No differences were identified between groups for any of the other strength outcomes ($p = 0.31 – 0.87$). Similarly, no differences in patient reported outcomes were found for Pedi-IKDC or ACL-RSI between groups ($p = 0.12 – 0.43$).

a **Corresponding author:**
Adam Weaver, PT, DPT
Connecticut Children's
399 Farmington Avenue
Farmington, CT 06032
Email: aweaver@connecticutchildren.org
Phone: 410-474-4550
Fax: 860-837-9341

Conclusion

At roughly three months after ACLR, normalized quadriceps peak torque on the uninvolved limb was reduced by 18.5% for adolescents who underwent surgery pre-COVID versus during the COVID-19 pandemic timeframe. No group differences were observed for other isometric strength outcomes, Pedi-IKDC, or ACL-RSI scores.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is one of the more common sports injuries, and 75% of high school athletes are likely to undergo surgical intervention with the aim to restore knee stability.[1] Though patients who undergo ACL reconstruction (ACLR) have been shown to have superior outcomes for knee function and symptoms compared those who choose non-surgical intervention,[2] outcomes are less than desirable in the young athletic population. Twelve months following ACLR, less than 50% of jumping, pivoting, and cutting athletes under the age of 25 are expected to return to sport.[2] Additionally, of those that do return, one in four individuals are expected to experience either graft failure or a contralateral injury.[3]

The novel coronavirus (COVID-19) has impacted daily human activities around the world, and there is mounting evidence that adolescents during this time experienced increases in sedentary behavior, physical inactivity, and disrupted sleep schedules.[4] Prior to the COVID-19 pandemic, less than 10% of school-aged children were achieving recommended amounts of 30-60 minutes of daily moderate-vigorous physical activity.[5] Since the beginning of the pandemic, only 2.6% of healthy adolescents were reaching recommended physical activity goals,[6] and sedentary behaviors including television, video games and computer usage increased 20-66%.[7,8] Along with these COVID-related changes in adolescent health and behavior, athletes rehabilitating from ACLR also experienced the impact of COVID-19.

In the United States, state government mandates included closing of gymnasiums, fitness centers, athletic fields, and courts, as well as school systems implementing remote learning to help mitigate virus transmission. Additionally, there were significant restrictions on elective orthopedic and physical therapy services during this time period.[9] COVID-19 caused rapid changes in the standard of care and implementation of telemedicine for many sports medicine providers, yet many other challenges persisted for these patients including limited access to in-person rehabilitation services, restricted access to weight rooms and training facilities, and a lack of resources to perform sport specific activities. In addition, there were other unintended consequences resulting from sheltering in place. Thirty-six percent of parents reported decreased physical activity levels in children and adolescents,[10] along with higher rates of anxiety, depression, and stress.[11] This is important, as stress and limited social support can negatively affect desired outcomes following ACLR.[12] These new challenges during the COVID-19 pandemic added to an already complex rehabilitation process.

A range of patient self-report and clinical outcome measures have been associated with the likelihood of successful return to sport after ACLR and are important to examine throughout rehabilitation. Measurement of knee strength after ACLR is commonly used in the return to sport decision making process, as adequate strength outcomes have shown to improve the likelihood of returning to prior level of sport[13,14] and reducing the risk of secondary ACL injury.[15] Early functional and isolated knee extension strength at six to twelve weeks post ACLR have been predictive of hop test and knee strength outcomes at time of return to play,[16–18] which highlights the importance of early strength testing after ACLR in order for clinicians to modify rehabilitation strategies accordingly. Further, psychological measures of self-efficacy, self-motivation, and optimism were predictive of an athlete's ability to return to sport, knee symptoms, and compliance with rehabilitation.[12] While many factors influence outcomes following ACLR, the impact of the COVID-19 pandemic on early patient outcomes after ACLR is currently unknown in an adolescent population. Therefore, the purpose of this study was to determine if short-term clinical outcomes were different in adolescents after ACLR for those who underwent surgery pre-COVID versus during the COVID-19 pandemic timeframe. The authors hypothesized that strength and patient reported outcomes would be different between groups.

METHODS

DESIGN

The Institutional Review Board at Connecticut Children's approved the study. A retrospective review of records occurred for consecutive patients who underwent ACLR at the institution during the following timeframes according to date of surgery: control group between September 2017 and October 15, 2019 (pre-COVID group), and between March 2020 and May 2021 (COVID Group). The pre-COVID surgical timeframe was determined by available data that included only patients who underwent ACLR with the use of quadriceps autograft. The end date of the control group (pre-COVID) was selected to ensure follow up testing did not overlap with the COVID group. The surgical date range for the COVID group was selected as this coincided with the temporary pandemic-related closure of Connecticut Children's, as well as the many resources used during ACLR rehabilitation (physical therapy clinics, fitness centers, etc.) in the state of Connecticut. Demographic, surgical, and clinical outcome data were collected.

PATIENTS

The inclusion criteria were as follows: 1) age 10-20 years old, 2) underwent primary ACLR using a quadriceps autograft, and 3) completed standard ACLR testing procedures between 60 -140 days (2 – 4.5 months) postoperative. Patients were included if a concomitant meniscal procedure was performed at the time of surgery. A prior investigation

demonstrated that the presence of meniscal repair did not influence functional outcomes after ACLR.[19] Patients were excluded for any multi-ligament knee surgery and all contralateral or secondary ACLR. Groups were matched according to age and sex. In the event groups were unbalanced according to sex, randomization software[20] was used to select patients for inclusion to achieve balanced groups.

All patients in the sample underwent surgery with one of five different orthopedic sports medicine surgeons at a single surgical center. A standardized rehabilitation program was provided to all patients with recommendations to seek supervised postoperative rehabilitation. All strength testing was performed at Connecticut Children's.

PROCEDURES

A standardized strength testing protocol was applied for all patients within a comprehensive battery of tests, including range of motion, strength testing, dynamic movement evaluation, and patient reported outcomes in conjunction with their 3-month post-operative surgeon visit. A sports medicine trained physical therapist at Connecticut Children's administered the tests.

An isokinetic dynamometer (Humac CSMI USA, Stoughton, MA, USA) was used to measure maximum isometric muscle torque. Patients were positioned in short sitting with their trunk and thigh supported with straps and hip joint positioned in 90 degrees of flexion. The dynamometer arm was secured proximal to the ankle joint. The uninvolved limb's quadriceps and hamstring strength were assessed prior to the involved limb. The therapist provided verbal encouragement to the patient throughout the test to deliver maximal effort. Measuring quadriceps and hamstring peak torque using this method was shown to be reliable in adults[21,22] and children.[23]

Isometric quadriceps and hamstring torque was assessed with the knee positioned at 60 degrees of knee flexion with gravity correction applied.[24] Two practice trials and five test trials were performed. Of the five trials, the maximum peak torque measurement was collected and documented in newton-meters (Nm). The limb symmetry index (LSI) was calculated as the ratio of peak torque between the involved limb and uninvolved limb and expressed as a percentage. Normalized peak torque was expressed relative to the patient's body mass and recorded for analysis (Nm/kg).[23,24]

Patients completed either the Pedi International Knee Documentation Committee Subjective Knee Evaluation Form (patients under age 18)[25] or the 2000 IKDC Subjective Knee evaluation form (patients 18 and older).[26] The reliability and validity of the Pedi-IKDC has been shown to be acceptable in children and adolescents between the ages of 10 and 18.[25] The Anterior Cruciate Ligament- Return to Sport (ACL-RSI) is a validated 12 question scale to evaluate patients' confidence and psychological readiness related to emotions, confidence and risk appraisal after ACL injury.[27,28]

STATISTICAL ANALYSIS

SPSS version 26.0 (IBM Corp, Armonk, NY, USA) was used to perform the statistical analysis. Mean values, standard deviations, and 95% confidence intervals were calculated for all outcomes including normalized quadriceps peak torque, normalized hamstring peak torque, Pedi-IKDC, and ACL-RSI. Normal distribution of the data was examined using Shapiro-Wilk tests. In cases where non-normal distribution of data was observed, the nonparametric testing equivalent was used. Group differences were evaluated using independent samples t-tests (parametric test) or Mann-Whitney U tests (nonparametric test). Chi-square tests were used to evaluate differences in group frequencies. Alpha level was set *a priori* to 0.05. Effect size (ES) was evaluated using Cohen's *d* according to the following criteria: < 0.2 (trivial), 0.2 – 0.49 (small), 0.5 – 0.79 (medium), and ⩾ 0.8 (large).[29] G*Power software (Version 3.1, University of Dusseldorf, Dusseldorf, Germany) was used to perform a *post hoc* power analysis.[30]

RESULTS

Sixty patients met the inclusion criteria (34 females, 56.7%) with 17 females and 13 males in each group, respectively (Table 1). No significant differences in age, height, mass, and time since surgery were observed between groups ($p > 0.05$). Testing occurred at roughly 3.2 months (98.13 ± 14.91 days) postoperative. Descriptive statistics are reported in Table 2. There was a statistically significant difference between groups in mean normalized quadriceps peak torque on the uninvolved limb, with those in the control group (2.03 ± 0.47 Nm/kg) demonstrating decreased peak torque compared to those who underwent surgery during the COVID-19 pandemic timeframe (2.49 ± 0.61 Nm/kg), $p = 0.002$, effect size (d) = 0.84. For the involved limb, no difference in normalized quadriceps peak torque was observed between the control group (1.25 ± 0.33 Nm/kg) and those who underwent surgery during the COVID-19 pandemic (1.49 ± 0.70 Nm/kg), $p = 0.09$. No differences were identified between groups for any of the other strength outcomes ($p = 0.31 – 0.87$). Similarly, no differences in patient reported outcomes were found for Pedi-IKDC or ACL-RSI between groups ($p = 0.12 – 0.43$). A *post hoc* power analysis demonstrated 89% statistical power with an alpha level set to 0.05 based on the observed effect size for the group differences in normalized quadriceps peak torque on the uninvolved limb.

DISCUSSION

This study sought to examine potential differences in short-term outcomes in adolescents who underwent ACLR surgery during the COVID-19 pandemic versus the pre-pandemic timeframe. The normalized quadriceps peak torque for the uninvolved limb was significantly greater for those who underwent surgery during the COVID pandemic with a large effect size compared to those who underwent surgery pre-COVID. There were no other group differences for normalized peak torque on the involved limb (quadriceps or hamstrings) or limb symmetry indices. Similarly, no differences were observed between groups for Pedi-IKDC and ACL-RSI scores. Other than the difference in quadriceps peak torque for the uninvolved limb, the results suggest similar short-

Table 1. Patient Demographics

		Total (n = 60)	Control (n = 30)	COVID (n = 30)	p value
	Female (%)	34 (56.7%)	17 (56.7%)	17 (56.7%)	
	Age (years)[a]	15.79 ± 1.70 (15.35, 16.23)	15.86 ± 1.52 (12.29, 16.43)	15.71 ± 1.89 (15.01, 16.41)	0.731
	Height (cm)[a]	168.78 ± 9.77 (166.26, 171.31)	167.56 ± 10.23 (163.73, 171.38)	170.01 ± 9.23 (166.54, 173.48)	0.335
	Mass (kg)[a]	69.04 ± 17.70 (64.46, 73.61)	68.30 ± 19.23 (61.12, 75.48)	69.78 ± 16.33 (63.68, 75.87)	0.779
	Time Since Surgery (days)	98.13 ± 14.91 (94.28, 101.99)	100.50 ± 16.54 (94.32, 106.68)	95.77 ± 12.92 (90.94, 100.59)	0.137
	Skeletally Immature	11 (18.3%)	4 (13.3%)	7 (23.3%)	0.506
Surgical Procedure	Isolated ACL reconstruction	24 (40%)	11 (36.7%)	13 (43.3%)	0.598
	ACL reconstruction with medial and/or lateral meniscus repair	36 (60%)	19 (63.3%)	17 (56.7%)	

Control group: pre-COVID pandemic surgical date; COVID group: surgical date occurred during COVID pandemic
[a]Values are expressed as mean ± SD, (95% confidence interval). ACL, anterior cruciate ligament

Table 2. Short-term Outcomes after ACL Reconstruction in Adolescents

	Total	Control	COVID	p value
Quadriceps peak torque – Involved (Nm/kg)	1.37 ± 0.56 (1.23, 1.51)	1.25 ± 0.33 (1.12, 1.37)	1.49 ± 0.70 (1.23, 1.75)	0.087
Quadriceps peak torque – Uninvolved (Nm/kg)	2.26 ± 0.59 (2.11, 2.41)	**2.03 ± 0.47 (1.85, 2.20)**	**2.49 ± 0.61 (2.26, 2.72)**	**0.002**
Quadriceps Limb Symmetry Index (%)	60.75 ± 17.65 (56.19, 65.31)	62.98 ± 15.86 (57.06, 68.90)	58.52 ± 19.28 (51.32, 65.72)	0.332
Hamstring peak torque – Involved (Nm/kg)	0.95 ± 0.25 (0.88, 1.01)	0.91 ±.20 (0.84, 0.99)	0.98 ± 0.30 (0.86, 1.09)	0.323
Hamstring peak torque – Uninvolved (Nm/kg)	1.22 ± 0.30 (1.14, 1.29)	1.18 ± 0.24 (1.09, 1.27)	1.25 ± 0.35 (1.13, 1.38)	0.313
Hamstring Limb Symmetry Index (%)	79.0 ± 15.7 (74.94, 83.05)	78.67 ± 13.06 (73.80, 83.55)	79.32 ± 18.18 (72.54, 86.12)	0.873
Pedi-IKDC	69.48 ± 14.64 (65.70, 73.26)	72.59 ± 13.17 (67.68, 77.52)	66.26 ±15.57 (60.55, 72.18)	0.115
ACL-RSI	60.73 ± 22.69 (54.87, 66.59)	63.07 ± 24.74 (53.83, 72.31)	58.39 ±20.58 (50.70, 66.07)	0.429

Control group: pre-COVID pandemic surgical date; COVID group: surgical date occurred during COVID pandemic. Pedi-IKDC: (Pediatric) International Knee Documentation Committee Subjective Knee form; ACL-RSI: Anterior Cruciate Ligament- Return to Sport after Injury.
Bolded values indicated significant differences between groups, p <0.05

term outcomes between patient groups who underwent surgery pre-COVID versus during the COVID-19 pandemic. These outcomes may add useful information when examining the impact of the COVID-19 pandemic on adolescents in the first three months after ACLR.

This study examined differences in short-term outcomes after ACLR in adolescents with a mean follow up time of 3.2 months after surgery, but it should be recognized that ACLR rehabilitation typically lasts six to nine months (or longer). Recently, Lee et al[31] showed that there were no differences in IKDC and Lysholm scores after ACLR during COVID-19 in an adult population (mean age 32.5 ± 14.5 years) with minimum one-year follow up. Further, postoperative orthopedic and physical therapy follow up visit attendance and satisfaction were reported, and further specified by in-person attendance versus telehealth delivery.[31] The current investigation did not examine the number of physical therapy visits, use of telehealth, or patient compliance with a home exercise program, which may be important factors for patient success, as athletes who were compliant with supervised physical therapy visits reported better function and were more than four times more likely to return to sport.[32] Although a short-term postoperative timeframe was specified for this study, there are several patient and COVID-related factors that likely impacted ACLR outcomes, yet their specific influence remains unclear. As the COVID-19 pandemic continues, longer follow up timeframes of one to two years postoperative may offer additional insight.

The early aims of ACLR rehabilitation are to restore range of motion, normalize gait, and regain quadriceps function. The importance of the restoration of quadriceps strength after ACLR has been well established in its rela-

tionship to return to play,[33] landing biomechanics,[34] osteoarthritis[35] and future re-injury.[15] Better performance during early stage strength testing after ACLR has been shown to be associated with greater self-reported function and greater readiness to return to functional activities.[36] Pedi-IKDC and ACL-RSI values were generally similar in both groups at three months postoperatively compared to a previous study with a similar age group (Pedi-IKDC: 64.2 ± 20.5; ACL-RSI: 69.2 ± 13.8).[36] However, patients in the current cohort had quadriceps limb symmetry indices that were 18% decreased, comparatively.[36] Some of the variation in strength outcomes between studies may be partly explained by differences in surgical procedures and patient group characteristics.

More recent data has shown the COVID-19 pandemic has continued to impact all aspects of society, and the delivery of physical therapy services was not spared. In outpatient physical therapy settings, the frequency of visits after ACLR varies but is not uncommon for patients to attend physical therapy sessions on a weekly or biweekly basis with orthopedic surgery follow up visits occurring at six-week and three-month postoperative timeframes. The closure and restriction of orthopedic and physical therapy services led to rapid changes in the standard of care including the stoppage of non-essential outpatient visits and the implementation of telemedicine.[37,38] The height of disruption in clinical care was between March-June 2020, which led to limited physical therapy access and increased telemedicine services.[9,31] However, as health care accessibility increased after June 2020, there continued to be limited patient access to important resources traditionally used during rehabilitation after ACLR (school gyms, recreational fitness centers) due to remote schooling and local governmental closures which extended into May 2021 in many parts of the United States. In contrast, upon increasing physical therapy outpatient clinic accessibility, patient visits were altered to accommodate for space restrictions, cleaning protocols and social distancing.[39] One type of alteration during COVID-19 at Connecticut Children's included increased time of each individual patient visit to accommodate social distancing and organizational protocols. It was unclear how these factors (spacing, protocols) would impact patient progress after ACLR, but the outcomes of this study were somewhat counter to the assumptions associated with restricted access to resources during COVID-19. At this point, it is unclear how specific COVID-19 restrictions may have impacted short-term outcomes after ACLR in adolescents.

One notable finding from this study was those who attained surgery during the COVID pandemic timeframe, in fact, had superior quadriceps peak torque on the uninvolved limb compared to those who underwent surgery pre-COVID. It is difficult to speculate, but plausible explanations for the observed difference in uninvolved limb quadriceps peak torque may include potential changes in rehabilitation practice patterns over time such as using the uninvolved limb for cross-education exercise strategies.[40] Also, each individual patient visit was longer in duration during the COVID pandemic timeframe, which may have allowed for increased total exercise volume per session. Other than quadriceps peak torque in the uninvolved limb, postoperative strength outcomes were generally similar between groups, which may be a reflection of the relatively narrow, early postoperative window in which patient outcomes were collected. Examining patient outcomes over a longer timeframe from surgery may allow for better comparison of the trajectory for strength recovery between groups after ACLR.

LIMITATIONS

This study only investigated outcomes on a single type of ACL graft within a specified timeframe of postoperative rehabilitation using isometric strength testing. Investigating patient groups with other ACL graft types, postoperative timeframes, and methods of strength assessment may offer additional means to compare patient outcomes during the COVID-19 pandemic. Finally, this study did not directly assess the influence of other areas of adolescent health that were previously reported to have been impacted during the COVID-19 pandemic, such as physical activity levels and mental health.[41,42]

CONCLUSION

At roughly three months after ACLR, normalized quadriceps peak torque on the uninvolved limb was reduced by 18.5% for adolescents who underwent surgery pre-COVID versus during the COVID-19 pandemic timeframe. There were no other group strength differences noted on either limb, or any differences found in patient reported outcomes for Pedi-IKDC or ACL-RSI scores. Generally, changes in practice patterns due to COVID-19 did not seem to adversely impact short-term outcomes when compared to those who underwent surgery prior to the pandemic. Future investigation is warranted to examine the longer-term implications of the COVID-19 pandemic on adolescent patient outcomes after ACLR.

CONFLICT OF INTEREST STATEMENT

AW, BN DR, NG, JC have no conflicts of interest to disclose.

Submitted: November 16, 2021 CDT, Accepted: March 24, 2022 CDT

REFERENCES

1. Joseph AM, Collins CL, Henke NM, Yard EE, Fields SK, Comstock RD. A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics. *J Athl Train*. 2013;48(6):810-817. doi:10.4085/1062-6050-48.6.03

2. Ardern CL, Taylor NF, Feller JA, Webster KE. Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *Br J Sports Med*. 2014;48(21):1543-1552. doi:10.1136/bjsports-2013-093398

3. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of secondary injury in younger athletes after anterior cruciate ligament reconstruction: a systematic review and meta-analysis. *Am J Sports Med*. 2016;44(7):1861-1876. doi:10.1177/0363546515621554

4. Bates L, Zieff G, Stanford K, et al. COVID-19 impact on behaviors across the 24-hour day in children and adolescents: physical activity, sedentary behavior, and sleep. *Children*. 2020;7(9):138. doi:10.3390/children7090138

5. Roman-Viñas B, Chaput JP, Katzmarzyk PT, et al. Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. *Int J Behav Nutr Phys Act*. 2016;13(1). doi:10.1186/s12966-016-0449-8

6. Moore SA, Faulkner G, Rhodes RE, et al. Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey. *Int J Behav Nutr Phys Act*. 2020;17(85). doi:10.1186/s12966-020-00987-8

7. Guan H, Okely AD, Aguilar-Farias N, et al. Promoting healthy movement behaviours among children during the COVID-19 pandemic. *Lancet Child Adolesc Health*. 2020;4(6):416-418. doi:10.1016/s2352-4642(20)30131-0

8. Xiang M, Zhang Z, Kuwahara K. Impact of COVID-19 pandemic on children and adolescents' lifestyle behavior larger than expected. *Prog Cardiovasc Dis*. 2020;63(4):531-532. doi:10.1016/j.pcad.2020.04.013

9. Sarac NJ, Sarac BA, Schoenbrunner AR, et al. A review of state guidelines for elective orthopaedic procedures during the COVID-19 outbreak. *J Bone Joint Surg Am*. 2020;102(11):942-945. doi:10.2106/JBJS.20.00510

10. Dunton GF, Do B, Wang SD. Early effects of the COVID-19 pandemic on physical activity and sedentary behavior in children living in the U.S. *BMC Public Health*. 2020;20(1). doi:10.1186/s12889-020-09429-3

11. Jones EAK, Mitra AK, Bhuiyan AR. Impact of COVID-19 on mental health in adolescents: a systematic review. *Int J Environ Res Public Health*. 2021;18(5):2470. doi:10.3390/ijerph18052470

12. Everhart JS, Best TM, Flanigan DC. Psychological predictors of anterior cruciate ligament reconstruction outcomes: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(3):752-762. doi:10.1007/s00167-013-2699-1

13. Burgi CR, Peters S, Ardern CL, et al. Which criteria are used to clear patients to return to sport after primary ACL reconstruction? A scoping review. *Br J Sports Med*. 2019;53(18):1154-1161. doi:10.1136/bjsports-2018-099982

14. Lentz TA, Zeppieri G Jr, Tillman SM, et al. Return to preinjury sports participation following anterior cruciate ligament reconstruction: contributions of demographic, knee impairment, and self-report measures. *J Orthop Sports Phys Ther*. 2012;42(11):893-901. doi:10.2519/jospt.2012.4077

15. Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L, Risberg MA. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med*. 2016;50(13):804-808. doi:10.1136/bjsports-2016-096031

16. Pua YH, Mentiplay BF, Clark RA, Ho JY. Associations among quadriceps strength and rate of torque development 6 weeks post anterior cruciate ligament reconstruction and future hop and vertical jump performance: a prospective cohort study. *J Orthop Sports Phys Ther*. 2017;47(11):845-852. doi:10.2519/jospt.2017.7133

17. Garrison C, Bothwell J, Wolf G, Aryal S, Thigpen C. Y balance test anterior reach symmetry at three months is related to single leg functional performance at time of return to sports following anterior cruciate ligament reconstruction. *Int J Sports Phys Ther*. 2015;10(5):602-611.

18. Hannon JP, Wang-Price S, Goto S, et al. Twelve-week quadriceps strength as a predictor of quadriceps strength at time of return to sport testing following bone-patellar tendon-bone autograft anterior cruciate ligament reconstruction. *Int J Sports Phys Ther*. 2021;16(3):681-688. doi:10.26603/001c.23421

19. Casp AJ, Bodkin SG, Gwathmey FW, et al. Effect of meniscal treatment on functional outcomes 6 months after anterior cruciate ligament reconstruction. *Ortho J Sports Med*. 2021;9(10):232596712110312. doi:10.1177/23259671211031281

20. Urbaniak GC, Plous S. Research randomizer (version 4.0) [computer software].

21. Toonstra J, Mattacola CG. Test-retest reliability and validity of isometric knee-flexion and -extension measurement using 3 methods of assessing muscle strength. *J Sport Rehabil*. 2013;22(1). doi:10.1123/jsr.2013.TR7

22. Hirano M, Katoh M, Gomi M, Arai S. Validity and reliability of isometric knee extension muscle strength measurements using a belt-stabilized hand-held dynamometer: a comparison with the measurement using an isokinetic dynamometer in a sitting posture. *J Phys Ther Sci*. 2020;32(2):120-124. doi:10.1589/jpts.32.120

23. Johnsen MB, Eitzen I, Moksnes H, Risberg MA. Inter- and intrarater reliability of four single-legged hop tests and isokinetic muscle torque measurements in children. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(7):1907-1916. doi:10.1007/s00167-013-2771-x

24. Undheim MB, Cosgrave C, King E, et al. Isokinetic muscle strength and readiness to return to sport following anterior cruciate ligament reconstruction: is there an association? A systematic review and a protocol recommendation. *Br J Sports Med*. 2015;49(20):1305-1310. doi:10.1136/bjsports-2014-093962

25. van der Velden CA, van der Steen MC, Leenders J, van Douveren F, Janssen RPA, Reijman M. Pedi-IKDC or KOOS-child: which questionnaire should be used in children with knee disorders? *BMC Musculoskelet Disord*. 2019;20(1):240. doi:10.1186/s12891-019-2600-6

26. Logerstedt D, Di Stasi S, Grindem H, et al. Self-reported knee function can identify athletes who fail return-to-activity criteria up to 1 year after anterior cruciate ligament reconstruction: a delaware-oslo ACL cohort study. *J Orthop Sports Phys Ther*. 2014;44(12):914-923. doi:10.2519/jospt.2014.4852

27. Sadeqi M, Klouche S, Bohu Y, Herman S, Lefevre N, Gerometta A. Progression of the psychological ACL-RSI Score and return to sport after anterior cruciate ligament reconstruction: a prospective 2-year follow-up study from the French Prospective Anterior Cruciate Ligament Reconstruction Cohort Study (FAST). *Orthop J Sports Med*. 2018;6(12). doi:10.1177/2325967118812819

28. Webster KE, Feller JA. Development and validation of a short version of the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale. *Orthop J Sports Med*. 2018;6(4):2325967118763763. doi:10.1177/2325967118763763

29. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Erlbaum Associates; 1988.

30. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191.

31. Lee D, Lencer AJ, Gibbs BS, Paul RW, Tjoumakaris FP. Disruptions in standard care: anterior cruciate ligament reconstruction outcomes during the SARS-COV2 pandemic. *Phys Sportsmed*. Published online 2021:1-7. doi:10.1080/00913847.2021.1971494

32. Han F, Banerjee A, Shen L, Krishna L. Increased compliance with supervised rehabilitation improves functional outcome and return to sport after anterior cruciate ligament reconstruction in recreational athletes. *Orthop J Sports Med*. 2015;3(12):232596711562077. doi:10.1177/2325967115620770

33. Webster KE, Feller JA, Leigh WB, Richmond AK. Younger patients are at increased risk for graft rupture and contralateral injury after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2014;42(3):641-647. doi:10.1177/0363546513517540

34. Schmitt LC, Paterno MV, Ford KR, Myer GD, Hewett TE. Strength asymmetry and landing mechanics at return to sport after anterior cruciate ligament reconstruction. *Med Sci Sports Exerc*. 2015;47(7):1426-1434. doi:10.1249/MSS.0000000000000560

35. Shimizu T, Samaan MA, Tanaka MS, et al. Abnormal biomechanics at 6 months are associated with cartilage degeneration at 3 years after anterior cruciate ligament reconstruction. *Arthroscopy*. 2019;35(2):511-520. doi:10.1016/j.arthro.2018.07.033

36. Burland JP, Kostyun RO, Kostyun KJ, Solomito M, Nissen C, Milewski MD. Clinical outcome measures and return-to-sport timing in adolescent athletes after anterior cruciate ligament reconstruction. *J Athl Train*. 2018;53(5):442-451. doi:10.4085/1062-6050-302-16

37. Miller MJ, Pak SS, Keller DR, Barnes DE. Evaluation of pragmatic telehealth physical therapy implementation during the COVID-19 pandemic. *Phys Ther*. 2021;101(1). doi:10.1093/ptj/pzaa193

38. Parisien RL, Shin M, Constant M, et al. Telehealth utilization in response to the novel coronavirus (COVID-19) pandemic in orthopaedic surgery. *J Am Acad Orthop Surg*. 2020;28(11):e487-e492. doi:10.5435/jaaos-d-20-00339

39. Ditwiler RE, Swisher LL, Hardwick DD. Professional and ethical issues in united states acute care physical therapists treating patients with covid-19: stress, walls, and uncertainty. *Phys Ther*. 2021;101(8). doi:10.1093/ptj/pzab122

40. Harput G, Ulusoy B, Yildiz TI, et al. Cross-education improves quadriceps strength recovery after ACL reconstruction: a randomized controlled trial. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(1):68-75. doi:10.1007/s00167-018-5040-1

41. Guan H, Okely AD, Aguilar-Farias N, et al. Promoting healthy movement behaviours among children during the COVID-19 pandemic. *The Lancet Child & Adolescent Health*. 2020;4(6):416-418. doi:10.1016/s2352-4642(20)30131-0

42. Xiang M, Zhang Z, Kuwahara K. Impact of COVID-19 pandemic on children and adolescents' lifestyle behavior larger than expected. *Progress in Cardiovascular Diseases*. 2020;63(4):531-532. doi:10.1016/j.pcad.2020.04.013