

# Effect of Concomitant Meniscal Tear on Strength and Functional Performance in Young Athletes 6 Months After Anterior Cruciate Ligament Reconstruction With Hamstring Autograft

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**Background:** The effect of concomitant meniscal tears, and their associated treatment, on strength and functional recovery after anterior cruciate ligament reconstruction (ACLR) has not been adequately investigated in young populations.

**Hypothesis:** Concomitant meniscal tears, treated with or without repair, would not adversely affect strength, balance, or functional hop test performance at 6 months postoperatively.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** The authors retrospectively analyzed return-to-sports (RTS) assessments prospectively collected 6 months after ACLR with hamstring autograft in 165 patients  $\leq 25$  years of age. Descriptive, surgical, and RTS testing data were analyzed, and subgroups were compared using analysis of covariance models designed to assess the effects of sex, meniscal tear, and meniscal repair on RTS performance.

**Results:** Included were 115 female (70%) and 50 male (30%) patients with a mean age of 16.4 years (range, 12.3-25 years). Of these patients, 58% had concomitant meniscal tears (59% lateral, 27% medial, 14% lateral + medial), comprising 53% of the female and 70% of the male patients. The authors treated 61% of the tears with repair, with range of motion (ROM) and weightbearing limitations imposed within the first 6 weeks postoperatively, whereas 39% were treated with partial meniscectomy, rasping, or trephination (no ROM or weightbearing restrictions). The mean deficit in hamstring strength at 6 months postoperatively was significantly greater in the meniscal tear group than in those without a tear (32.3% vs 24.6%;  $P = .028$ ). The meniscal repair group had greater hamstring strength deficits than the group with meniscectomy, rasping or trephination (34.3% vs 26.2%;  $P = .023$ ). Performance on dynamic balance and functional hop tests was similar among all meniscus subgroups. There were no sex-based effects on any subgroup comparisons.

**Conclusion:** At 6 months postoperatively, both young male and young female patients who underwent ACLR with hamstring autograft demonstrated significant hamstring strength deficits compared with their nonoperative leg. The presence of a meniscal tear and subsequent repair, or its related rehabilitation restrictions, appears to have adverse effects on the postoperative recovery of hamstring strength.

**Keywords:** ACL injury; ACL reconstruction; meniscal tear; postoperative strength; return to sport

Anterior cruciate ligament (ACL) injury is a common multiple season–ending injury in adolescent and young adult athletes. Because persistent knee instability associated with ACL deficiency can lead to secondary meniscal tears, chondral injuries, and accelerated degenerative

changes in young athletes,<sup>13</sup> ACL reconstruction (ACLR) is now considered the standard of care, even in the skeletally immature adolescent athlete.<sup>8,9,19</sup> However, this group of patients also has a relatively higher risk of both subsequent graft failure and contralateral ACL injury as compared with older patients.<sup>10,12,14,16</sup> While hamstring autograft and patellar tendon autograft have emerged as relative co–gold standard graft options for ACLR in adults, hamstring ACLR is the most common technique utilized in

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most centers for adolescent subpopulations because patellar tendon grafts are not an option in skeletally immature athletes.

Balanced cocontraction of the quadriceps and hamstring musculature is essential to properly stabilize the knee during sports-related activities such as cutting, pivoting, and landing. Decreased hamstring strength relative to quadriceps strength and recruitment has been shown to increase the risk of ACL injury in athletes.<sup>15</sup> Given the importance of the hamstrings in stabilizing the knee joint, recovery of hamstring strength after autograft harvest for ACLR is a concern. In a magnetic resonance imaging study, the harvested tendons displayed morphological regeneration; however, hamstring strength deficits persisted at 2 years postoperatively regardless of tissue regeneration at the graft harvest site.<sup>22</sup> Physiologic studies have shown that persistent hamstring weakness after ACLR can be overcome but the timing of such optimization of strength and return to sports remains unclear.<sup>2</sup> Subtle persistence of hamstring weakness and quadriceps-hamstring imbalance after hamstring tendon harvest, and the associated loss of dynamic knee stability, combined with return-to-sports activities may contribute to a higher risk of ACL re-tear, particularly in this adolescent and young adult patient population. Criteria for return to play in this higher-risk population have not firmly been established.

Muscle strength assessments and functional hop tests are important to determine adequate rehabilitation progress after ACLR in anticipation of return to sports. Postoperative strength, dynamic balance, and functional hop tests at 6 months are among the best studied and utilized criteria for making return-to-play assessments. The quantitative results of these performance measures have not been well studied in younger athletes. It is also unclear what effect having a concomitant meniscal tear has on their performance and whether undergoing a meniscal repair further inhibits their performance on return-to-sports assessments.<sup>20</sup> Treatments for meniscal tears include partial meniscectomy, rasping, trephination, or repair. It has been hypothesized that despite early postoperative range of motion and weightbearing restrictions, patients who undergo meniscal repair eventually would catch up to their counterparts who are not similarly restricted.

The purpose of this study was to determine the results of these strength and functional tests in an adolescent and

young adult population after ACLR with hamstring tendon autograft and to determine whether sex, meniscal pathology, or meniscal tear treatment affects performance and therefore readiness to return to sports. We hypothesized that there would be equal performance in young athletes on functional testing with or without a concomitant meniscal tear and/or meniscal repair.

## METHODS

### Sample Selection

Participants for this study were adolescent and young adult athletes from a large pediatric tertiary referral center who had undergone ACLR between January 2011 and October 2015 (n = 1655). We excluded patients >25 years old (n = 152), those with duplicate instances of Current Procedural Terminology code 29888 (n = 118), and patients without 6-month postoperative functional movement assessment (n = 1155). Of the 230 remaining patients, an additional 65 were excluded for having grafts other than doubled semitendinosus and gracilis autograft (iliotibial band, n = 29; patellar tendon/bone-tendon-bone, n = 17; allograft, n = 8) and chondral or collateral ligament injuries requiring surgical intervention (n = 11) (Figure 1).

After institutional review board approval, prospectively collected 6-month postoperative return-to-sports assessments were retrospectively analyzed on 165 adolescent and young adult patients who had undergone ACLR with hamstring autograft, representing 10% of all ACLRs done during the study time period. Of note, all surgeons in the study require that such testing be performed before provision of documentation for clearance to return to sports, and such testing is provided to patients free of charge. However, because of geographic and logistical restraints, as well as losses to follow-up in this highly mobile population, many patients meeting the inclusion criteria did not come for 6-month testing.

### Surgical Management

All patients underwent standard anatomic femoral and tibial drilling with suspensory fixation on the femur and bio-composite screw fixation on the tibia. All patients started physical therapy with a standard protocol at 1 week after

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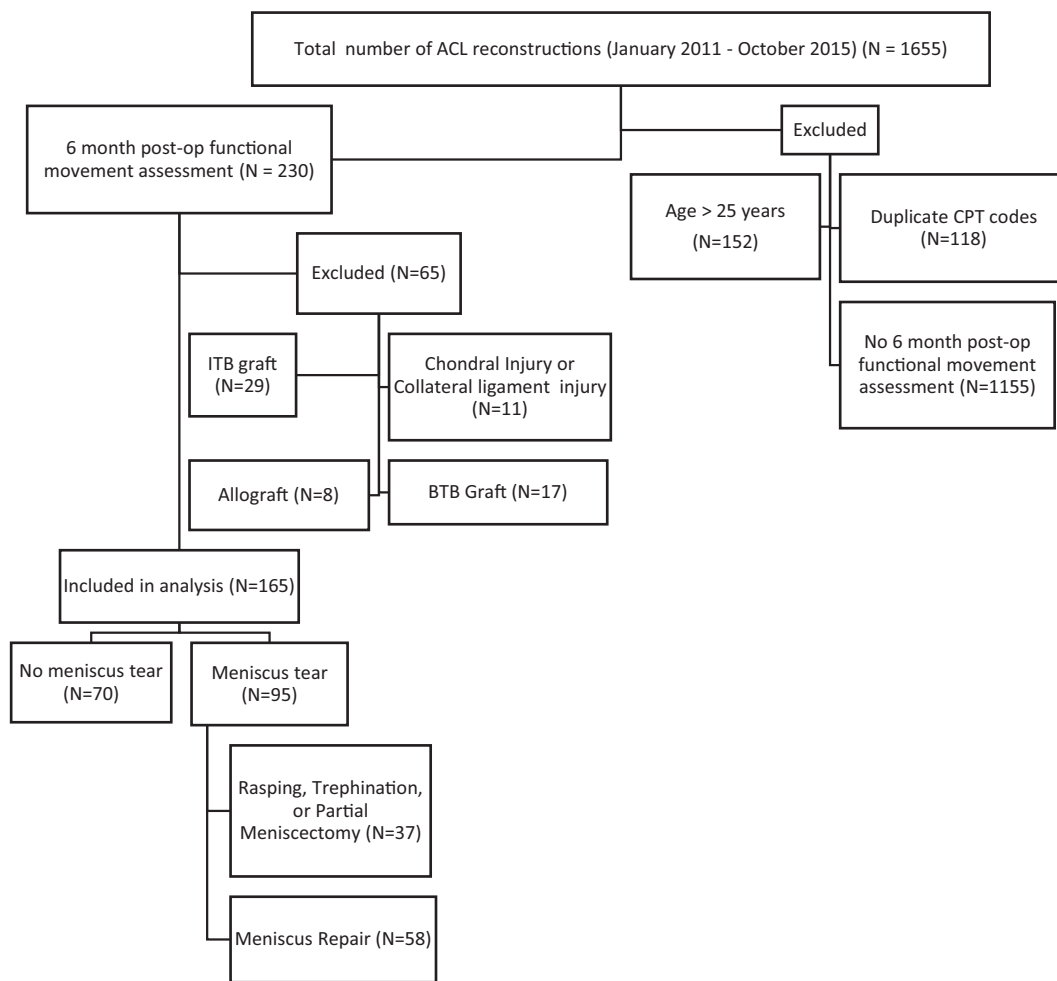
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Ethical approval for this study was obtained from Boston Children's Hospital (protocol No. IRB-P00015975).



**Figure 1.** Flowchart of participant selection for the study. ACL, anterior cruciate ligament; BTB, bone-tendon-bone; CPT, Current Procedural Terminology; ITB, iliotibial band.

surgery. Those patients who underwent meniscal repair had some form of range of motion and weightbearing limitations for the first 6 weeks postoperatively. Protected weightbearing ranged from 4 to 6 weeks postoperatively. Range of motion restrictions ranged from 30° to 40° in the first 2 to 4 weeks; this was advanced to 90° by 6 weeks postoperatively.

### Clinical Testing

The testing protocol is specific to the study institution, but it consists of well-established functional tests of strength, dynamic balance, and hop testing, the details of which have been comprehensively described in a prior publication.<sup>21</sup> Functional assessments were performed by injury prevention specialists (certified athletic trainers or kinesiologists with master’s degrees and additional strength and conditioning certification). Functional movement testing consisted of thigh circumference measurements; knee range of motion measurements; muscular strength tests (hamstring, quadriceps, hip abductor, and hip extensors) via manual muscle testing; functional straight-leg Y-balance

testing; and hop tests, including single hop for distance, single-leg triple hop for distance, 6-m timed single-leg hop, and crossover single-leg hop. Dynamic balance was quantified using a commercially available Y-balance assessment system (Functional Movement Systems) as previously described.<sup>21</sup> All tests were completed twice, and the results were averaged.

### Statistical Analysis

For analysis, athletes were initially separated into 2 groups: (1) those who underwent isolated ACLR with no concomitant meniscal tear and (2) those who underwent ACLR with identification of a concomitant meniscal tear. This second group was then analyzed in 2 subgroups: those treated with partial meniscectomy, meniscal rasping, or trephination (meniscectomy group) and those treated with meniscal repair (meniscal repair group). Operative reports were reviewed to make the group assignments. Details regarding size of meniscectomy, extent of rasping or trephination, and precise size or number of sutures utilized in

the repairs were not available to allow for substratified analyses.

Descriptive, surgical, and performance data were analyzed, and subgroups were compared using analysis of covariance models. Physical characteristics (height and weight) and sex distributions were incorporated into the model as covariates to adjust for baseline differences.

TABLE 1  
Characteristics of Study Participants.<sup>a</sup>

|            | Meniscal Tear<br>(n = 96) | No Meniscal Tear<br>(n = 69) | P                       |
|------------|---------------------------|------------------------------|-------------------------|
| Age, y     | 16.6 ± 1.9                | 16.0 ± 1.7                   | .058                    |
| Height, cm | 167.7 ± 8.4               | 165.3 ± 8.6                  | <b>.017</b>             |
| Weight, kg | 69.3 ± 14.3               | 63.4 ± 12.0                  | <b>.002</b>             |
| Sex        |                           |                              | <b>.042<sup>b</sup></b> |
| Female     | 61 (53)                   | 54 (47)                      |                         |
| Male       | 35 (70)                   | 15 (30)                      |                         |

<sup>a</sup>Data are reported as mean ± SD or n (%). Bolded P values indicate a statistically significant difference between groups ( $P < .05$ ).

<sup>b</sup>Chi-square test.

TABLE 2  
Lower Extremity Strength Deficits 6 Months After ACLR  
With or Without a Concomitant Meniscal Tear<sup>a</sup>

| Muscle Group | Meniscal Tear<br>(n = 96), Mean %<br>Strength (LSI) | No Meniscal Tear<br>(n = 69), Mean %<br>Strength (LSI) | P           |
|--------------|-----------------------------------------------------|--------------------------------------------------------|-------------|
| Quadriceps   | 4.3 (-3.8 to 12.5)                                  | -4.2 (-13.0 to 5.5)                                    | .192        |
| Hamstring    | -32.3 (-28.0 to -36.6)                              | -24.6 (-19.5 to -29.8)                                 | <b>.028</b> |
| Hip abductor | 5.3 (0.1 to 9.5)                                    | 5.1 (0.0 to 10.2)                                      | .966        |
| Hip extensor | 1.8 (-2.7 to 6.3)                                   | 0.0 (-5.1 to 5.6)                                      | .663        |

<sup>a</sup>Data are reported as mean (95% CI). Bolded P value indicates a statistically significant difference between groups ( $P < .05$ ). ACLR, anterior cruciate ligament reconstruction.

## RESULTS

The study population consisted of 115 female (70%) and 50 male (30%) patients, with an overall mean age of 16.4 years (range, 12.3-25 years) and a mean body mass index of 24. Of these patients, 58% had concomitant meniscal tears (59% lateral, 27% medial, 14% lateral + medial), which comprised 53% of the female and 70% of the male patients. Patients with a meniscal tear were statistically significantly taller and heavier than those without a tear. Male patients were more likely to have a meniscal tear compared with their female counterparts (Table 1). Overall, 61% of tears were treated with repair, whereas 39% were treated with partial meniscectomy, rasping, or trephination.

The interval between surgery and postoperative physical test was not different between the meniscectomy (6.1 ± 0.1 months) and meniscal repair (6.2 ± 0.1 months) groups ( $P = .672$ ). When strength of the quadriceps, hip abductor, and hip adductor muscle groups were compared between meniscus subgroups, no statistically significant differences were detected (Tables 2 and 3). However, the presence of a meniscal tear was associated with greater deficits in hamstring strength at 6 months postoperatively when compared with not having a concomitant meniscal tear (32.3% vs 24.6%;  $P = .028$ ) (Table 2). This was not affected by the location of the meniscal tear (medial, lateral, or both) ( $P = .318$ ).

When compared with patients with no meniscal tear, patients who underwent a meniscal repair had significantly greater hamstring strength deficits at 6 months (24.6% vs 34.3%;  $P = .035$ ). When compared with the meniscectomy group, patients in the meniscal repair group did not show significantly greater hamstring strength deficits at 6 months (29.5% vs 34.3%;  $P = .860$ ) (Table 3). This was also not affected by the location of the meniscal tear ( $P = .078$ ). When the meniscectomy group was combined with the no-tear group and compared with the meniscal repair group, significant hamstring strength deficits were found in the repair group at 6 months postoperatively (26.2% vs 34.3%;  $P = .023$ ). There were no differences in performance on dynamic balance or functional hop tests between patients with and without meniscal tears (anterior reach,  $P = .086$ ; posterolateral reach,  $P = .091$ ; single hop,  $P = .603$ ; triple hop,  $P = .456$ ; 6-m timed hop,  $P = .770$ ;

TABLE 3  
Lower Extremity Strength Deficits 6 Months After Isolated ACLR and ACLR With Treatment of Meniscal Tear<sup>a</sup>

| Muscle Group | No Treatment Group (n = 71),<br>Mean % Strength (LSI) | Meniscectomy Group (n = 26),<br>Mean % Strength (LSI) | Meniscal Repair Group (n = 14),<br>Mean % Strength (LSI) | P                       |
|--------------|-------------------------------------------------------|-------------------------------------------------------|----------------------------------------------------------|-------------------------|
| Quadriceps   | -3.6 (-13.1 to 5.8)                                   | 15.0 (1.8 to 28.2)                                    | -2.4 (-12.7 to 7.9)                                      | .059                    |
| Hamstring    | -24.6 (-19.5 to -29.6)                                | -29.5 (-22.4 to -36.5)                                | -34.3 (-28.8 to -39.8)                                   | <b>.041<sup>b</sup></b> |
| Hip abductor | 5.6 (0.6 to 10.6)                                     | 3.9 (3.1 to 10.9)                                     | 5.5 (0.0 to 11.0)                                        | .916                    |
| Hip extensor | 0.7 (-4.5 to 5.9)                                     | 3.4 (-3.9 to 10.7)                                    | 0.4 (-5.3 to 6.1)                                        | .792                    |

<sup>a</sup>Data are reported as mean (95% CI). Bolded P value indicates a statistically significant difference between treatment groups ( $P < .05$ ). ACLR, anterior cruciate ligament reconstruction.

<sup>b</sup>There was a significant difference between the no treatment and meniscal repair groups ( $P = .035$ ; Bonferroni). There were no differences between the no treatment and meniscectomy groups ( $P = .799$ ) or between the meniscectomy and meniscal repair groups ( $P = .860$ ).

TABLE 4  
Characteristics of Study Participants vs Entire Cohort<sup>a</sup>

|            | Study Participants<br>(N = 165) | Entire Cohort<br>(n = 1155) | P    |
|------------|---------------------------------|-----------------------------|------|
| Age, y     | 16.4 ± 3.1                      | 17.7 ± 4.7                  | .479 |
| Height, cm | 166.8 ± 8.6                     | 167.1 ± 8.4                 | .657 |
| Weight, kg | 68.7 ± 13.2                     | 67.2 ± 13.9                 | .364 |

<sup>a</sup>Data are reported as mean ± SD. Entire Cohort represents patients who underwent anterior cruciate ligament reconstruction at the study institution but did not undergo 6-month functional strength, balance, or hop test assessments.

crossover hop,  $P = .805$ ). There were also no differences in performance on dynamic balance or functional hop tests among the meniscal tear treatment groups (no treatment vs meniscectomy vs meniscal repair) (anterior reach,  $P = .368$ ; posterolateral reach,  $P = .683$ ; posteromedial reach,  $P = .073$ ; single hop,  $P = .808$ ; triple hop,  $P = .570$ ; 6-m timed hop,  $P = .808$ ; crossover hop,  $P = .570$ ).

To further ensure that sampling or selection bias was minimized when deriving the study population (N = 165) from the population of interest (n = 1155), statistical comparisons were made between key demographic features of the study population and the larger source population. In total, 115 female and 50 male patients (matching the study population) were randomly selected from the population of interest who did not have 6-month functional movement assessment data. Age, height, and weight were compared, with no statistically significant differences detected between the groups (Table 4).

## DISCUSSION

The study results indicated that at 6 months postoperatively, the overall cohort of young athletes who underwent ACLR with hamstring autograft had significant hamstring strength deficits compared with their nonoperative leg. Our results are in line with other recent literature showing persistent hamstring weakness after ACLR with hamstring autograft.<sup>2,4-7,11,18</sup> Nomura et al<sup>17</sup> recently showed that hamstring tendons regenerated in 21 of 24 (88%) patients after ACLR with hamstring autograft. However, the muscle showed significant atrophy and shortening that correlated with decreased knee flexion torque. This is similar to a previous finding by Tadokoro et al,<sup>22</sup> who showed significant weakness, as well as regrowth in 22 of 24 semitendinosus tendons but only 13 of 24 gracilis tendons. Findings by Tashiro et al<sup>23</sup> suggested that this hamstring weakness can be minimized by preserving the gracilis tendon and performing the ACLR with only a quadrupled semitendinosus tendon graft.

This common finding of decreased hamstring strength and its resultant knee strength imbalance may have an adverse effect on dynamic knee joint stabilization. Using 3-dimensional motion analysis, Abourezk et al<sup>1</sup> recently showed that patients with hamstring strength asymmetry post-ACLR showed altered knee mechanics during gait and

jogging compared with those with more symmetric hamstring strength. In spite of this, our study showed that the significant weakness detected does not appear to affect these young athletes' performance on dynamic balance and functional hop tests, which may speak to the inadequacy of such rudimentary tests in assessing performance on higher-level impact activities. While it remains unclear how these results will translate to long-term clinical outcomes, long-term clinical follow-up of these patients is being pursued to better quantify sports performance, ACL retear/graft rupture, and the correlation of such outcomes with 6-month testing results.

The current study further demonstrated that adolescent and young adult patients with hamstring ACLR with a concomitant meniscal tear had more severe hamstring strength deficits compared with those without a meniscal tear. This may speak to slightly higher rotational energy or overall mechanisms of injury in the meniscal tear group relative to the no-tear group. Because a well-designed prior study comparing patients with ACLR with and without meniscal treatment<sup>3</sup> found no difference in the early postoperative pain between cohorts, this is unlikely to be an alternative cause of the slower recovery in the current study's meniscal tear cohorts.

Additionally, adolescent and young adult patients with hamstring ACLR who underwent a meniscal repair showed increased hamstring strength deficits compared with the 2 other meniscus subgroups, independently: (1) patients without a meniscal tear and (2) those who had a meniscal tear but underwent treatment only with a partial meniscectomy, rasping, or trephination. Of note, patients with any of these 3 treatment types, or some combination of them, were grouped together for study purposes based on the fact that no restrictions were imposed on such patients in their weightbearing or range of motion, unlike the meniscal repair group. Thus, there appeared to be a stepwise decline in performance across the 3 subpopulations when rearranged based on treatment type from "no tear" showing the least deficit to the presence of a meniscal tear that needed minimal treatment and to the worst performance in those patients undergoing a repair. It is likely that the related rehabilitation restrictions in the immediate postoperative period, including both range of motion and weightbearing restrictions, could inhibit the recovery of hamstring strength. The question that arises then is, are we imposing unnecessarily restrictive rehabilitation protocols on our patients with meniscal repair? Perhaps allowing these patients to be weightbearing as tolerated with locked extension bracing and focusing on early hamstring strengthening would enhance their recovery of postoperative strength. However, the unknown remains—whether a change in rehabilitation protocols would adversely affect the success of the meniscal repair, which was not the subject of the current investigation and requires more long-term follow-up. Alternatively, if the somewhat restrictive or conservative approach is directed appropriately at optimal meniscal healing in a relatively noncompliant adolescent and young adult population, should patients with meniscal repair be counseled that their return to sports will likely not be until a minimum of 9 months postoperatively instead of 6 months,

which is a commonly utilized global time frame for rehabilitation? As it is currently unknown if the weakness detected at 6 months postoperatively will translate to increased graft retear rates at these time points, additional investigations into the functional implications of performance deficits and the associated ACL retear rates are warranted. Optimal research protocols would allow for these return-to-play testing results to be correlated with outcomes at 2 years, 5 years, and 10 years.

## LIMITATIONS

The study was somewhat limited in its generalizability for patients of all ages undergoing ACLR, given the focused age-based population of pediatric, adolescent, and young adult athletes. Such a group may not be as compliant as other populations with their rehabilitation regimens, given their school-related restrictions, age, motivation levels, and busy schedules. Patients were also not enrolled in a single, well-monitored physical therapy program. However, while a stricter, more standardized rehabilitation approach at the study institution would have had methodological advantages from a research perspective, pooling of multiple surgeons' regimens in patients pursuing therapy at a wide variety of community therapy facilities may be more representative of the average experience in the United States after ACLR and therefore may have allowed for more generalizable findings. There was also a potential for sampling or selection bias with our study population, although characteristic comparisons were performed in Table 4, which suggested minimal differences between the study population and the larger ACLR population at the study institution. Also, baseline, preinjury functional assessment data were not available for most patients. However, this may not be practical in a retrospective study design, given the differences in timing of ACLR after acute or chronic ACL injury. While postinjury preoperative rehabilitation (ie, prehabilitation) is consistently utilized by all of the study surgeons, it is possible that patients became deconditioned in the postinjury period such that their contralateral leg was weaker than their preinjury baseline. Thus, the deficits identified in the study cohort may be even bigger than were reported utilizing the contralateral comparative approach. Additional limitations stem from the nature of retrospective chart review of patients' operative records, with regard to technical details and technique-based differences that may exist between patients, surgeons, or the overall cohort compared with those of other studies. Moreover, as a retrospective study that lacks functional outcome measures and pain scores at various stages after surgery, there were limited quantitative data to inform conjecture on the precise cause of the different performance of strength or functional testing among study subgroups.

## CONCLUSION

Both female and male adolescent and young adult patients undergoing ACLR with hamstring autograft demonstrated a

significant deficit in 6-month postoperative hamstring strength. There appeared to be a stepwise decline in postoperative hamstring strength in patients with ACLR, from those with no concomitant meniscal tear to those with meniscal tears treated with partial meniscectomy, rasping, or trephination and finally to those with a meniscal tear treated with a meniscal repair, in whom postoperative weightbearing and range of motion restrictions were consistently applied in this cohort. No difference in performance on dynamic balance or functional hop tests was seen among these meniscus subgroups. While early postoperative rehabilitation restrictions on range of motion and weightbearing may have an adverse effect on postoperative recovery of hamstring strength, the precise etiology of these findings warrants further investigation.

## REFERENCES

1. Abourezk MN, Ithurburn MP, McNally MP, et al. Hamstring strength asymmetry at 3 years after anterior cruciate ligament reconstruction alters knee mechanics during gait and jogging. *Am J Sports Med.* 2017;45(1):97-105.
2. Ageberg E, Roos HP, Silbernagel KG, Thomeé R, Roos EM. Knee extension and flexion muscle power after anterior cruciate ligament reconstruction with patellar tendon graft or hamstring tendons graft: a cross-sectional comparison 3 years post surgery. *Knee Surg Sports Traumatol Arthrosc.* 2009;17(2):162-169.
3. Beck PR, Nho SJ, Balin J, et al. Postoperative pain management after anterior cruciate ligament reconstruction. *J Knee Surg.* 2004;17(1):18-23.
4. Bizzini M, Gorelick M, Munzinger U, Drobný T. Joint laxity and isokinetic thigh muscle strength characteristics after anterior cruciate ligament reconstruction: bone patellar tendon bone versus quadrupled hamstring autografts. *Clin J Sport Med.* 2006;16(1):4-9.
5. Condouret J, Cohn J, Ferret JM, et al. Isokinetic assessment with two years follow-up of anterior cruciate ligament reconstruction with patellar tendon or hamstring tendons. Article in French. *Rev Chir Orthop Reparatrice Appar Mot.* 2008;94(8 suppl):375-382.
6. Dauty M, Tortellier L, Rochcongar P. Isokinetic and anterior cruciate ligament reconstruction with hamstrings or patella tendon graft: analysis of literature. *Int J Sports Med.* 2005;26(7):599-606.
7. Emami Meybodi MK, Jannesari M, Rahim Nia A, Yaribeygi H, Sobhani Firoozabad V, Dorostegan A. Knee flexion strength before and after ACL reconstruction using hamstring tendon autografts. *Trauma Mon.* 2013;18(3):130-133.
8. Fabricant PD, Jones KJ, Delos D, et al. Reconstruction of the anterior cruciate ligament in the skeletally immature athlete: a review of current concepts. AAOS exhibit selection. *J Bone Joint Surg Am.* 2013;95(5):e28.
9. Hui C, Roe J, Ferguson D, Waller A, Salmon L, Pinczewski L. Outcome of anatomic transphyseal anterior cruciate ligament reconstruction in Tanner stage 1 and 2 patients with open physes. *Am J Sports Med.* 2012;40(5):1093-1098.
10. Kaeding CC, Pedroza AD, Reinke EK, Huston LJ, Spindler KP; MOON Consortium. 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(7):1583-1590.
11. Kilingç BE, Kara A, Camur S, Oc Y, Celik H. Isokinetic dynamometer evaluation of the effects of early thigh diameter difference on thigh muscle strength in patients undergoing anterior cruciate ligament reconstruction with hamstring tendon graft. *J Exerc Rehabil.* 2015;11(2):95-100.
12. Maletis GB, Chen J, Inacio MC, Funahashi TT. Age-related risk factors for revision anterior cruciate ligament reconstruction: a cohort study of 21,304 patients from the Kaiser Permanente Anterior Cruciate Ligament Registry. *Am J Sports Med.* 2016;44(2):331-336.

13. Mizuta H, Kubota K, Shiraishi M, Otsuka Y, Nagamoto N, Takagi K. The conservative treatment of complete tears of the anterior cruciate ligament in skeletally immature patients. *J Bone Joint Surg Br.* 1995; 77(6):890-894.
14. Morgan MD, Salmon LJ, Waller A, Roe JP, Pinczewski LA. Fifteen-year survival of endoscopic anterior cruciate ligament reconstruction in patients aged 18 years and younger. *Am J Sports Med.* 2016;44(2): 384-392.
15. Myer GD, Ford KR, Barber Foss KD, Liu C, Nick TG, Hewett TE. The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clin J Sport Med.* 2009;19(1):3-8.
16. Nelson IR, Chen J, Love R, Davis BR, Maletis GB, Funahashi TT. A comparison of revision and rerupture rates of ACL reconstruction between autografts and allografts in the skeletally immature. *Knee Surg Sports Traumatol Arthrosc.* 2016;24(3):773-779.
17. Nomura Y, Kuramochi R, Fukubayashi T. Evaluation of hamstring muscle strength and morphology after anterior cruciate ligament reconstruction. *Scand J Med Sci Sports.* 2015;25(3):301-307.
18. Petersen W, Taheri P, Forkel P, Zantop T. Return to play following ACL reconstruction: a systematic review about strength deficits. *Arch Orthop Trauma Surg.* 2014;134(10):1417-1428.
19. Redler LH, Brafman RT, Trentacosta N, Ahmad CS. Anterior cruciate ligament reconstruction in skeletally immature patients with transphyseal tunnels. *Arthroscopy.* 2012;28(11):1710-1717.
20. Spindler KP, Schils JP, Bergfeld JA, et al. Prospective study of osseous, articular, and meniscal lesions in recent anterior cruciate ligament tears by magnetic resonance imaging and arthroscopy. *Am J Sports Med.* 1993;21(4):551-557.
21. Sugimoto D, Heyworth BE, Collins SE, Fallon RT, Kocher MS, Micheli LJ. Comparison of lower extremity recovery after anterior cruciate ligament reconstruction with transphyseal hamstring versus extra-physeal iliotibial band techniques in skeletally immature athletes. *Orthop J Sports Med.* 2018;6(4):2325967118768044.
22. Tadokoro K, Matsui N, Yagi M, Kuroda R, Kurosaka M, Yoshiya S. Evaluation of hamstring strength and tendon regrowth after harvesting for anterior cruciate ligament reconstruction. *Am J Sports Med.* 2004;32(7):1644-1650.
23. Tashiro T, Kurosawa H, Kawakami A, Hikita A, Fukui N. Influence of medial hamstring tendon harvest on knee flexor strength after anterior cruciate ligament reconstruction: a detailed evaluation with comparison of single- and double-tendon harvest. *Am J Sports Med.* 2003; 31(4):522-529.