Quadriceps Strength and Endurance After Posterior Cruciate Ligament Tears Versus Matched Group With Anterior Cruciate Ligament Tears

Dae-Hee Lee, M.D., Seung-Beom Han, M.D., Jin-Hyuck Lee, P.T., Seok-Joo Lee, P.T., Dong-Won Suh, M.D., and Hye-Jin Jeong, P.T.

Purpose: This study was designed to compare the preoperative strengths and endurances of the quadriceps and hamstring muscles in patients with anterior cruciate ligament (ACL) versus posterior cruciate ligament (PCL) tears. **Methods:** Quadriceps and hamstring muscle strength and endurance were compared between 20 prospectively enrolled patients with isolated PCL tears and a retrospective, matched control group of 20 patients with isolated ACL tears. The maximal torque (60°/s) and total work (180°/s) of the quadriceps and hamstring were evaluated with an isokinetic testing device. **Results:** Total work (1,094.4 ± 505.8 J *v* 797.5 ± 332.7 J, $P = .035$) and peak torque (129.9 ± 56.2 N • m *v* 98.2 ± 37.4 N • m, $P = .046$) of the quadriceps muscle on the involved side were higher in the PCL tear group than in the ACL tear group. However, there were no significant differences between the PCL tear group and ACL tear group in hamstring muscle strength (45.8 ± 42.3 N • m and 46.0 ± 24.4 N • m, respectively; $P = .940$) and endurance (429.3 ± 238.9 J and 382.4 ± 256.1 J, respectively; $P = .574$) on the involved side. **Conclusions:** The strength and endurance of the quadriceps muscle of the injured limb were greater after PCL tears than after ACL tears. However, there were no significant between-group differences in hamstring muscle strength and endurance on the involved side. **Level of Evidence:** Level III, retrospective comparative study.

Decreased quadriceps muscle strength after tears of the anterior cruciate ligament (ACL) is regarded as universal and due to processes such as arthrogenic muscle inhibition or quadriceps avoidance gait.[1,2] Hamstring muscle strength, however, is relatively preserved because the hamstring can be facilitated or activated in response to an ACL tear.[3-5] These situations are thought to be due to a compensating mechanism to prevent anterior subluxation of the tibia,[6-8] which can be painful and potentially detrimental to injured knees with ACL tears.[9,10] Theoretically, the reverse situation (increased quadriceps and decreased hamstring muscle strength) could be expected in patients with posterior cruciate ligament (PCL) tears to lessen the posterior subluxation of the tibia. It remains unclear, however, whether the strength of the quadriceps and hamstring increases or decreases after tears of the PCL.

Although many studies have evaluated changes in muscle strength and endurance around the knee joint in patients with ACL tears,[11-14] few studies have evaluated these changes in patients with PCL tears. This study was designed to compare the preoperative strengths and endurances of the quadriceps and hamstring muscles in patients with ACL versus PCL tears. We hypothesized that, although thigh muscle strength and endurance in both sets of patients would be lower on the injured side than on the normal side, thigh muscle strength and endurance on the injured side would be similar in patients with ACL tears and patients with PCL tears.

Methods

Patient Enrollment

This study compared the preoperative status of thigh muscle strength and endurance between patients with

From the Department of Orthopaedic Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine (D-H.L.), Seoul; the Department of Orthopaedic Surgery (S-B.H.) and Sports Medical Center (D-H.L., J-H.L., S-J.L., H-J.J.), Korea University College of Medicine, Seoul; and Barunsesang Hospital (D-W.S.), Seongnam, Republic of Korea.

The authors report the following potential conflict of interest or source of funding: Supported by a Korea University grant (K1423281). The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received June 14, 2014; accepted January 14, 2015.

Address correspondence to Dae-Hee Lee, M.D., Department of Orthopaedic Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Ilwon-ro, Gangnam-gu, Seoul 135-710, Republic of Korea. E-mail: eoak22@empal.com

0749-8063/14495/$36.00

http://dx.doi.org/10.1016/j.arthro.2015.01.012

ACL tears and patients with PCL tears. The PCL tear group consisted of prospectively enrolled patients with unilateral isolated PCL tears who were candidates for isolated PCL reconstruction between May 2009 and October 2012, with muscle strength and endurance measured before PCL reconstruction. For comparison, the ACL tear group consisted of patients who underwent isolated ACL reconstruction between 2008 and 2010 with the transtibial technique and hamstring tendon autografts. The ACL tear group was composed of patients matched by age, height, and body mass index to patients in the PCL tear group. Because thigh muscle strength and endurance were assessed preoperatively in all patients with ACL tears, these preoperative findings could be compared with those in patients with PCL tears. All patients in both groups were diagnosed by magnetic resonance imaging and physical examinations, with the diagnoses confirmed arthroscopically. Patients with bilateral injuries or concomitant medial or lateral meniscus tears, as well as those with associated ligament injury such as medial collateral ligament or posterolateral corner structure injury, were excluded. In addition, to exclude a learning-curve effect, individuals who had previously undergone dynamic balance testing or training using the Biodex Stability System (Biodex Medical Systems, Shirley, NY) or force platform were excluded. Patients with a history of vestibular or neurologic dysfunction and those who could not perform the balance test because of pain or limited motion of the knee joint were also excluded. Of the 45 patients (45 knees) approached, 42 agreed to take part in the study. After assessment for eligibility, we enrolled 40 patients: 20 with ACL tears and 20 with PCL tears. The baseline demographic characteristics of the 2 groups were similar (Table 1). The study protocol was approved by our institutional review board. All patients provided written informed consent before participation.

Isokinetic Strength and Endurance Testing

The Biodex Multi-Joint System 4 (Biodex Medical Systems) was used for evaluation of isokinetic knee strength. The patient sat in an upright position on the dynamometer chair with a strap across the chest, grasped the edge of the bench, and flexed the hip and knee 90° each. The center of motion of the lever arm was aligned as accurately as possible to the lateral femoral condyle of the knee being tested. The thigh was immobilized with a strap, and the dynamometer attachment was aligned with the lateral malleolus of the lower leg of the knee being tested. The resistance pad was placed as distally as possible on the tibia while still allowing full dorsiflexion at the ankle.

The range of motion of the knee joint was from full extension (0°) to flexion of 100°. Testing consisted of maximal concentric quadriceps/concentric hamstring reciprocal contractions, with 5 at an angular velocity of 60°/s and 15 at 180°/s with a rest time of 30 seconds between tests. Before each test session, patients performed 5 warm-up knee flexions and extensions of each leg at 60°/s.

Peak torque, defined as the single highest point in the torque curve (in Newtons times meters per kilogram), of flexion and extension at 60°/s was evaluated to determine muscle strength. Total work, defined as the sum total of the area under all torque curves in the test repetitions (in joules), of flexion and extension at 180°/s was evaluated to determine muscular endurance. Extensor strength and endurance were regarded as quadriceps strength and endurance, respectively, and flexor strength and endurance were regarded as hamstring strength and endurance, respectively. Two trials of each position were performed, with their mean value set as maximal peak torque and total work of the hamstring and quadriceps muscles.

Statistical Analysis

A post hoc power analysis was performed to determine the minimum number of patients required in each group, based on comparisons of quadriceps strength and endurance in the injured leg in the ACL and PCL tear groups. To determine the sample size required to detect between-group differences in quadriceps strength and endurance, α was set at .05 and power was set at 0.8. Minimum sample sizes of 20 and 18 patients per group were calculated as required to detect between-group differences in quadriceps strength and endurance, respectively. Overall, this study included 40 patients, 20 in the ACL tear group and 20 in the PCL tear group, with adequate power to detect significant between-group differences in quadriceps muscle strength (power, 0.8) and endurance (power, 0.839) in the injured leg.

All statistical analyses were performed using IBM SPSS Statistics software (version 20; IBM, Armonk, NY). The mean values of the strengths of the hamstring and quadriceps muscles, as well as their ratio, were compared in the ACL and PCL tear groups and on the uninvolved and involved sides using Student t tests or Mann-Whitney U tests as appropriate. $P < .05$ was considered statistically significant.

Results

Peak torque of the quadriceps muscle in the involved limb at 60°/s was significantly higher in the PCL tear group than in ACL tear group (129.9 ± 56.3 N • m v 98.2 ± 37.4 N • m, $P = .046$). The total work of the quadriceps muscle on the involved side at 180°/s was also significantly greater in the PCL tear group than in the ACL tear group (1,094.4 ± 505.8 J v 797.5 ± 332.7 J, $P = .035$). However, there were no significant between-group differences in hamstring muscle strength