Isokinetic Evaluation of Internal/External Tibial Rotation Strength After the Use of Hamstring Tendons for Anterior Cruciate Ligament Reconstruction

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Background: Evaluation of the knee after an anterior cruciate ligament reconstruction with the use of the semitendinosus and gracilis (hamstring) autografts has primarily focused on flexion and extension strength. The semitendinosus and gracilis muscles contribute to internal tibial rotation, and it has been suggested that harvest of these tendons for the purpose of an anterior cruciate ligament reconstruction contributes to internal tibial rotation weakness.

Hypothesis: Internal tibial rotation strength may be affected by the semitendinosus and gracilis harvest after anterior cruciate ligament reconstruction.

Study Design: Prospective evaluation of internal and external tibial rotation strength.

Methods: Inclusion criteria for subjects (N = 30): unilateral anterior cruciate ligament reconstruction at least 2 years previously, a stable anterior cruciate ligament (<5-mm side-to-side difference) at time of testing confirmed by surgeon and KT-1000 arthrometer, no history of knee problems after initial knee reconstruction, a normal contralateral knee, and the ability to comply with the testing protocol. In an attempt to minimize unwanted subtalar joint motion, subjects were immobilized using an ankle brace and tested at angular velocities of 60°/s, 120°/s, and 180°/s at a knee flexion angle of 90°.

Results: The mean peak torque measurements for internal rotation strength of the operative limb (60°/s, 17.4 ± 4.5 ft-lb; 120°/s, 13.9 ± 3.3 ft-lb; 180°/s, 11.6 ± 3.0 ft-lb) were statistically different compared to the nonoperated limb (60°/s, 20.5 ± 4.7 ft-lb; 120°/s, 15.9 ± 3.8 ft-lb; 180°/s, 13.4 ± 3.8 ft-lb) at 60°/s ($P = .012$), 120°/s ($P = .036$), and 180°/s ($P = .045$). The nonoperative limb demonstrated greater strength at all speeds. The mean torque measurements for external rotation were statistically similar when compared to the nonoperated limb at all angular velocities.

Conclusions: We have shown through our study that patients who undergo surgical intervention to repair a torn anterior cruciate ligament with the use of autogenous hamstring tendons demonstrate with weaker internal tibial rotation postoperatively at 2 years when compared to the contralateral limb.

Keywords: anterior cruciate ligament (ACL); internal tibial rotation; isokinetic evaluation; strength

Surgical intervention in the form of ligament reconstruction has been advocated to improve knee joint instability associated with an ACL tear. Several soft tissue grafts have been used to reconstruct and replace a torn ACL. The 2 most common tissues are the central third patellar tendon and the semitendinosus and gracilis hamstring tendons.[3] Evaluation of the knee after an ACL reconstruction using the semitendinosus and gracilis (hamstring) autografts has primarily focused on flexion and extension strength.[2,5-8] The semitendinosus and gracilis muscles contribute to internal tibial rotation,[11] and it has been suggested that harvest of these tendons for the purpose of an ACL reconstruction contributes to internal tibial rotation weakness.[12] Internal tibial rotation is essential to the normal biomechanics of the knee[10] and is necessary in gait. It follows the ankle in pronation and supination. Tibial rotation if initiated from the ankle will transfer to the knee.

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The tibiofemoral joint must then respond. This response occurs faster with greater load in running. Tibial rotation strength, although not well studied, is necessary to internal rotation of the tibia to control external rotation and in the "screw home" mechanism at the end of extension where the tibia externally rotates on the femur. Loss of tibial rotation strength is felt by some to impair functional activities such as alpine skiing.[12]

Although the primary motions of the knee joint are flexion, extension, and rotation, there have been few published reports investigating isokinetic torque production of internal and external tibial rotation strength after an ACL reconstruction. Viola et al[12] measured internal and external tibial rotation torque at 60°/s, 120°/s, and 180°/s in 23 subjects who were 51 ± 40 months from ACL reconstruction using hamstring tendons (semitendinosus and gracilis) in a method previously described by Hester and Falkel.[4] They found that subjects who had undergone an ACL reconstruction using the semitendinosus and gracilis tendons demonstrated internal tibial rotation weakness in their reconstructed limb when compared to their contralateral normal limb. The authors suggested that a lack of adequate foot stabilization and the inability to control unwanted subtalar and midtarsal foot motion, although not documented, may have had confounding effects on the results by allowing a certain amount of unwanted joint motion.[12] It has been previously thought that this would increase torque values. Previous attempts to describe dynamic assessment of normal rotary mechanics have also presented similar challenges with regard to standardization, which explains the varying results reported in the literature. These include inconsistencies within patient positioning and stabilization, a clinical knee-testing apparatus that is difficult and costly to reproduce, and the inability to control unwanted foot motion, such as inversion and eversion of the talocalcaneal joint.

The primary purpose of this study was to evaluate internal and external tibial rotation torque when compared to the contralateral normal limb after ACL reconstruction using hamstring tendons during a technique that minimizes unwanted subtalar motions during testing procedures.

METHOD

Subjects

Inclusion criteria for subjects (N = 30) were the following: unilateral ACL reconstruction at least 2 years previously, a stable ACL (<5-mm side-to-side difference) at time of testing confirmed by surgeon and KT-1000 arthrometer, no history of knee problems after initial knee reconstruction, a normal contralateral knee, and the ability to comply with the testing protocol. The patients were recruited from the clinics of 4 surgeons, and subjects performed rehabilitation at several outlying physical therapy clinics. Surgeons followed a standardized protocol for ACL reconstruction for each subject using a semitendinosus and gracilis harvest with EndoButton (Smith and Nephew, Mississauga, Canada) femoral fixation and low-profile belt-buckle tibial fixation. The patients were given a standardized rehabilitation protocol to present to their physical therapist. Before isokinetic evaluation, the time from reconstruction to testing, age, height, weight, sex, and leg dominance were recorded for each subject. All subjects signed informed consent forms before evaluation. Data were collected in the physiotherapy department at the Fowler Kennedy Sport Medicine Clinic by a single evaluator who was not blinded to the study knee.

Isokinetic Evaluation

Subjects were instructed to wear loose-fitting shorts and running shoes that did not rise above the malleoli. Before each test, subjects were instructed to perform a 3-minute warm-up on an exercise bike ergometer. A Cybex 6000 dynamometer (Cybex division of Lumex Inc, Ronkonkoma, NY) was used to evaluate both the operative and nonoperative legs for internal and external tibial rotation. For each of the test procedures, patients were placed supine on a UBXT (Cybex, CSMI, Norwood, Mass) bench, and the pelvis, chest, and thigh were stabilized using large Velcro straps. Knee flexion angle was maintained at 90° for all tests. Subjects started with their foot perpendicular to their frontal plane when supine on the UBXT. This was recorded as their neutral position. The foot of each subject was positioned securely onto a footplate with straps crossing the top (toes), midfoot, and heel of the foot. Straps were pulled tightly in each case to provide maximum stability. For consistency, subjects were asked to place their contralateral limb on the base bar of the UBXT. For these tests, all subjects were fitted with an appropriate Air-Stirrup Ankle Brace (Aircast, Summit, NJ) commonly used to restrict ankle inversion and eversion motions. Once the test foot had been placed comfortably in the footplate, dorsiflexion was increased approximately 30° by the tester to further isolate tibial rotation and restrict unwanted foot motion.

Subjects were tested at angular velocities (concentric) of 60°/s, 120°/s, and 180°/s internal and external tibial rotation. Each subject performed 4 submaximal warm-up repetitions before testing. Subjects were instructed to exert a maximal effort throughout each of 4 test repetitions. No verbal encouragement was offered throughout any of the test procedures. Testing for all subjects was performed on the nonoperative limb first, followed by the contralateral normal limb. Subjects were allowed a 30-second rest between the tests and approximately 2 minutes of rest between testing of the opposite limb to permit equipment setup.

Statistical Analysis

Statistical analysis was performed using SPSS version 10.0 (SPSS Inc, Chicago, Ill). Descriptive statistics describe the test subjects' baseline variables. All data, including torque scores and range of motion measurements for the ACL-reconstructed limb, were compared to the contralateral limb using an analysis of variance. A *P*

TABLE 1
Mean Physical Data (N = 30)

Subject Characteristic	Mean ± SD
Age	32.3 ± 9.7
Height, in	173.99 ± 8.1
Weight, kg	90.5 ± 29.3
Sex distribution (men/women)	22/8
Hours of activity performed per week	9.1 ± 9.4

TABLE 2
Means and Standard Deviations for Peak Torque Measurements (feet-pounds) for Internal and External Tibial Rotation at All of the Tested Angular Velocities

Test Condition	Involved-Side Torque	Noninvolved-Side Torque	*P* Value
Internal rotation			
60°/s	17.4 ± 4.5	20.5 ± 4.7	.012[a]
120°/s	13.9 ± 3.3	15.9 ± 3.8	.036[a]
180°/s	11.6 ± 3.0	13.4 ± 3.8	.045[a]
External rotation			
60°/s	19.7 ± 4.8	21.1 ± 5.3	.303
120°/s	16.1 ± 4.0	16.9 ± 4.3	.428
180°/s	12.7 ± 3.1	13.5 ± 3.9	.367

[a]Statistically significant at the .05 level.

value of less than .05 was considered to indicate statistically significant differences. Analysis was calculated using the mean absolute difference of the average of 4 maximal peak torque repetitions.

RESULTS

Subject Data

Table 1 describes the age, height, weight, hours of activity performed per week (described as any activity that required exertion, was structured or organized exercise, increased heart rate, or required strength), sex distribution, and time from surgery to testing. Table 2 lists the means and standard deviations for peak torque measurements (feet-pounds) for internal and external tibial rotation at all of the tested angular velocities. The mean peak torque measurements for internal rotation strength of the operative limb were statistically different compared to the nonoperative limb at 60°/s (P = .012), 120°/s (P = .036), and 180°/s (P = .045) (Table 2). The nonoperative limb demonstrated greater strength at all speeds. The mean torque measurements for external rotation were statistically similar when compared to the nonoperative limb at all angular velocities (Table 2).

DISCUSSION

The semitendinosus and gracilis tendons remain an attractive graft choice for surgical reconstruction of a torn ACL. The ease of harvest is thought to decrease donor site morbidity, and because of their size, stiffness, and cylindrical shape, they still provide a substantial graft source comparable to the natural ACL. However, controversy still remains as to whether muscle weakness occurs after harvesting of the tendons. Some authors have demonstrated that a loss of knee flexion strength exists,[5,7] whereas others have been unable to detect a significant difference.[2,8] Viola et al[12] found that subjects who had undergone an ACL reconstruction using the semitendinosus and gracilis tendons demonstrated internal tibial rotation weakness in their reconstructed limb when compared to the contralateral limb at angular velocities of 60°/s, 120°/s, and 180°/s.

It has been suggested that this deficit in internal rotation weakness may contribute to deficits in athletic performance.[12] Although the hamstrings work as an agonist to the ACL by helping to resist anterior tibial translation, protection to the ACL may be compromised if hamstring muscle weakness develops as a result of the harvest. Deficits in internal rotation strength of between 12% and 15% were found in the involved extremity as compared to the uninvolved side. The accepted position at risk for producing an ACL injury is knee valgus and external tibial rotation. In this position, the tibial internal rotators are working eccentrically to counteract forces on the ACL. It is possible that by weakening the tibial internal rotators through graft harvesting, we are putting the postreconstructed knee at increased risk of reinjury. The knee is subjected repeatedly to challenges involving tibial external rotation in any cutting sport such as soccer, basketball, and volleyball. In sports requiring tibial rotation such as alpine skiing, it is also possible that these deficits would be clinically significant.

As noted in this study and by other authors,[4,9,12] it is difficult to obtain normative torque data for internal/external tibial rotation because of variations in testing protocol. Although a standardized and widely accepted protocol exists to test flexion and extension strength, there are several limitations when testing internal and external tibial rotation. These include variation in patient positioning and stabilization, use of a modified clinical knee-testing apparatus that is difficult and costly to reproduce, and the inability to control unwanted foot motions such as inversion and eversion of the talocalcaneal joint. The purpose of our study was to determine whether internal/external tibial rotation weakness occurs as a result of the hamstring harvest using a technique that minimizes unwanted foot motions during testing. Subjects who were at least 2 years post–ACL reconstruction, had no contralateral knee instability, and had no complications after surgery participated in this study. Comparisons were made between operative and nonoperative limbs for differences in torque values and range of motion. To achieve maximal torque and range of motion values, an optimal knee position of 90° was maintained. To obtain the desired dorsiflexion and avoid compromising knee joint angle, the dynamometer height and angle were adjusted to accommodate the subject being tested. Variations in hip angle, which occurred to maintain knee flexion angle, were not considered to have an effect on peak torque production, as it had been documented that flexion of the hip has little effect on torque production when 90° of flexion is maintained at the knee joint.[11]

Rotary neutral position was identified using the parameters set by Osternig et al,[9] in which the foot is dorsiflexed with the subtalar joint in an estimated neutral position and the medial border of the foot and knee is perpendicular to the body's frontal plane. This position was recorded as the tibial rotary neutral position. It was noted that at all angular velocities tested, the involved limb range of motion measurements were consistently lower than that of the opposite limb; however, these results were not statistically significantly different.

The most notable results were the statistically different values demonstrated for internal tibial rotation at 60°/s, 120°/s, and 180°/s. Previous attempts to measure normal rotary torque and torque deficits associated with hamstring harvest have resulted in higher peak torques than were demonstrated in our evaluation. We believe that the peak torques presented before our investigation may have been inflated because of an inability to maintain ankle stabilization in previous protocols, resulting in unwanted talocalcaneal joint motion. Our values were consistently lower for internal and external tibial rotation at all angular velocities. This may be due to several factors. First, because the head of the talus is wider anteriorly, increasing dorsiflexion locks the talus in the mortise inhibiting or preventing rotation. Second, dorsiflexion may also have an effect on the potential force production of many of the lower leg muscles.[1] Although the muscles used cannot be identified without electromyography, it is thought that the tibialis anterior, which passes anterior to the medial malleolus, becomes lax when the ankle is passively dorsiflexed, putting it at a mechanical disadvantage for the production of external torque. Concurrently, muscles of the deep flexor compartments, the tendons of which pass posterior to the medial and lateral malleoli, respectively, would be stretched with passive ankle dorsiflexion. Third, lateral and deep flexor compartment muscles act as antagonists to inward and outward ankle rotation, and if sufficiently stretched with passive dorsiflexion, they may resist any further stretch that would result from ankle inversion and eversion. In this study, a decrease in external tibial rotary torque was also noted. Although not statistically significant, this decrease in torque suggests that deconditioning may also be a factor associated with decreases in rotational torque. These factors remain hypotheses of individual muscle contributions to internal and external tibial rotation. However, we believe that in this patient population, a decrease in ankle rotation and greater isolation of internal and external tibial rotation contributed to the lower torque values in this study.

One limitation of our study is lack of data regarding the flexion/extension strength of our subjects. It is difficult to determine from our subjects whether the internal rotation strength deficit was isolated or in conjunction with other strength deficits.

We have demonstrated in our study that patients who undergo surgical intervention to repair a torn ACL with the use of autogenous hamstring tendons demonstrate weaker internal tibial rotation at 2 years after surgery when compared to the contralateral limb. However, because these subjects are not evaluated longitudinally, it is difficult to definitively determine if this deficit is a result of the harvest or if it was present at the time of reconstruction. In addition, we do not know if the deficit is caused by the specific surgical technique or if there would likely be a deficit after the use of other graft choices (ie, central third of the patellar tendon). Further research into these areas is important in answering these clinically meaningful questions. These data may be of use to clinicians in preoperative planning to determine which graft choice is suitable for particular patient populations and those who might conduct research on internal/external tibial rotary strength deficit after an ACL reconstruction. Although we have attempted to isolate subtalar movement during testing, which specific muscles are responsible for producing internal and external torque remains unclear and should be investigated through the use of electromyography. The decreased peak torque and range of motion values demonstrated in this study may be attributed to the increase in dorsiflexion and better isolation of internal and external tibial rotation movements. This study further supports previous studies that have demonstrated a loss of internal rotational strength after ACL reconstruction using semitendinosus and gracilis hamstring tendons.

Identifying a significant deficit is important for both clinical and therapeutic settings. It is important for future research to clearly define the role of internal and external tibial rotation strength and determine how deficits affect performance in athletic endeavors and rehabilitation.

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