Effect of ACL Reconstruction and Tibial Rotation on Anterior Knee Laxity

By: Kevin M. Guskiewicz, PhD, ATC; David H. Perrin, PhD, ATC; David E. Martin, PhD, ATC; David M. Kahler, MD; Bruce M. Gansneder, PhD; and Frank C. McCue, MD*

Guskiewicz, K.M., Perrin, D.H., Martin, D.E., Kahler, D.M., & McCue, F.C. (1995). Effect of ACL reconstruction and tibial rotation on anterior knee laxity. Journal of Athletic Training, 30: 243-246.

*****Note: Figures may be missing for this format of the document**
*****Note: Footnotes and endnotes indicated with brackets**

Abstract:

The anterior cruciate ligament (ACL) is the primary restraint to anterior translation of the tibia on the femur. Research suggests that resistance to anterior translation changes as the tibia is rotated internally and externally. This study assessed the degree to which ACL reconstruction and tibial rotation affects anterior knee laxity. Nine subjects with ACL lesions and functional instabilities participated in the study. Subjects were measured 1 to 10 days before surgery and 6 to 8 months after ACL reconstruction using the Kr-1000 knee arthrometer. A mechanical leg stabilizer was used to assess anterior translation at 20° of knee flexion in three positions: internal rotation of 15°, neutral, and external rotation of 15°. Subjects were measured at 89 and 67 N of anterior force. Data were analyzed with a three-factor (test x position x force) repeated measures ANOVA. Following surgery, reduction in laxity (mm) for the three positions (internal rotation, neutral, and external rotation) was 1.9, 2.8, and 3.4, respectively, at 89 N and 1.5, 2.0, and 2.6, respectively, at 67 N. The degree of reduction in laxity (presurgery to postsurgery) was dependent upon rotation and force, and was greatest in external rotation and least in internal rotation pre- to postsurgery. We concluded that ACL reconstruction using a patellar tendon graft significantly decreased anterior tibial translation at all three positions, but a greater amount of reduction was observed postsurgically at the externally rotated position. This supports the theory that mechanical blocks and secondary restraints such as a taut mid-third of the iliotibial tract may interfere with clinical laxity tests in some positions of tibial rotation. Fixing the tibia in an externally rotated position may decrease the effect of secondary restraints and improve sensitivity in testing for ACL laxity.

* Kevin M. Guskiewicz is an assistant professor in the department of Physical Education, Exercise and Sport Science at the University of North Carolina at Chapel Hill, NC 27599-8700. He was a doctoral candidate in Sports Medicine at the Curry School of Education at the University of Virginia at the time this research was completed.
David H. Perrin is an associate professor and Director of Graduate Athletic Training and Bruce M. Gansneder is an associate professor of Educational Studies at the Curry School of Education at the University of Virginia.
David E. Martin is an assistant professor in the Department of Radiology at the University of Virginia Medical Center. He was a doctoral candidate in Sports Medicine at the Curry School of Education at the time this research was completed.
David M. Kahler is an assistant professor of Orthopedic Surgery and Frank C. McCue is an Alfred R. Shands Professor of Orthopedic Surgery and Plastic Surgery of the Hand. Both are associated with the Department of Orthopedics at the University of Virginia.

Article:

The anterior cruciate ligament (ACL) plays a vital role in providing functional stability to the knee. The diagnostic tests used to assess its integrity have generated much interest in both clinical practice and research.[3,7,8,14,22,26,29,30] Clinicians disagree on the involvement of the secondary restraints to anterior displacement of the knee,[2,10,19] thus leading to uncertainty in interpreting clinical examinations. Much of the debate surrounds the interaction between tibial rotation and laxity as well as the role of the ACL in restraining tibial rotation.

Tibial rotation appears to play a vital role in properly assessing the ACL.[6,16,18,19,27,30] Joint laxity is a result of a complex interaction among all the ligaments.[21] This interaction is altered when a ligament is cut or injured. Therefore, the change in laxity is due not only to loss of the ligament, but also to a change in the interaction among the remaining ligaments. The roles of these structures as restraints change as the tibia is rotated.[21]

Fukubayashi et al [6] reported a decrease in anterior and posterior translation when the tibias of intact cadaveric knees were restrained in a neutral position. In the same study, however, there were no significant differences reported in anterior or posterior translation between tests allowing free tibial rotation and tests preventing free tibial rotation in knees with sectioned ACLs.

Torzilli et a1 [31] reported that an anterior force applied to the tibia produced internal tibial rotation in 98% of intact knees tested, while a posterior force produced an external rotation in 82%. MarkoIf et al[17] reported marked differences in anterior knee laxity when comparing injured and normal knees at 15° external rotation, at both 20° and 90° of knee flexion, but failed to see a similar trend at neutral and/or 15° internal rotation. Fiebert et al[5] reported significant differences of tibial translation based upon the position of the tibia in neutral, 30° internal rotation, and 30° external rotation using the KT-1000 on normal knees. In the internally rotated position, anterior translation was limited and gave lower readings when compared with neutral and external rotation of the tibia.

Inconsistencies in the interpretation of clinical laxity tests such as the Lachman and anterior drawer [2,13,14,19,29] are usually attributed to either knee flexion or tibial rotation. While much of the research available has focused on the effects of various angles of knee flexion, the issue of mild (15°) tibial rotation in performing clinical laxity tests has yet to be thoroughly investigated. As a result of biomechanical studies investigating knee flexion,[2,11,12,14,22,26] modifications to joint laxity testing of the knee have become routine in clinical practice.

The Lachman test, performed with the knee flexed 10° to 20°, is positive more often than the anterior drawer test because the hamstrings are less able to resist anterior translation near full extension. Furthermore, rollback of the femur on the tibia is not complete at 20° of flexion; therefore, the menisci are less likely to produce a stabilizing effect.

Several researchers have reported anterior displacement of the tibia using instrumented arthrometry in injured and noninjured populations preoperatively,[1,15,23] postoperatively,[15,20,24] and during nonsurgical management of ACL-deficient patients.[17,27,28] Markolf et al[17] and more recently, Martin et al[18] and Fiebert et al[5] established that tibial positioning influences anterior tibial displacement. No study, however, has attempted to determine the extent to which fixed tibial rotation during knee laxity testing at 20° of knee flexion might better isolate the ACL through minimizing the effect of the secondary restraints preoperatively to postoperatively. The purpose of this study was to assess the effect of tibial rotation on anterior knee laxity in the injured knee and to determine the effect of surgical intervention on laxity from three positions of tibial rotation (neutral, 15° internal rotation, 15° external rotation).

METHODS

Anterior translation of the tibia on the femur was measured bilaterally in nine subjects (age = 25.2 ± 9.5 yr, ht = 175.5 ± 8.8 cm, wt = 79.8 ± 14.6 kg) with ACL lesions and functional instabilities. Functional instability was defined as feeling that the knee was going to "give way" and/or being unable to perform normal activities of daily living. Tears of the ACL had been diagnosed through clinical examination (positive Lachman and positive pivot shift) and confirmed through magnetic resonance imaging and/or Telos stress radiography. Before participation in this study, each subject read and signed a consent form approved by the university institutional review board.

Subjects used in this study presented with subacute tears of the ACL. The time between injury and surgery ranged from 1 to 7.3 months (x = 4.9 months). Subjects were evaluated 1 to 10 days before surgery (preoperative) and 6 to 8 months following ACL reconstruction (postoperative) using a modified KT-1000 knee arthrometer (MEDmetric Corporation, San Diego, CA). The arthrometer was equipped with a strain gauge and a processor (Omega Technologies, Inc, Stamford, CT) that permitted continuous readouts of force from a digital diode.[23] The built-in dial tones on the standard KT-1000 were not used. Forces were displayed on the diode and recorded to 1×10^{-1}. A masonry line bubble level (Stanley Works, New Britain, CT) was also attached to the KT-1000 to ensure that all displacement forces were applied in the anatomical sagittal plane (Fig 1).

The Tibial Fixator Device (patent pending) was used to control tibial rotation (Fig 1). The foot was placed in the ankle-foot orthosis accompanying the Tibial Fixator Device, thus securing the tibia into the mortise and allowing foot positioning to control tibial rotation. The ankle-foot orthosis pivots at the heel and allows the tibia to be fixed in one of three positions: neutral, internally rotated 15°, and externally rotated 15°, as referenced from the head of the second metatarsal of the foot. The Tibial Fixator Device also maintains the knee in 20° of flexion, while stabilizing the thigh.

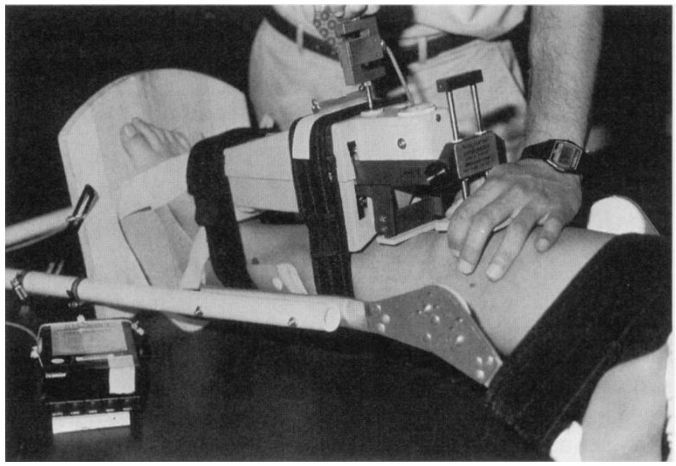


Fig 1: The modified KT-1000 arthrometer, with strain gauge attached to the handle and digital diode. The Tibial Fixator Device, with ankle-foot orthosis, controls tibial positioning and maintains the knee in 20° of flexion.

Anterior translation of the tibia relative to the femur was recorded at both 67 N (15 lbs) and 89 N (20 lbs) on the uninjured legs, followed by the injured legs at all three positions of rotation. The uninjured legs were assessed to establish test-retest reliability. The selected order of testing positions was randomized.

Following surgical reconstruction using a mid-third patella tendon autograft, subjects completed a standard rehabilitation program. They returned 6 to 8 months postsurgery for a follow-up evaluation.

Statistical analyses were performed using SPSS Release 4.1 statistical package (SPSS Inc, Chicago, IL). A three-factor (test X position X force) repeated measures analysis of variance (ANOVA) was performed to test main effects for test, position, and force, as well as any interactions. Tukey post hoc comparisons were performed to determine where significant differences occurred. Intraclass correlation coefficients were calculated for test-retest reliability at each level of rotation using the Shrout and Fleiss formula.[25]

RESULTS

The tibial displacement measurements obtained for the two forces at each position of rotation are presented in the Table. Main effects for test ($F(1,8) = 179.27$, $p < .05$), rotation ($F(2,16) = 4.25$, $p < .05$), and force ($F(1,8) = 5.19$, $p < .05$), test by rotation by force interaction ($F(2,16) = 18.51$, $p < .05$) were all significant; thus the degree of reduction in displacement (presurgery to postsurgery) was dependent upon rotation and force, and was greatest in external rotation and least in internal rotation (Tukey post hoc test $p < .05$).

Test-retest intraclass correlation coefficients and associated standard error of measurements were established using the normal limb for internal rotation (.94 and .46 mm), neutral (.84 and .50 mm), and external rotation (.72 and .83 mm).

Anterior Displacement for Injured and Uninjured Knees at 89 N and 67 N Force in 15° Internal Rotation, Neutral, and 15° External Rotation (mm; mean ± SD)

	Presurgery	Postsurgery	Difference
Injured at 67 N Force			
Internal Rotation	4.9 ± 1.5	3.4 ± 1.2	1.5
Neutral	6.3 ± 1.9	4.3 ± 1.2	2.0
External Rotation	7.9 ± 2.2	5.3 ± 2.3	2.6
Uninjured at 67 N Force			
Internal Rotation	2.9 ± 1.3	2.8 ± 1.4	0.1
Neutral	3.1 ± 0.9	2.7 ± 0.5	0.4
External Rotation	4.9 ± 1.1	4.3 ± 1.1	0.4
Injured at 89 **N** Force			
Internal Rotation	6.3 ± 1.8	4.4 ± 1.3	1.9
Neutral	8.1 ± 1.6	5.3 ± 1.6	2.8
External Rotation	10.1 ± 2.3	6.7 ± 2.3	3.4
Uninjured at 89 N Force			
Internal Rotation	3.9 ± 1.9	3.6 ± 1.8	0.3
Neutral	3.9 ± 1.5	3.4 ± 1.6	0.5
External Rotation	5.7 ± 1.6	5.4 ± 1.6	0.3

DISCUSSION

Testing anterior knee laxity in fixed external tibial rotation may be better than in the fixed neutral or internally rotated positions. As expected, ACL reconstruction using a patellar tendon graft significantly decreased anterior tibial translation when measured 6 to 8 months postoperatively; returning to near normal (< 2 mm) postoperatively as defined by Daniel et al[4] (See Table).

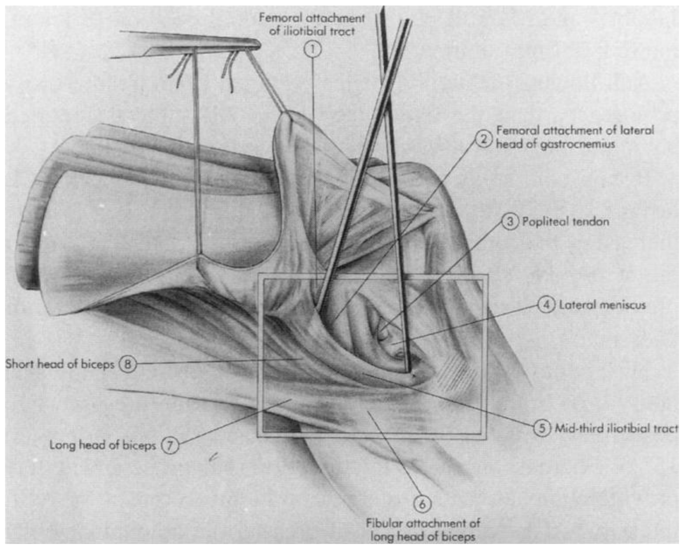
The reduction in anterior displacement at 89 N was greatest from the externally rotated position (3.4 mm) as compared to the other positions (2.8 mm, 1.9 mm). This trend was also observed at 67 N (2.6 mm compared to 2.0 mm and 1.5 mm); however, reductions were not as drastic as those recorded at 89 N. Thus, the three-way interaction is significant, and fixing the tibia in 15° of external rotation, similar to that suggested by Slocum[26] and Larson,[14] may decrease the effect of secondary restraints seen when performing the anterior drawer test or even the standard Lachman test.

The need to better define the drawer test in near extension becomes evident in Hughston's[9] description: "The hand grasping the proximal tibia naturally constrains the rotation of the tibia in a neutral position or may allow it to move relatively unconstrained." We contend this test can be improved by fixing the tibia in 15° of external rotation using the hand that also applies the anterior force to the tibia. Our findings suggest that this may be a better test of ACL integrity.

We believe that the tautness of the mid-third of the iliotibial tract (capsulo-osseus layer) when the knee is fixed in mild (15°) external rotation is crucial to the assessment of the ACL. This portion of the iliotibial tract progresses from the tibial attachment proximally to the lateral femoral condyle and intermuscular septum (Fig 2).[9] The iliotibial tract is relatively taut with the knee in 20° knee flexion. However, by externally rotating the tibia, the capsulo-osseus layer becomes less taut, allowing for a more accurate test of the ACL.

Secondly, the ACL itself is under tension when the tibia is fixed in the neutral-internally rotated position. Thus, by externally rotating the tibia, the ACL uncoils to a more functional position, again allowing for a more accurate test of the ACL.

Fig 2: Mid-third iliotibial tract (capsulo-osseus layer) progresses from the tibial attachment proximally to the lateral femoral condyle and intermuscular septum. (Reprinted from: Hughston JC. Knee Ligaments: Injury and Repair. 1993. Permission granted by Mosby- Year Book, Inc.)



Finally, as described earlier by Torg,[29] the posterior surfaces of the tibial and femoral condyles provide an anatomical block to anterior tibial motion from the 90° position as a complete rollback or glide occurs beyond 30° flexion. This was resolved by limiting knee flexion to 20° for testing (ie, Lachman position). We further propose that slight external rotation (15°) of the tibia from this position further enhances the joint mechanics. We believe muscle guarding, joint compression, and a complete rollback (glide) of the femur are eliminated from this position, thus allowing for a more isolated assessment of the ACL.

Our findings are consistent with those of Markolf et al[17] who studied injured vs normal knees at the same three positions of rotation. Although mean values of displacement for the three positions were not reported in this study, extrapolation of data indicates the externally rotated position also demonstrated the greatest difference in anterior displacement when comparing injured and uninjured knees. Based on their graphically presented data, estimated changes in joint laxity at the three positions of rotation were 2.7 mm (internal), 3.2 mm (neutral), and 3.7 mm (external) when a 100 N anterior force was applied.

One of the strengths of our study was that all subjects had isolated complete lesions of the ACL with no associated capsular or collateral ligament involvement. Five of our nine subjects had associated meniscal lesions; however, when anterior translation of the tibia is tested with the knee fixed in 20° of flexion, the menisci are not likely to produce a stabilizing effect. Therefore, we feel that meniscal pathology had no effect on anterior displacement. The results of the anterior displacement tests using the KT-1000 on both injured and uninjured knees are consistent with those of Steiner et al,[28] Staubli and Jakob,[27] and Markolf et al,[17] at the neutral position (8.1 mm, injured; 3.9 mm, uninjured).

At followup, the involved knee averaged 1.6 mm more laxity postsurgery than the uninvolved knee. All subjects reported having achieved at least 85% of their original function. Because our study involved only subjects with isolated ACL lesions, a small sample size was inevitable. However, a study increasing the sample size and therefore the statistical power might provide stronger evidence that external tibial rotation provides the clinician with a more accurate measure of anterior knee laxity.

In summary, our findings suggest that decreases in knee laxity hold true at three levels of tibial rotation presurgery to postsurgery from a position of 20° of knee flexion. Moreover, 15° of external rotation of the tibia during the assessment may provide clinicians with a more accurate measurement of ACL integrity. ACL reconstruction decreased the amount of tibial displacement, but to a different degree depending on the position of the tibia during testing. Our findings are consistent with those of Slocum and Larson[26] who described a test for rotary instabilities different from the anterior drawer test or Lachman test. They established the role of tibial rotation in assessing rotary instabilities specific to the ACL and related joint capsule. Our findings suggest that rotation has a significant impact on clinical assessment of anterior tibial displacement when attempting to isolate the ACL from 20° of knee flexion. Our study warrants the need for further research in this area.

ACKNOWLEDGMENTS
We thank Brent L. Arnold, ATC, for his assistance with this article.

REFERENCES

1. Anderson AF, Lipscomb AB. Preoperative instrumented testing of anterior and posterior knee laxity. Am J Sports Med. 1989;17:387-392.

2. Butler DL, Noyes FR, Grood ES. Ligament restraints to anterior-posterior drawer in the human knee. J Bone Joint Surg [Am]. 1980;62A:259-270.

3. Daniel DM. Assessing the limits of knee motion. Am J Sports Med. 1991;19:139-147.

4. Daniel DM, Malcom LL, Losse G, Stone ML, Sachs R, Burks R. Instrumented measurement of anterior laxity of the knee. J Bone Joint Surg [Am]. 1985 ;67A:720 -726.

5. Fiebert I, Gresley J, Hoffman S, Kunkel K. Comparative measurements of anterior tibial translation using the KT-1000 Knee Arthrometer with the leg in neutral, internal rotation, and external rotation. J Orthop Sports Phys Ther. 1994;19:331-334.

6. Fukubayashi T, Torzilli PA, Sherman MF, Warren RF. An in vitro biomechanical evaluation of the anterior-posterior motion of the knee. J Bone Joint Surg [Am]. 1982;64A:258-264.

7. Gurtler RA, Stine R, Torg JS. Lachman test evaluated. Clin Orthop. 1987;216:141-150.

8. Howell SM. Anterior tibial translation during a maximum quadriceps contraction: is it clinically significant? Am J Sports Med. 1990;18:573578.

9. Hughston JC. Knee Ligaments: Injury and Repair. St. Louis, MO: Mosby-Year Book, Inc; 1993:50-66.

10. Hughston JC, Andrews JR, Cross MJ, Moschi A. Classification of the knee ligament instabilities. Part I: The medial compartment and cruciate ligaments. J Bone Joint Surg [Am]. 1976;58A:159-172.

11. Hughston JC, Norwood LA. The posterolateral rotatory instability of the knee. Clin Orthop. 1980;147:82-87.

12. Kennedy JC, Stewart R, Walker DM. Anterolateral rotatory instability of the knee joint. J Bone Joint Surg. [Am] 1978;60A:1031-1039.

13. King S, Butterwick DJ, Currier JP. The anterior cruciate ligament: a review of recent concepts. J Orthop Sports Phys Ther. 1986;8:110-122.

14. Larson RL. Physical examination in the diagnosis of rotatory instability. Clin Orthop. 1983;172:38-44.

15. Malcom LL, Daniel DM, Stone ML, Sachs R. The measurement of anterior knee laxity after ACL reconstructive surgery. Clin Orthop. 1985;196:35-41.

16. Markolf KL, Bargar WL, Shoemaker SC, Amstutz HC. The role of joint load in knee stability. J Bone Joint Surg [Am]. 1981;63A:570-585.

17. Markolf KL, Kochan A, Amstutz HC. Measurement of knee stiffness and laxity in patients with documented absence of the anterior cruciate ligament. J Bone Joint Surg [Am]. 1984;66A:242-252.

18. Martin DE, Guskiewicz KM, Perrin DH, Kahler DM, McCue FC. Tibial rotation affects anterior displacement of the knee. J Sport Rehab. 1994; 4:275-281.

19. McQuade KJ, Crutcher JP, Sidles JA, Larson RA. Tibial rotation in anterior cruciate deficient knees: an in vitro study. J Orthop Sports Phys Ther. 1989;11:146-149.

20. Meyers JF, Caspari RB, Cash JD, Manning JB. Arthroscopic evaluation of allograft anterior cruciate ligament reconstruction. Arthroscopy. 1992;8: 157-161.

21. Noyes FR, Grood ES, Butler DL, Malek M. Clinical laxity tests and functional stability of the knee: biomechanical concepts. Clin Orthop. 1980;146:84-89.

22. Noyes FR, Grood ES, Cummings JF, Wroble RR. An analysis of the pivot shift phenomenon-the knee motions and subluxations induced by different examiners. Am J Sports Med. 1991;19:148-155.

23. Rijke AM, Perrin DH, Goitz HT, McCue FC. Instrumented arthrometry for diagnosing partial versus complete anterior cruciate ligament tears. Am J Sports Med. 1994;22:294-298.

24. Shelbourn KD, Rettig AC, Hardin G, Williams R. Miniarthrotomy versus arthroscopic assisted anterior cruciate ligament reconstruction with autogenous patellar tendon graft. Arthroscopy. 1993;9:72-75.

25. Shrout PE, JL Fleiss. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979;86:420-428.

26. Slocum DB, James SL, Larson RL, Singer KM. Clinical laxity test for anterolateral rotary instability of the knee. Clin Orthop. 1976;118:63-69.

27. Staubli H, Jakob RP. Anterior knee motion analysis-measurement and simultaneous radiography. Am J Sports Med. 1991;19:172-177.

28. Steiner ME, Brown C, Zerins B, Brownstein B, Koval PS, Stone P. Measurement of anterior-posterior displacement of the knee. J Bone Joint Surg [Am]. 1990;72A:1307-1315.

29. Torg JS, Conrad W, Kalen V. Clinical diagnosis of anterior cruciate ligament instability in the athlete. Am J Sports Med. 1976;4:84-93.

30. Torzilli PA, Greenberg RL, Hood RW, Pavlov H, Insall JN. Measurement of anterior-posterior motion of the knee in injured patients using a biomechanical stress technique. J Bone Joint Surg [Am]. 1984;66A:14381442.

31. Torzilli PA, Greenberg RL, Insall J. An in vivo biomechanical evaluation of anterior-posterior motion of the knee-roentgenographic measurement technique, stress machine, and stable population. J Bone Joint Surg [Am]. 1981;63A:960-968.