

Association of KT-1000 Measurements With Clinical Tests of Knee Stability 1 Year Following Anterior Cruciate Ligament Reconstruction

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Study Design: Prospective, observational study.

Objectives: To determine the association between KT-1000 measurements with an anterior translation force of 89 N and other measures of outcome (the Tegner activity score, the modified Lysholm score, subjective rating of instability, Lachman test, and pivot-shift test) 1 year following anterior cruciate ligament (ACL) reconstruction.

Background: Health care professionals often use the side-to-side difference measured with the KT-1000 arthrometer to determine ACL integrity during passive motion. It has been postulated that a 5-mm or greater difference between impaired and nonimpaired knees represents a procedural failure.

Methods and Measures: Ninety patients (46 men, 44 women) with a mean age of 30 ± 8 years were examined 1 year after surgery. Patients were classified in 1 of 3 groups depending on the amount of laxity between the impaired knee and the nonimpaired knee. Seventy percent of the subjects had a side-to-side difference less than or equal to 3 mm (tight), 13% had a difference of between 3 and 5 mm (moderate), and 17% had a difference greater than or equal to 5 mm (loose) on examination using the KT-1000.

Results: Mean Lysholm and Tegner scores did not differ significantly among groups. Side-to-side differences in KT-1000 measurements at 89 N were not associated with the Lysholm score ($r = -0.09$) or Tegner score ($r = 0.02$). Lachman tests were related to involved-knee KT-1000 measurements ($r = 0.39$) but not to side-to-side differences in KT-1000 measurements ($r = 0.15$). Similarly, pivot-shift tests were related to involved-knee KT-1000 measurements ($r = 0.26$) but not to side-to-side differences ($r = -0.08$).

Conclusions: These results suggest that side-to-side KT-1000 measurements obtained with an anterior translation force of 89 N should not be used in isolation to determine ACL reconstruction success or failure 1 year following surgery. *J Orthop Sports Phys Ther* 1999;29:540-545.

Key Words: anterior tibial translation, arthrometer, outcome measures

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The KT-1000 knee ligament arthrometer (MEDmetric, San Diego, Calif) is a device that is used to quantify anterior-posterior tibial-femoral displacement. Measurements obtained from this device have been used to identify anterior cruciate ligament (ACL) tears.⁷ At a pull of 89 N, a difference of 3 mm or more between anterior tibial displacement in the involved knee and anterior tibial displacement in the uninvolved knee has been shown to represent an ACL disruption.^{2,7,8,12} A side-to-side difference of less than 3 mm is thought to represent nonimpaired anterior tibial translation.^{7,18,20,21}

Apart from normative and pathological values, an acceptable post-ACL reconstruction side-to-side difference has yet to be well established, although a 5-mm criterion has been used by some authors.^{1,2} Following surgery, the KT-1000 is used to document an amount of passive restraint provided by the reconstruction.^{10,17} In addition, clinicians use repeated

measures of anterior tibial displacement following ACL reconstruction to determine if the integrity of the graft changes during the course of the patient's rehabilitation.^{5,11-13,18}

Success or failure following ACL reconstruction has often been linked to the amount of anterior tibial translation present following reconstruction. Aglietti et al¹ and Bach et al² defined ACL reconstruction failure as a KT-1000 side-to-side difference greater than 5 mm regardless of other "success" criteria. Despite increasing use of the KT-1000, there has been very little literature that describes the significance of KT-1000 measurements postoperatively and their relationship to other measures of clinical success.

A number of functional tests have been described to evaluate the clinical success of ACL reconstruction. These functional tests evaluate parameters such as pivoting function, force absorption, and force production.^{4,14,23,24,28} The single-leg vertical jump and hop tests for distance are commonly used to detect functional limitations of the lower extremity following ACL reconstruction.^{4,23} Sekiya et al²⁸ determined the relationship of the single-leg hop test to KT-1000 scores in patients with ACL reconstruction. Their data showed no association between the hop test and residual anterior knee laxity, ranging from -2-mm to 8-mm side-to-side difference. In addition, Barber-Westin⁵ did not find a relationship between the type of sports activity of patients and what these authors defined as abnormal displacement (≤ 3 mm) 2 years following ACL reconstruction.

The Lachman and pivot-shift tests are the standard clinical tests used to determine the knee joint laxity; they also reflect the success of ACL reconstruction.⁹ Following ACL reconstruction, significant improvements in both tests have demonstrated the restoration of knee stability.^{1-3,22}

The Lysholm, Tegner, Hospital for Special Surgery, Cincinnati Knee Ligament Rating, and International Knee Documentation Committee scales have all been used to determine the outcome of ACL reconstruction. Overall, these rating systems have demonstrated similar amounts of improvements in the patients tested following surgery.²⁷

The relationship between side-to-side KT-1000 measurements and functional tests of knee stability is not clear. The purpose of this study was to determine the association between measurements of the KT-1000 arthrometer at 89 N and other outcome measures 1 year following ACL reconstruction.

METHODS

Subjects

Ninety patients (46 men, 44 women) with a mean age of 31 ± 8 years who underwent an arthroscopi-

cally assisted intra-articular ACL reconstruction using a patellar tendon autograft were included in this study. All reconstructions were performed by a single surgeon (S.J.N.). Prior to surgery, all patients signed an informed consent. This project was approved by the Institutional Review Board at the Nicholas Institute of Sports Medicine and Athletic Trauma.

KT-1000 Testing

One year following surgery (average 13 ± 3 months), KT-1000 testing was performed by 1 of 2 experienced testers, both with more than 5 years of clinical experience using the instrument. The KT-1000 exam was performed with the patient in the supine position with the knees at approximately 25° of flexion. The amount of anterior tibial displacement for both knees was recorded following an applied anterior translation force 89 N, and difference in anterior tibial displacement between the involved knee and the uninvolved knee was calculated. The 89 N force was chosen because the audible beep gave the measurement more objectivity than an arbitrary force exerted by the tester during the maximum manual test. Using a force of 89 N, Robnett et al²⁵ demonstrated fair intertester reliability of KT-1000 measurements on knees with ACL reconstruction. The reliability of results derived through use of a maximum manual force has yet to be documented. Patients were divided into 3 groups based on the amount of anterior tibial displacement (side-to-side difference) 1 year postoperatively as determined by the following KT-1000 measurement categories: tight was less than or equal to 3 mm; moderate was more than 3 but less than 5 mm; and loose was more than or equal to 5 mm. This classification was based on the previously published work of Bach et al.²

Subjective Assessment of Functional Activity

Lysholm and Tegner questionnaires were administered following KT-1000 measurements. The Lysholm score is a questionnaire that subjectively rates squatting, stairclimbing, pain and other activities. The score ranges from 1 to 100, and improvement is demonstrated by an increase in the score. The Tegner activity scale gives a numerical value to a patient's level of activity, ranging from 0 to 10. Zero represents a patient who is impaired because of knee problems, and 10 indicates a patient who competes at the professional level. Scores in ACL-impaired knees have been shown to be low, but they increase significantly with ACL reconstruction.^{19,31} The Lysholm and Tegner activity scales originally designed for knee ligament injuries demonstrated good reliability.²⁹ Subjective complaints of instability were also recorded, ranging from reports of knees never giving way to knees buckling on every step.

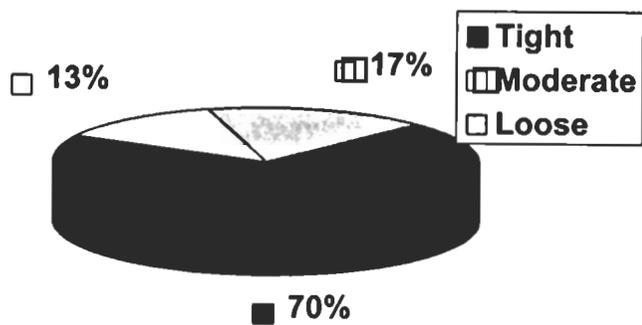


FIGURE 1. The distribution of KT-1000 measurements at 89 N on 90 patients 1 year following anterior cruciate ligament reconstruction; tight equals less than 3 mm; moderate equals between 3 and 5 mm; loose equals more than or equal to 5 mm.

Physical Examination

A physical examination was performed on the both knees of all patients and graded clinically by the first author. This examiner was blinded to the results of the KT-1000 measurements. Lachman and pivot-shift tests were performed. A predetermined grading system was established for all stability tests.^{2,3} The Lachman test was graded with an "A" for feeling a firm end point or end feel and "B" for the feeling of no end point. In addition to the end point grade, a grade of displacement was also assigned to each knee with 1 = tight, 2 = moderate, and 3 = loose. The pivot shift was graded as 0 (negative), 1+ (slip), 2+ (jump), and 3+ (subluxation). Research examining the reliability of the Lachman and pivot-shift tests have produced mixed results in ACL-impaired knees.^{6,7,15,16} However, there have been no published studies on the reproducibility of these clinical tests on knees with ACL reconstruction or their association to KT-1000 measurements.

Data Analysis

Pearson Product Moment correlations were used to examine the association between KT-1000 measurements at 89 N, Lysholm scores, and Tegner scores. Spearman rank correlations were used to examine the association between KT-1000 measurements at 89 N, Lachman grades, and pivot-shift grades. Additionally, 1-way ANOVA was used to compare Lysholm and Tegner scores between patients with tight, moderate, and loose KT-1000 measurements. Post hoc comparisons were made between tight and loose groups. Independent *t* tests were used to compare side-to-side differences between KT-1000 measurements in patients with 1A and 2A Lachman scores and KT-1000 measurements in patients with +1 and +2 pivot-shift scores.

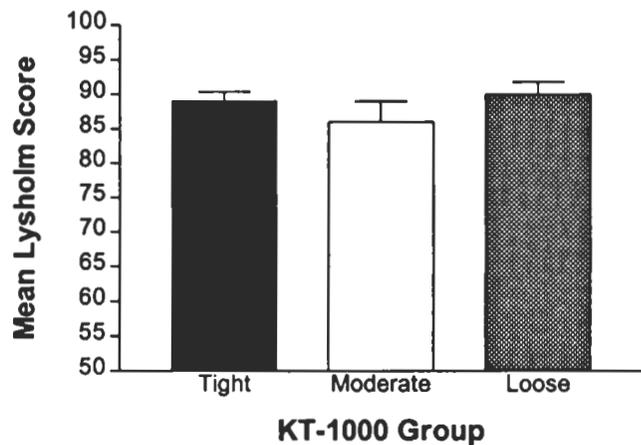


FIGURE 2. Mean and standard error for Lysholm scores 1 year following surgery for 90 patients based on KT-1000 side-to-side differences (tight equals less than 3 mm; moderate equals between 3 and 5 mm; loose equals more than or equal to 5 mm). Lysholm scores were not different between subjects with tight and loose KT-1000 measurements ($P = .50$).

RESULTS

KT-1000

There were 60 tight, 11 moderate, and 19 loose KT-1000 scores taken 1 year after ACL reconstruction (Figure 1).

Lysholm and Tegner Scores

Lysholm scores were not significantly associated with side-to-side differences in KT-1000 measurements ($r = -0.09$, $P = .42$). There were no statistically significant differences in the mean Lysholm scores among groups of patients classified as tight, moderate, or loose ($P = .50$) (Figure 2). Subjectively, 2 patients reported symptoms of "instability on a rare occasion during sports or exertion." One patient had a loose KT-1000 measurement, and the other had a tight score. The remaining 88 patients reported "no feeling of instability on physical activity."

Tegner activity scores were not associated with the side-to-side differences in KT-1000 measurements ($r = 0.02$, $P = .9$) Tegner scores were not different between patients with tight KT-1000 measurements and patients with loose KT-1000 measurements ($P = .39$) (Figure 3).

Lachman and Pivot-Shift Tests

A firm end feel was palpated during the Lachman test on all patients. Lachman grades were related to KT-1000 measurements from the involved leg ($r = 0.39$, $P < .001$) but not to side-to-side differences in KT-1000 measurements ($r = 0.15$, $P = .16$). Patients ($n = 16$) with a 2A Lachman had 2.7 ± 0.7 mm more anterior tibial displacement than patients ($n = 74$) with 1A Lachman grades ($P = .001$).

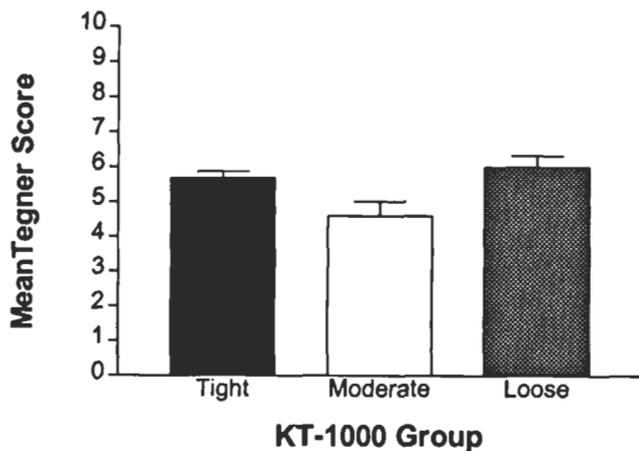


FIGURE 3. Mean and standard error for Tegner activity scores 1 year following surgery for 90 patients based on KT-1000 side-to-side differences (tight equals less than 3 mm; moderate equals between 3 and 5 mm; loose equals more than or equal to 5 mm). Tegner scores were not different between subjects with tight and loose KT-1000 measurements ($P = .39$).

Sixty-one patients had a negative pivot shift, 23 had a +1 pivot shift, and 6 had a +2 pivot shift. In the tight group, 16 patients had a +1 pivot shift and 4 patients had a +2 pivot shift. In the loose group, 6 patients had a +1 and 1 patient had a +2 pivot shift. Pivot-shift grades were related to the involved-limb KT-1000 measurements ($r = 0.024$, $P = .021$) but not to side-to-side differences in KT-1000 measurements ($r = -0.08$, $P = .50$). Patients with negative pivot shifts had 8.1 ± 0.3 mm anterior tibial displacement compared with 11.1 ± 0.9 mm anterior tibial displacement in patients with +2 pivot-shift grades ($P < .01$). However, side-to-side differences in KT-1000 measurements were not different in patients with negative pivot shifts (2.1 ± 0.4 mm) and patients with +2 pivot shifts (2.1 ± 1.2 mm) ($P = .9$).

DISCUSSION

Although 3 mm or less of anterior tibial translation has been established to represent nonimpaired side-to-side difference,^{7,18,20,21} a difference of greater than 5 mm is considered a failure in the knee with ACL reconstruction.^{1,2} The results of this study show no clear association between the amount of laxity on a 89 N KT-1000 measurement and other indices of successful ACL reconstruction at 1 year following surgery.

Harter et al¹³ reported no association between KT-1000 measurements and episodes of giving way in knees with ACL reconstruction. Tibone and Antich³⁰ showed that functional stability was restored in patients with ACL reconstruction despite measured laxity, as reported 2 years postoperatively by the KT-1000 arthrometer. In the present study, only 2 patients subjectively reported instability 1 year following surgery, and 1 had a tight KT-1000 measurement.

One potential reason for a lack of association in

side-to-side differences found in our study may be the amount of force used during KT-1000 testing. Although there are no reproducibility studies using a maximum manual force, KT-1000 testing may produce a significantly greater millimeter displacement and have a higher association to various clinical tests. Bach et al² documented that smaller differences were found with an 89 N pull compared with the maximum manual force in knees with ACL reconstruction. In addition, maximum manual KT-1000 measurements may be associated to functional tests that have also been described to evaluate the clinical success of ACL reconstruction. Functional testing was not evaluated in our study.

Our results demonstrated that, following ACL reconstruction, arthrometer measurements alone do not necessarily indicate success, as evident by the fact that the Lysholm scores and Tegner activity levels were not associated with KT-1000 measurements. Our data concurs with Harter et al,¹² who suggested that it is inappropriate to extrapolate the results of a static ligament test to dynamic activity. Harter et al found no correlation between KT-1000 measurements and the Knee Function Rating Form score or the Post Operative Physical Findings scale in patients following ACL reconstruction. These findings may be attributed to the fact that, during a KT-1000 measurement, we attempt to isolate only the passive restraints provided by the ligaments, while the muscles remain silent.²⁰

The data indicated that Lysholm and Tegner scores were not different between patients with tight and loose KT-1000 measurements. Based on the standard deviation for the tight (10.8) and loose (7.9) groups, we had an 80% power to detect a 7.7-point difference in Lysholm scores between tight and loose groups given an α level of 5%. Similarly, we had an 80% power to detect a 1-point difference in Tegner activity scores between tight (1.3 SD) and loose (1.3 SD) groups. These power calculations indicate that we had the ability to detect clinically evident differences in Lysholm and Tegner scores between tight and loose groups if such differences had existed.

On examination, our data indicate that there was no association between side-to-side KT-1000 measurements and Lachman or pivot-shift tests. Sixteen patients with 2A Lachman grades did not have a greater side-to-side difference in KT-1000 measurements than the 74 patients with a 1A Lachman. Nonetheless, our findings were able to show an association between grades of these standard clinical tests used to determine the knee joint laxity and absolute KT-1000 measurements. To our knowledge, there have been no studies that have directly related postoperative KT-1000 measurements to these clinical measures. Other researchers have shown that ACL reconstruction improves Lachman and pivot-shift tests.^{1-3,12,15,22} We feel that the Lachman test is important following

surgery in order to determine if a firm endpoint is restored, and our data support the association between the subjective translation measured by the Lachman test and the absolute KT-1000 score. However, when it comes to preventing functional instability, it may be restoration of a firm endpoint during dynamic weight-bearing activity that prevents instability and not the amount of passive laxity determined by a KT-1000 or subjective Lachman grading.

Aglietti et al¹ has used the KT-1000 measurements as a sole criterion for failure of ACL reconstruction. However, failure criteria following ACL reconstruction are not consistent throughout the literature.^{1,2,7,26} The assessment of outcome following surgery is further complicated by the fact that the improvement in the amount of anterior tibial translation is likely to vary between surgeons. Two varying philosophies are apparent in discussions concerning the amount of acceptable anterior tibial translation following ACL reconstruction. Many authors have reported that to overconstrain a knee may be just as detrimental as to leave a knee too loose.^{8,20,27} A knee that is too loose may later present with instability or meniscal tears as a result of increased shear forces at the joint surface. Conversely, a knee that is too tight may show earlier signs of osteoarthritis with possible abnormal biomechanics and increased joint compression.³² Longitudinal studies of patients with postoperative KT-1000 measurements are necessary to determine if "tight" knees go on to have an increased incidence of osteoarthritis or if "loose" knees go on to have a higher incidence of meniscal degeneration.

Based on the results of this study, it is evident that side-to-side KT-1000 measurements are not associated with other clinical measures of ACL instability and therefore should not be used in isolation to assess ACL integrity. A universal postsurgical "failure" criterion must be established and accepted by all clinicians so that comparisons of outcome can be made across various studies.

CONCLUSION

We found that subjective assessment of functional activity was independent of KT-1000 measurements. Additionally, we found no association between KT-1000 side-to-side differences and other standard clinical tests. Our findings did show an association between grades of standard clinical tests used to determine knee joint laxity and absolute KT-1000 measurements. KT-1000 measurements are not associated with other clinical measures of ACL instability and therefore should not be used in isolation to determine the success of ACL reconstruction.

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