Effect of trunk position on anterior tibial displacement measured by the KT-1000 in uninjured subjects.

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Abstract:

Objective: Clinicians may obtain false-negative Lachman tests for tibial displacement when the trunk position of the athlete varies as the anterior cruciate ligament injury is assessed on the field, on the sideline, and in the clinic. We examined the influence of supine, semireclined, and sitting trunk positions on arthrometric laxity measurements of the knee.

Design and Setting: Subjects in the 3 trunk-thigh test positions (15°, 45°, and 90° of hip flexion) were passively supported and tested in a counterbalanced order. The right knee was maintained at 29.0° ± 3.1° of flexion. A 133-N (30-lb) anterior force was applied to the right knee using a modified KT-1000 knee arthrometer equipped with a strain gauge that allowed for digital display of the displacement force.

Subjects: Ten males and 5 females without present knee injury or history of knee ligament repair to the right lower extremity.

Measurements: Three tibial displacement (mm) trials at each trunk position were averaged and used for analysis.

Results: A 1-factor (trunk-thigh position) repeated-measures analysis of variance revealed no significant difference in anterior tibial displacement values among the 3 trunk-thigh positions ($P > .05$). Group means for displacement were 7.9 ± 2.3 mm (supine), 8.1 ± 2.5 mm (semireclined), and 8.3 ± 2.6 mm (sitting).

Conclusions: These findings suggest that alterations in trunk position are not a problem in the instrumented assessment of anterior tibial displacement in an uninjured population. Further research should determine the relevance of these findings, as well as "end-feel" (ie, stiffness) in subjects with injury to the anterior cruciate ligament. Further research should also determine if these findings can be applied when comparing passive versus active (eg, propped on elbows or hands) trunk support in subjects with anterior cruciate ligament-injured knees.

Key Words: knee, arthrometer, Lachman test, anterior cruciate ligament, laxity

Article:

Clinicians frequently use the Lachman test to evaluate acute knee injuries on the field, but athlete positioning often varies. We have observed athlete positioning to include supine, semireclined (eg, propped on elbows), or sitting-upright positions, which result in different trunk-thigh angles. Yasukouchi and Isayama[1] demonstrated that, when the knee is extended in sitting postures of trunk-thigh angles of 90° and 60°, the lumbar curve is reduced and the pelvis is posteriorly rotated. They believe that hamstrings and gluteal muscles together significantly affect the lumbar curve and pelvic tilting.

Adler et al[2] compared the traditional supine Lachman test with a drop-leg Lachman test. Anterior cruciate ligamentdeficient subjects were positioned for the drop-leg Lachman test supine with the hip extended (posterior thigh contacting the table, ie, no hip flexion) and abducted and the knee off the side of the table and flexed 25°. An 89-N (20-lb) anterior force was applied using the KT-1000 arthrometer (MedMetric Co, San Diego, CA), first while subjects were conscious, then while they were anesthetized. The drop-leg Lachman test resulted in a 2.3-mm (conscious group and anesthetized group) greater mean anterior tibial displacement than the traditional Lachman test in the injured knees. The authors hypothesized that the increased anterior tibial displacement demonstrated in the drop-leg Lachman test may be explained in part by the hips being positioned in extension and abduction, thereby providing greater relaxation to the hamstrings and fascia lata.[2]

Instrumented knee arthrometry is used to quantify knee joint laxity after anterior cruciate ligament injury.[3-l0] The devices are attached directly to the limb, and manual force is applied to displace the tibia on the femur. The arthrometers provide displacement measures of knee laxity in millimeters.[3-l0] Instrumented knee arthrometers have demonstrated greater sensitivity for determining anterior tibial displacement at 20° to 30° of knee flexion (the angle used for the Lachman test) compared with 90° of knee flexion (the angle used for the manual drawer test).[ll-14]

Our study evaluated the effect of three different trunk-thigh flexion angles on anterior tibial displacement of uninjured subjects as measured by a modified KT-1000 knee arthrometer. We hypothesized that anterior tibial displacement measures would decrease as trunk-thigh flexion angles increased, due to increased passive hamstring tension associated with increased trunk-thigh flexion angles.

METHODS

Subjects:

Fifteen volunteer subjects (10 males and 5 females) ranging in age from 20 to 36 years (age = 23.9 ± 5.0 years; ht = 176.4 ± 6.4 cm; wt = 72.0 ± 10.2 kg) participated in the study. A minimum sample size of 14 subjects was determined based upon a power analysis, using average correlation = 0.80, alpha = 0.05, medium effect size = 0.56, and power = 0.80.(15) Disqualification criteria included presence of knee pathology or history of knee ligament repair to the right lower extremity. Each subject read and signed a human consent form approved by a university review board before participating.

Instrumentation:

We used a modified KT-1000 (MedMetric, San Diego, CA) arthrometer to assess anterior tibial displacement. Normally, anterior displacement is recorded at forces of 67, 89, and 133 N (15, 20, and 30 lb) since they correspond to 3 consecutive audiotones. However, we modified the arthrometer by equipping it with a model LCCB-50 strain gauge on line with a DP41-V processor (Omega Technologies, Inc, Stamford, CT) that permitted readouts of force from a digital diode instead of the audiotones.[9] The strain gauge and digital diode modifications allowed us to apply a more valid anterior displacement force.

Force validity of the LCCB-SO strain gauge was determined before subject data collection by hanging certified calibration weights (accurate to ± 0.01%)[16] from the KT-1000 in an inverted position. A drawstring bag was attached to the force-sensing handle of the arthrometer, and 13.64 kg (30 lb) of calibration weight was added to the hanging drawstring bag. The drawstring bag and the force-sensing handle of the arthrometer in the inverted position weighed 0.45 kg (1.0 lb). Ten consecutive loading trials revealed a mean force (minus the weight of the drawstring bag and force-sensing handle) of 13.63 kg (29.99 lb) and ranged from 13.59 to 13.64 kg (29.8 to 30.0 lb).

Previous studies have found that tibial rotation affects the measurement of anterior tibial displacement.[17,18] To control for this confounding factor, a masonry bubble level was attached to the KT-1000 housing. The bubble level helped to ensure consistent device positioning in the anatomic sagittal (anteriorposterior) plane during the application of the displacement force.

Trunk-thigh flexion angles and knee flexion angles were measured with a standard, double-armed goniometer with full-circle protractor made of transparent plastic. The goniometer arms were 30.48 cm (12 in) long, and the protractor was marked in 1° increments.

Procedure:
We tested each subject for anterior tibial displacement (mm) of the right knee at each of the 3 trunk-thigh positions (15°, 45°, and 90° trunk-thigh flexion) in counterbalanced order. The right knee was arbitrarily chosen as the test extremity for all subjects. Figures 1-3 show the 3 trunk-thigh positions with arthrometer placement. The trunk-thigh positions were counterbalanced between subjects to decrease the potential effect of test order on the tibial displacement measures.

To determine trunk-thigh angle, the stationary arm of the goniometer was aligned with the trunk's midaxillary line, and the moving arm was aligned with the lateral femoral epicondyle. An adjustable, hinged traction table provided subjects with trunk support at the selected trunk-thigh flexion angles. A plywood board (61.0 cm long by 61.0 cm wide by 0.64 cm thick) was placed under the subject's lower extremities to prevent the plastic thigh support (height, 11.0 cm) from being positioned in separations of the tabletop. A nonslip rug cushion was attached to the undersurface of the plywood to prevent movement between the board and vinyl tabletop. A second plywood board (61.0 cm long by 20.3 cm wide by 0.64 cm thick) was placed under the plastic foot support. The plastic thigh and foot supports were secured to the plywood boards by 5.1-cm wide VELCRO (VELCRO USA Inc, Manchester, NH) strips. Subjects sat on a piece of nonslip rug cushion (55.9 cm long by 25.4 cm wide) to help stabilize trunk positioning. A VELCRO strap provided further stabilization by securing the pelvis to the table. A VELCRO strap was then applied around the distal portions of both thighs and adjusted to position the right hip in neutral rotation. Neutral hip rotation was operationally defined as the parallel alignment of the medial and lateral superior patellar poles determined visually and with palpation by the examiner.

Following neutral hip rotation positioning, the knee-flexion angle was measured using the lateral malleolus and greater trochanter for goniometer arm alignment. The knee-flexion angle obtained at the first trunk-thigh test position of each subject was reproduced (29.0° ± 3.1°) in its positioning for subsequent trunk-thigh flexion angles. The medial joint line of the right knee was then palpated and marked with ink to allow proper alignment of the KT-1000 arthrometer. The medial joint line marking allowed consistent placement of the arthrometer with each trunk-thigh position change. The KT-1000 arthrometer alignment and test procedures used have been explained in detail by others.[5,6,19] Anterior tibial displacement was measured at 133 N (30 lb) of applied force as displayed on the digital diode.

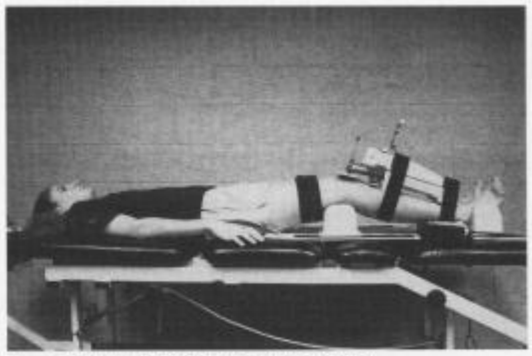

Figure 1. 15° trunk-thigh flexion angle (supine).

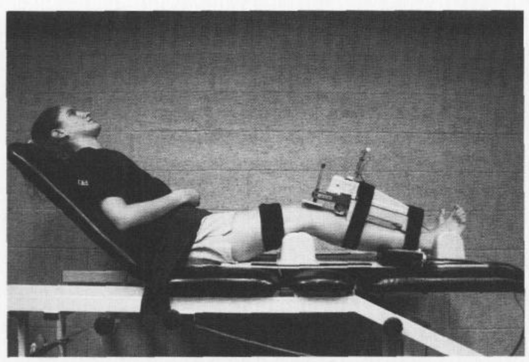

Figure 2. 45° trunk-thigh flexion angle (semireclined).

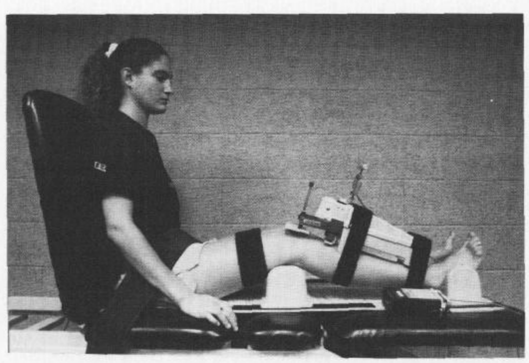

Figure 3. 90° trunk-thigh flexion angle (sitting).

The millimeters of anterior tibial displacement were indicated by a needle dial on the KT-1000 arthrometer case and visually interpreted to the nearest 0.5 millimeter.[6] Displacement values at each trunk-thigh test position were communicated by the examiner to an assistant who recorded the measurement. The mean of 3 consecutive displacement values at each test position, rounded to 0.5 mm, was used for statistical analysis. The KT-1000 arthrometer was left in place for the 3 consecutive displacement measures. The arthrometer was removed during trunk-thigh position changes and then reapplied.

Reliability:
Intratester reliability and standard error of measurement (SEM) were determined for KT-1000 anterior displacement measurements at each of the 3 trunk-thigh positions for the first 10 subjects of the study. Testing was performed as previously described, except all measures were immediately repeated a second time with the trunk-thigh positions again counterbalanced. All tests were performed by the same examiner. Intraclass correlation coefficients (ICC) (3,k)[20] and SEMs[21] were calculated for each of the 3 trunk-thigh positions. The ICCs and SEMs for the test-retest session were 0.98 and 0.31 mm, 0.97 and 0.42 mm, 0.98 and 0.31 mm at the 15°, 45°, and 90° trunk-thigh flexion angles, respectively. The intratester ICCs reflected a high degree of consistency between the test and retest scores at each of the thigh-trunk positions. The magnitude of measurement errors (SEMs) was relatively small and demonstrated a high degree of measurement precision.

Data Analysis:
A 1-factor (trunk-thigh position) analysis of variance (ANOVA) with repeated measures was computed using anterior tibial displacement (mm) as the dependent variable. The probability level accepted for statistical significance was set at $P < 0.05$. All statistics were generated using SPSS (version 6.1, Statistical Package for the Social Sciences, SPSS Inc, Chicago, IL).

RESULTS:
The mean anterior displacements were 7.9 ± 2.3 mm (supine), 8.1 ± 2.5 mm (semireclined), and 8.3 ± 2.6 mm (sitting). The ANOVA revealed no significant differences among the 3 test positions, $F_{2.28} = 1.77$, $P > .05$.

DISCUSSION:
We found no significant difference in mean anterior tibial displacement measures among the 3 trunk test positions. Anterior tibial displacement values measured with the KT1000 arthrometer were essentially the same regardless of the trunk-thigh position, be it supine, semireclined (45° of hip flexion), or sitting (90° of hip flexion). This result does not support our research hypothesis that anterior tibial displacement would decrease as trunk-thigh flexion angles increased.

The basis for our hypothesis was that passive hamstring tension would increase as the pelvis moved into a greater amount of relative anterior tilt when subjects were moved from the supine to sitting position. Our study indicates that, if passive hamstring tension was produced, it was not enough to reduce anterior tibial displacement in our sample of uninjured subjects. Future research should look to determine the relationship of hamstring inflexibility to anterior tibial displacement measured in different trunk positions of anterior cruciateinjured subjects. The mean tibial displacement difference between anterior cruciate ligament-injured knees and uninjured knees ranges between 3 and 6 mm.[4-22] This increased laxity in anterior cruciate-injured knees may have greater potential to be reduced as a result of increased passive hamstring tension.

Average Anterior Displacement (mm) of Uninjured Knees at 133 N (30 lb) with Subject in Supine Lachman Position

Source	n	Mean	SD
Daniel and Stone[19]	37	6.8	NA
Highgenboten et al[7]	30	6.1,7.6*	± 2.0, ± 2.3*
Steiner et al[22]	28	4.6	NA
Present study	15	7.9	± 2.3

* = right, left knees
NA = not available

Adler et al[2] recorded a 2.3-mm tibial displacement difference in anterior cruciate-injured knees of conscious patients when comparing the traditional Lachman test with the drop-leg Lachman test. They reasoned that the hip extension and abduction of the drop-leg Lachman allowed greater relaxation of the hamstrings and tensor fascia lata compared with the flexed-hip position of the traditional Lachman test. The contralateral uninjured knees of the conscious group showed a 0.5-mm tibial displacement difference between the test conditions.[2] The use of uninjured subjects in our study reflected the similar finding that hip position did not affect tibial displacement.

Our displacement values tended to be higher than other published values using the KT-1000 at 133 N on uninjured knees of conscious subjects (Table). For comparative purposes, we included our supine displacement values in the Table. The higher displacement values in our study at all trunk positions may be due to the valid force application of 133 N measured by our strain gauge modification to the KT-1000. The third audiotone of our arthrometer consistently sounded at approximately 25 pounds (111 N) of force on the strain gauge digital diode readout. The third audiotone's representing 30 pounds (133 N) in the other studies may have been less than the actual applied force, thereby producing comparatively smaller displacement values than our findings. Variance among the different subject samples and methodologic measurement error introduced by the different researchers would also contribute to different tibial displacement values.

The diagnosis of an anterior cruciate ligament tear involves the clinician's perception of both tibial displacement and end-point stiffness, or "end-feel." The KT-1000 can provide absolute displacement values, as used in our study, and an inverse measure of stiffness called the compliance index.[5] The compliance index is the difference in millimeters of displacement between 2 loads, such as 67 N and 89 N.[5] Future research is warranted using the compliance index, or a direct measure of stiffness, to compare anterior cruciate ligament-injured knees with uninjured knees in subjects with different trunk-thigh positions.

CONCLUSIONS

The Lachman test performed using the KT-1000 demonstrated no difference in tibial displacement (mm) with the trunk passively supported supine, semireclined, or sitting in subjects with intact anterior cruciate ligaments. A hypothesized increase in passive hamstring tension as the trunk moved from supine to sitting did not affect anterior tibial displacement. Future research should use anterior cruciate ligament-injured subjects and should compare active support (eg, propped on hands) with passive support that duplicates the same trunk position. Use of the compliance index, or stiffness, in comparing injured with uninjured extremities in the different trunk positions is indicated as well.

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