A METHOD FOR TESTING TIBIAL TRANSLATION WITH ACTIVE QUADRICEPS CONTRACTION: TESTED IN CONTROL AND ANTERIOR CRUCIATE LIGAMENT DEFICIENT POPULATION

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INTRODUCTION

Quadriceps muscle function has been correlated with changes in patterns of locomotion following injury to the anterior cruciate ligament (ACL) [1]. In particular, contraction of the quadriceps muscle can produce anterior tibial translation when the knee is near full extension [2] and increase ACL strain in knees with a functional ACL. Therefore, the interaction between active quadriceps contraction and ACL function is an important consideration when evaluating functional changes following ACL injury. It has been shown [3] that passive measurement of knee laxity is not related to active functional measurements or clinical outcome. Thus, there is need for a method to evaluate the relationship between the function of the quadriceps muscles and the anterior tibial translation in the ACL deficient knee. Past studies have attempted correlations but have used non-physiological loads (e.g. [4]).

The purpose of this study was to apply a method that integrates quadriceps activation with measurement of anterior tibial translation in the evaluation of functional changes following ACL injury. This was accomplished by measuring the amount of anterior tibial translation in control and ACL deficient subjects at known knee extensor torques and known flexion angles.

MATERIALS AND METHODS

Two groups were involved in the testing. First, the control group consisted of six subjects with no musculoskeletal involvement (average age = 30 ± 9, 2 Female). One control subject, male (25 yrs), was selected to demonstrate the repeatability of this test. The second group consisted of three anterior cruciate ligament deficient (ACLD) subjects (average age = 29 ± 7 yrs, 1 Female). All subjects signed an IRB approved consent form. Each subject was tested bilaterally using a KT-1000 Knee Ligament Arthrometer (MedMetric, San Diego, CA) in combination with a Cybex 350 (CSMI, Norwood, MA).

The subjects were seated in the Cybex test chair so that the back of their knees were touching the seat edge, the tibias were hanging over the edge of the seat, and the seat-back was giving low back support (Figure 1). Subjects were secured to the testing chair by a seat belt. A Velcro strap approximately 10 cm. above the knee secured the femur to the chair. The rotation axis of the cybex resistance arm was aligned with the flexion-extension axis of the knee. The lower limb was attached to the resistance arm with a foot plate instead of the resistance pad used by other researchers [4]. The foot was secured by two Velcro straps (Figure 1). Knee flexion angle could be set to 20°, 40°, 60°, or 80° for testing isometric quadriceps contraction.

The KT-1000 was placed on the anterior aspect of the tibia and secured with two Velcro straps (Figure 1). The tibial sensor pad was placed on the tibial tubercle and the patella sensor pad rested on the patella. The KT-1000 was then adjusted so the joint line arrow aligned with the knee joint line.

Figure 1: Subject test setup. The subject was seated in the Cybex chair. Lower limb is locked at 20° of flexion. Subject produced 1%, 2%, and 3% BW*Ht torque. KT-1000 provided relative motion between Femur and Tibia.

Four joint angles were tested: 20°, 40°, 60°, and 80°. At each of these flexion angles, three isometric torques were tested: 1%, 2% and 3% body weight times height (BW*Ht). The chosen torques represented physiological loads seen in the knee during walking.

Laxity measurements were first taken after the KT-1000 was zeroed at the specified flexion angle [4]. The tibial translation was measured when the quadriceps produced a torque of 1%, 2% and 3% BW*Ht. This was a measure of the amount of tibial translation produced by quadriceps contraction alone or quadriceps active drawer.

Repeatability and reproducibility were also tested. We processed a single normal subject at different times in the day and over 3 different days for a total of five tests. For each test, the tibial translation was measured while exerting a torque of 1%, 2% and 3% Body Weight*Height (BW*Ht). These measurements were reproduced at angles of 20°, 40° and 60°.

Comparisons were done by determining if side to side tibial translation was statistically different for the controls by using the Students' t-Test. Next the null hypothesis tested that the differences between the tibial translation of each leg for the ACL deficient subjects and also the control subjects equals zero. Averages were calculated at each of the flexion angles to determine retest variability. The significance level was set to $\alpha = 0.05$.

RESULTS

The amount of anterior tibial translation decreases as the flexion angle increases for both normal and ACL deficient knees (Figure 2). The magnitude of the extensor torque did not significantly affect the translation over the range of torques (1%, 2% and 3% BW*Ht) that were tested ($p > 0.05$). The anterior tibial translation of the ACL deficient's unaffected leg was on average 0.5 mm different than the control group (maximum 2 mm, minimum 0.01).

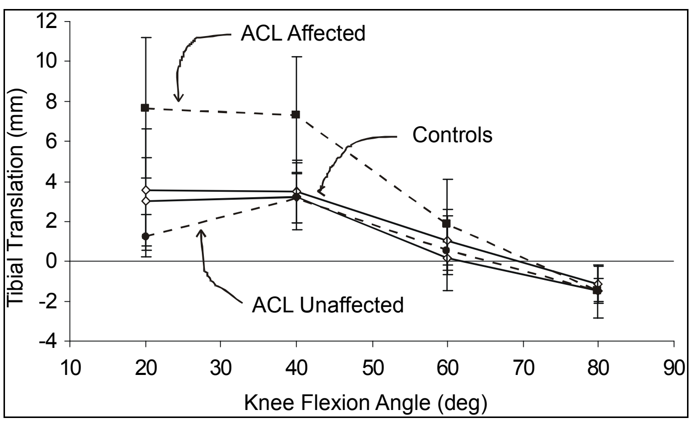

Figure 2: Average 2% BW*Ht Torque for the control population, unaffected ACL leg, and affected ACL leg.

Side to Side Differences

In the control population, side to side tibial translations were not significantly different ($p > 0.05$) for any of the flexion angles or torques. In contrast, the ACL deficient population had significant differences for the affected side at flexion angles of 20° and 40° and all torques (Figure 3). No significant differences were found for the affected leg at 60° and 80°.

Reproducibility

The retest variability was at the ±0.75mm interval (maximum 1.0mm, minimum 0.6 mm). However, for this subject, there was a consistent difference between legs. The tibial translation of the dominant leg was on average slightly smaller than the opposing leg. Right-Left differences had average values of 1 mm (maximum 1.3 mm, minimum 0.8mm). Significant differences were found at 1% torque at 20°, 2% torque at 20° and 40°, and 3% torque at 20°, 40° and 60°.

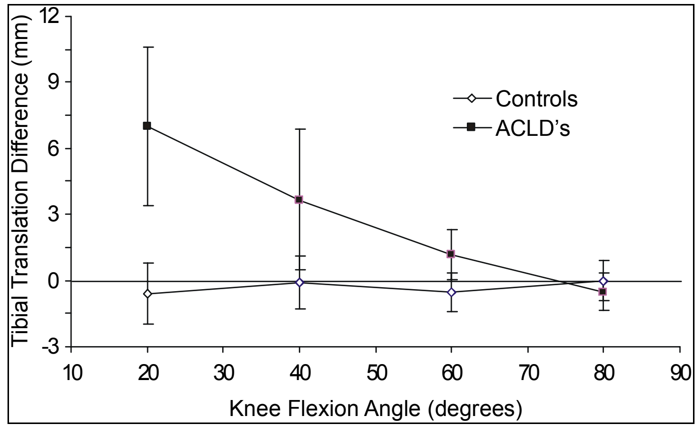

Figure 3: Average difference at 1% BW*Ht Torque for the control population, Right – Left (open diamonds), and the ACLD population, Affected – Unaffected (filled squares).

DISCUSSION

The results of this study demonstrate a method for determining functional laxity of the ACL deficient knee that integrates a known amount of quadriceps activation. The methods presented have shown to yield reproducible results and don't appear to be sensitive to the amount of muscle contraction. This type of functional test could provide a more meaningful test than one that calls for maximum quadriceps activation [4] or purely passive laxity test. Previous studies have shown that passive laxity tests do not adequately predict clinical outcome following ACL injury [3]. In addition, other studies [1] that have shown alterations in patterns of locomotion following ACL injury are related to changes in the pattern of muscle contraction during walking. Thus a functional test as described in this study that integrates active muscle contraction could provide a better measure of the functional status of the patient with ACL injury.

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