ON CHANGES IN HAMSTRING LENGTH DURING A SIMULATED JUMP LANDING: AN *IN VITRO* STUDY

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INTRODUCTION

Non-contact anterior cruciate ligament (ACL) injuries often involve a one-footed jump landing and may be associated with excessive ACL strain. ACL strain has been measured *in vivo* using a DVRT (Beynnon & Fleming 1998). ACL strain correlates with quadriceps force (Torzilli 1994; Dürselen 1995), and a rapid increase in quadriceps force > 6 bodyweights (BW) can rupture the ACL (Dikeman 1998, DeMorat 2004). In an *in vitro* model of a simulated 2-BW jump landing, using knees constrained only by pretensioned springs (7 kN/cm spring rate) representing preactivated quadriceps, medial and lateral hamstring and gastrocnemius muscle forces, the increase in the DVRT-measured relative ACL strain was proportional to the increase in tension in the quadriceps muscle-equivalent as the knee flexed under the impulsive compression and flexion knee moment loading (Withrow 2006a). However, when the hamstring muscle equivalents were instead arranged to lengthen as the knee flexed, then a significant (70%) reduction in peak relative ACL strain was found (Withrow 2006b).

It is not known whether the hamstring muscles shorten or lengthen when landing a jump on one or two legs. We therefore designed a cadaver experiment to test the hypothesis that hamstrings can indeed lengthen during a simulated jump landing. The significance of a "lengthening" muscle contraction (used in lieu of "eccentric", per Faulkner 2003) is that the muscle force can exceed 1.6 times the maximum isometric value (or shortening muscle contraction). As Withrow (2006b) showed, a lengthening hamstring muscle contraction helps limit peak ACL strain by limiting quadriceps-induced anterior tibial translation; an isotonic hamstring force provided no such protection.

METHODS

Three older adult cadavers (two female) were dissected to expose the origins and insertions of the three major hamstring muscles: semimembranosus (SM), semitendinosis (ST) and biceps femoris (BF). With the cadaver torsos and one limb supported in the prone position, Certus (Northern Digital, Inc., Waterloo, Canada) optoelectronic triads were mounted on the posterior aspect of the sacrum, and the anterior aspects of the femur and tibia of the other limb. The locations of the triads, the muscle origin and insertion locations, and standard anatomic landmarks on the pelvis, femur, tibia and foot were hand digitized using Certus. The knee and hip joints were then each flexed through 90 and 75 degrees in the neutral plane, as well as in $\pm 10^{o}$ hip ab- and adduction. Finally, the hip and knee were flexed simultaneously by protracting and retracting the ankle joint from the hip joint. Kinematic data were recorded at 100 Hz. The Euclidian distance between each muscle-tendon unit (MTU) origin and insertion was then calculated for each hip and knee angle.

RESULTS AND DISCUSSION

Isolated knee flexion caused all three hamstring MTUs to shorten but, because lever arms are larger at the hip than the knee, isolated hip flexion caused all three MTUs to lengthen to a greater degree (Fig. 1). If hip and knee angles both increase by 15 and 21^{o} from initial hip and knee angles of 30^{o} at foot touch down (landing data from Pflum 2004), then all three MTUs will lengthen (from 'a' to 'c', Fig. 1). Similar results were found with the other cadavers. However, landing and falling backward may preclude a lengthening hamstring contraction due to insufficient hip flexion, thereby placing the ACL at risk. Landing jumps with adequate hip flexion should reduce peak ACL strains (via a hamstring lengthening contraction), and vice versa.

SUMMARY/CONCLUSIONS

Hamstring lengthening can indeed occur during a jump landing, but only with adequate hip flexion (>10% knee flexion).

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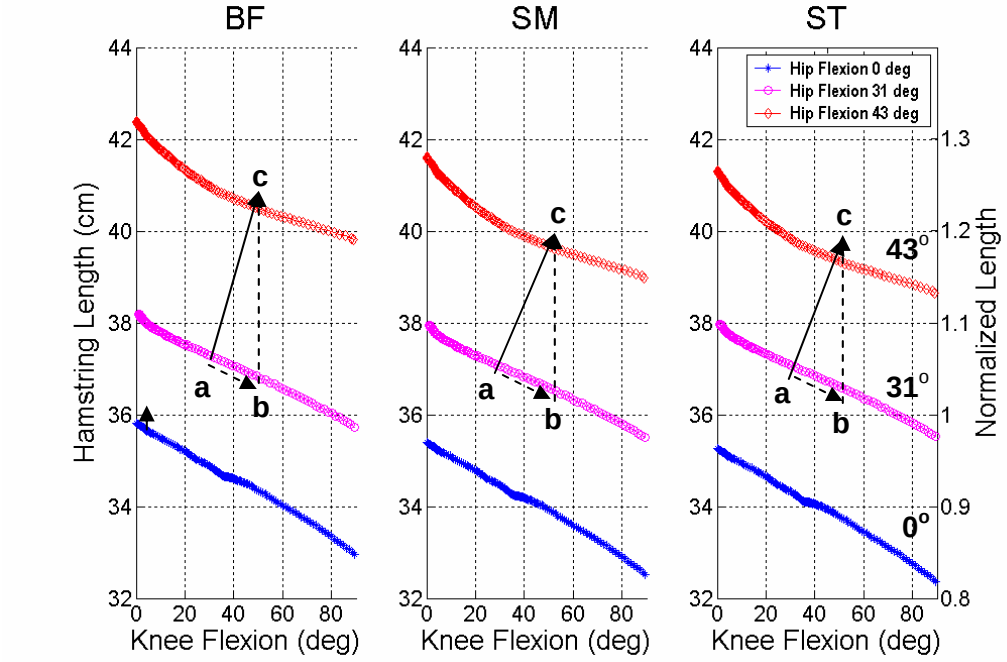

Figure 1: Effect of knee and hip flexion on the three hamstring MTU lengths (in cm) in a 92 year-old female cadaver. The BF, SM & ST MTUs would lengthen, from points 'a' to 'c', when hip and knee joints are both flexed through 15 and 21 degrees, respectively, from initial landing angles of 30^{o} each (jump landing data from Pflum 2004).