TENDON TRANSFER OF BIARTICULAR MUSCLES REDUCES BALANCE RECOVERY: A COMPUTER SIMULATION STUDY

Ashley E Clark[1], Ajay Seth[2], Jeffrey A. Reinbolt[1]
Mechanical, Aerospace, & Biomedical Engineering, The University of Tennessee Knoxville, Knoxville, TN, USA
Bioengineering, Stanford University, Stanford, CA, USA

Introduction: Stiff knee gait is a movement disorder among children with cerebral palsy, where peak knee flexion is diminished during swing phase. Rectus femoris transfer surgery, a common treatment for stiff-knee gait, reattaches the distal tendon of this biarticular, or two joint, muscle to a new site, such as the sartorius insertion on the tibia. Biarticular muscles play a unique role in motor control. As a biarticular muscle, rectus femoris may offer unrecognized benefits to maintain balance. In this study, we used musculoskeletal modeling and simulation to investigate the role of this biarticular muscle on balance recovery following support-surface translations. We hypothesized that a pre-surgical simulation has increased balance recovery compared with two post-surgical cases; in addition, a unilateral transfer simulation has better balance recovery relative to a bilateral transfer.

Materials and Methods: We assessed the influence of rectus femoris transfer surgery on balance recovery with 6 forward dynamic simulations of a patient with cerebral palsy (Fig. 1). A 3D musculoskeletal model with 92 muscle-tendon actuators and 23 degrees of freedom was scaled to represent the size of the patient using previously collected gait analysis data [1]. This pre-surgical model was altered to represent unilateral and bilateral rectus femoris tendon transfers to the sartorius [1]. The mechanism used to maintain balance was based on a muscle stretch-reflex control model, where reflex properties were found using optimization [2]. Each 6s simulation included 0.25s of quiet standing, 0.35s of support-surface translation (6 cm in the anterior and posterior directions, with a peak velocity of 23 cm/s [3]), and 5.4s of balance recovery. We evaluated balance recovery by recording whole-body center of mass displacements relative to the support surface.

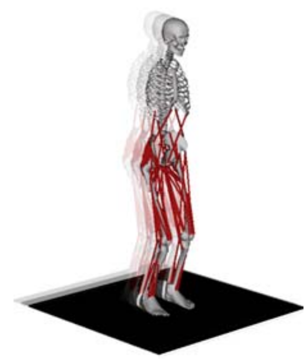

Figure 1. Simulation of balance recovery.

Results and Discussion: The pre-surgical simulations of balance recovery following support-surface translations maintained balance while both post-surgical tendon transfer simulations did not (Fig. 2). Moreover, the unilateral simulation maintained balance longer than the bilateral case in both support-surface translation directions. These findings support our hypothesis that the pre-surgical simulation has the best balance recovery, followed by the unilateral rectus femoris tendon transfer, and finally the bilateral transfer. This study's results suggest that rectus femoris tendon transfer reduces balance recovery compared with the pre-surgical case, illustrating the biomechanical advantage that biarticular muscles have in motor control.

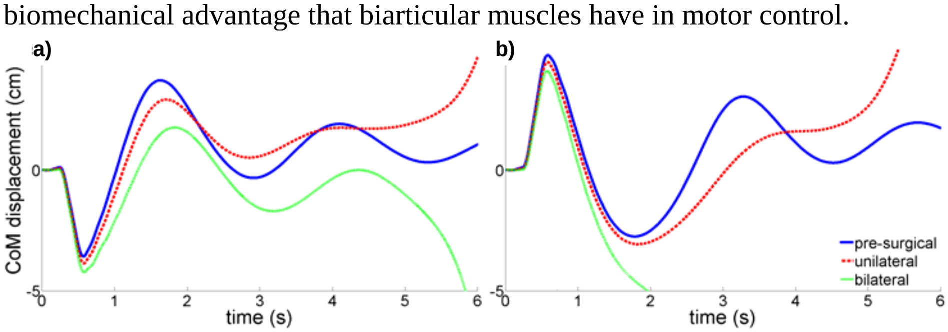

Figure 2. Center of mass displacements relative to the support surface translating (a) anterior and (b) posterior (*gray shade highlights support-surface translation*) for simulations of pre-surgical, unilateral, and bilateral tendon transfer.

Conclusions: Patient-specific simulation is a powerful tool to investigate the role of rectus femoris tendon transfer in control tasks. Future investigations will look at potential applications to examine biarticular muscles in other treatments (e.g., hamstrings lengthening) for other movement abnormalities (e.g., crouch gait).

Acknowledgements: We are appreciative to the Center for Motion Analysis at the Connecticut Children's Medical Center in Hartford, CT. This research was supported by The University of Tennessee.

References:

1. Fox M, et al. *J Biomech* **42**:614-619. 2009.
2. Feng CJ, et al. *IEEE Proceedings* **20-5**:2317-20. 1998.
3. Woollacott M, et al. *Dev Med Child Neurol* **47**: 455-461. 2005.