Investigating stiff-knee gait with subject-specific simulations

session III
4:00pm

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Purpose
Stiff-knee gait is a symptom of spastic cerebral palsy characterized by diminished knee flexion during the swing phase of gait. This diminished knee flexion has been attributed to excessive excitation of the rectus femoris (RF), a knee extensor, during swing [1]. It has more recently been observed that many stiff-knee patients exhibit excessive knee extension moments prior to swing [2]. Our first aim evaluated whether abnormal RF excitation prior to swing or during swing has a greater influence on peak knee flexion.

Rectus femoris transfer surgery, a common treatment for stiff-knee gait, reattaches the distal tendon to a new site, such as the sartorius muscle. Some patients show dramatic improvement after this surgery while others suffer further impairment. Our second aim evaluated the utility of computer simulations to determine the potential efficacy of RF transfer.

Materials and Methods
This study included ten cerebral palsy patients who exhibited stiff-knee gait and underwent RF transfer. Five patients were classified as “good outcomes” and five as “poor outcomes” based on measurements of postoperative knee flexion [2]. We generated subject-specific simulations of each patient using a musculoskeletal model with 21 degrees-of-freedom and 92 muscles. We used computed muscle control [3] to solve for muscle excitations that result in a simulation consistent with the measured preoperative gait. The first aim was investigated by eliminating RF excitation separately prior to swing and during swing. The simulated effects on peak knee flexion were compared for each subject, considering excitation magnitudes during each phase. The second aim was investigated by simulating RF transfer to the sartorius. The simulated effects on peak knee flexion were compared between good and poor outcome groups.

Results
Peak knee flexion was influenced more by abnormal RF excitations prior to swing compared to those during swing, given the excitation magnitudes during each phase. This finding redefines indications for RF transfer which traditionally focus solely on swing. Simulations of RF transfer show a significant difference ($p = 0.0296$) in peak knee flexion improvement between good (40 deg) and poor (28 deg) outcome groups. This difference illustrates the utility of subject-specific simulation for investigating treatments for stiff-knee gait.

Conclusion
Subject-specific simulation is a powerful tool for identifying the biomechanical causes of an individual’s gait abnormalities and has the potential to improve treatment planning.

References
1. Perry J, 1987. Dev Med Child Neurol, 29, 153-8.
2. Goldberg S, et al., 2006. J Biomech, 39, 689-98.
3. Thelen D, et al., 2003. J Biomech, 36, 321-8.