AN INTEGRATED APPROACH FOR IMPROVING GAIT IN A STROKE POPULATION: COMBINING ROBOTICS, FES AND NEUROMUSCULOSKELETAL MODELING

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INTRODUCTION

Stroke is one of the leading causes of functional disability among American adults. The effects of post-stroke hemiparesis include reduced muscular strength and endurance as well as diminished mechanical work output and altered muscular activation patterns during gait. These combined effects lead not only to reduced mobility but may also contribute to increased injuries from falls in this population (Nyberg et al 1995).
The overall goal of this project is to assist patients with CNS dysfunction to produce improved walking patterns through a combination of functional electrical stimulation (FES), robotic-assistive training and biomechanical modeling.

METHODS

This project combines the resources of the mechanical engineering and physical therapy departments at the University of Delaware to develop and integrate a robotic gait rehabilitation device with an intervention strategy to progressively facilitate hemiparetic patients during gait. This will be combined with an electrical stimulation protocol developed with a minimal intervention strategy based on musculoskeletal modeling and gait simulation.

<u>I. Robotic device:</u> This project required the creation of a novel robotic assistive device capable of providing varying and adjustable degrees of assistive intervention throughout the gait cycle. The first prototype achieved this by compensating for the effect of gravity on the subject's affected limb through the use of adjustable springs and pulleys[1]. The second generation device uses motorized joints that allow the subject to move within acceptable boundaries, or virtual walls, before assistance is provided within a dynamic control environment.

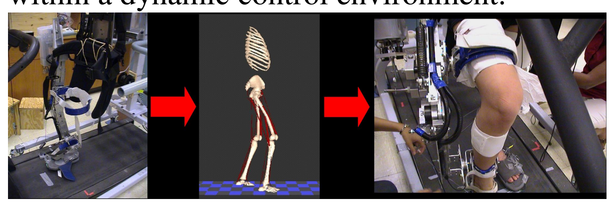

Figure 1: Organization of the research approach: from left, a robotic assistive device is combined with subject-specific musculoskeletal modeling and simulation in order to improve gait.

<u>II. Intervention strategy:</u> Since the robotic device is designed to be minimally assistive, the patient is required to initiate and correct their motions throughout the gait cycle while being guided through a movement pattern progressively more similar to the correct pattern. The level of assistance provided by the device can be adjusted to optimize learning and take advantage of the plasticity inherent in the central nervous system.

<u>III. Electrical stimulation:</u> Fatigue is a major concern when applying FES. A minimally invasive approach is therefore desired and can be achieved when the stimulation is meant to compliment, rather then replace, existing voluntary muscle activation. The

assistance provided by the electrical stimulation will vary according to the real-time needs of the patient to augment the volitional activity. The level of stimulation needed is based on that determined through modeling and simulation in order to minimize the intervention.

IV. Modeling and simulation: We have created a biomechanical model of the ankle to estimate the corrective increases in muscle activation patterns that would enable post-stroke patients to walk normally. This information will be used to control the stimulation device and will be optimized for each patient, thus providing the minimal additional activation required by the stimulator to achieve the desired joint motions.

RESULTS AND DISCUSSION

Robotic device and intervention: Preliminary results indicate that hemiparetic stroke patients using the device have increased joint excursions during gait (figure 2) when the effect of limb weight is reduced[2]. This improved range of motion is more similar to the motion of healthy controls using the device.

Muscle stimulation and modeling: We have found that the original ankle joint moment of the stroke patients can be 'morphed' to produce a healthy joint moment profile by increasing ankle and plantar flexor activity. The electrical stimulation model developed for this project also predicts joint torque outputs based on electrical stimulation and the additive effect of electrical stimulation on volitional activation is currently being explored.

SUMMARY/CONCLUSIONS

As all phases of the project more forward, integration of each component is taking place. This unique and multi-disciplinary approach promises to provide novel rehabilitation alternatives to patients exhibiting hemiparetic gait impairment.

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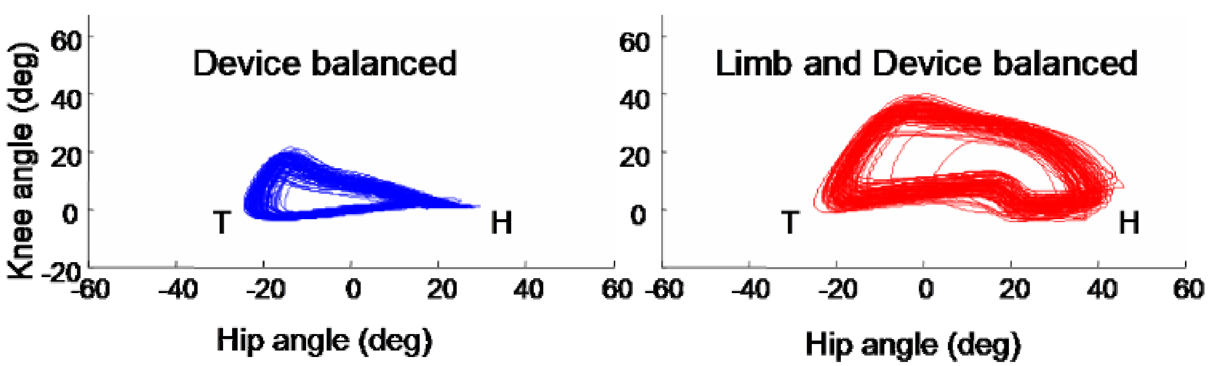

Figure 2: Hip and knee joint excursions of a representative stroke subject throughout the gait cycle. T and H represent toe-off and heel-strike respectively. In 'Device balanced' only the weight of the assistive device is removed; in 'Limb and device balanced' both the device and the limb weight are removed, reducing the work required by the patient to produce motion.