Neural Feedback Contributing to the Regulation of Limb and Joint Mechanics

Hui Shi, Mark Lyle, Nate Bunderson, T. Richard Nichols
Department of Applied Physiology Georgia Institute of Technology, Atlanta, GA

Fall 2014

Background

Muscle proprioceptors, categorized as muscle spindle and Golgi tendon organs, project from a given muscle to neurons associated with the same muscle and different muscles. This sensory feedback may be excitatory or inhibitory, depending upon the mechanical interrelationships of the muscles involved. In several motor disorders, such as spinal cord injury, these sensory feedback pathways are affected, producing disturbances of posture and balance. Mutually antagonistic muscles usually exchange inhibitory feedback from muscle spindles, pathways known as reciprocal inhibition. There are inhibitory pathways from Golgi tendon organs that project widely to extensor muscles in the limb. Understanding the neural feedback between different muscles could better equip ourselves with the neural mechanical properties of the muscle and therefore understand the regulation of joint and limb mechanics. Our working hypothesis is that the combination of length and force feedback results in the regulation of the stiffness of the limb

Objective

Understand how neural feedback contributes to the regulation of limb and joint mechanics:

- Characterize force and length feedback between muscles
- Establish a clear understanding of the sensory feedback between different muscle combinations
- Find how these sensory feedback pathways contribute to the stiffness of the muscle and limb

Experimental Method/Result

(1). Mapping Intermuscular Interactions

The experimental animal is permanently anesthetized by decerebration so that the neural pathways are still active. Muscles are attached to tendon clamps and connected to myographs and linear motors. The length of the muscle is controlled using linear motor system. Forces are measured using strain-gauge myographs.

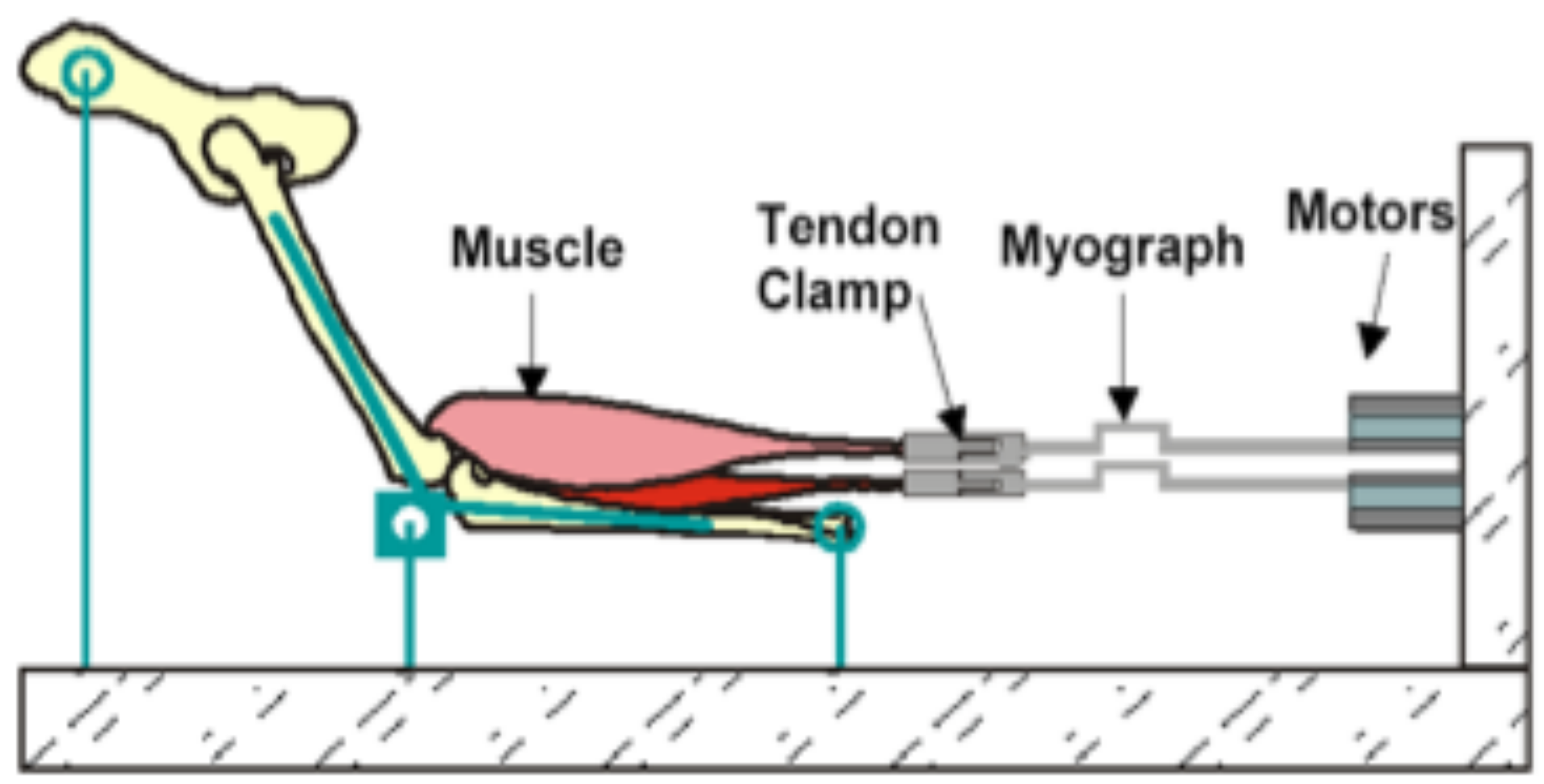

Figure 1.Schema of Experimental Design and Apparatus

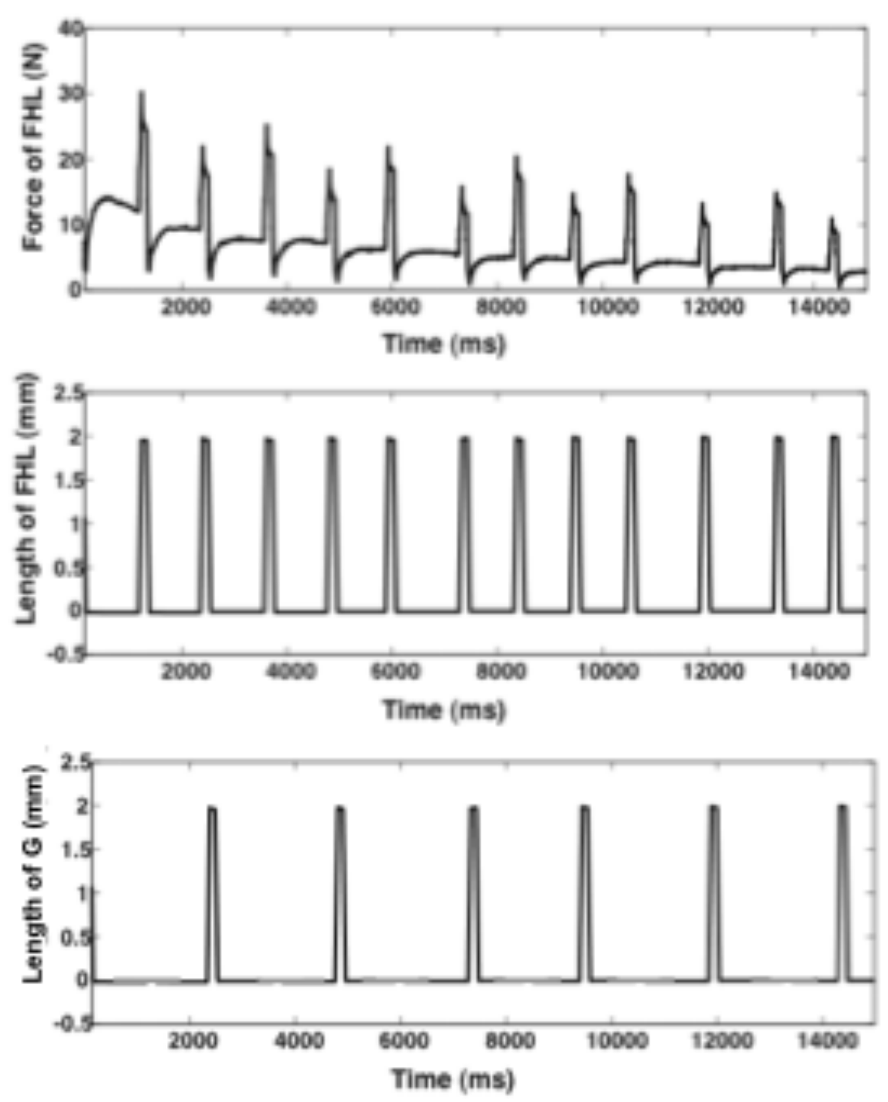

Figure 2 are graphs illustrating intermuscular inhibition. Flexor hallicus longus(FHL) is repeatedly stretched and the gastrocnemius(G) is stretched every other repetition.
It can be clearly seen that the force of FHL is reduced when stretched with the combination of the gastrocnemius muscle. This phenomenon is an example of the intermuscular inhibition.

Figure 2. Measurement of intermuscular inhibition

(2). Computational Modeling of Musculoskeletal System

Currently, there is a computational model of the cat hindlimb called Neuromechanic. This model can be used to do different simulations. This model contains architectural properties of hindlimb and mechanical properties of the muscles.

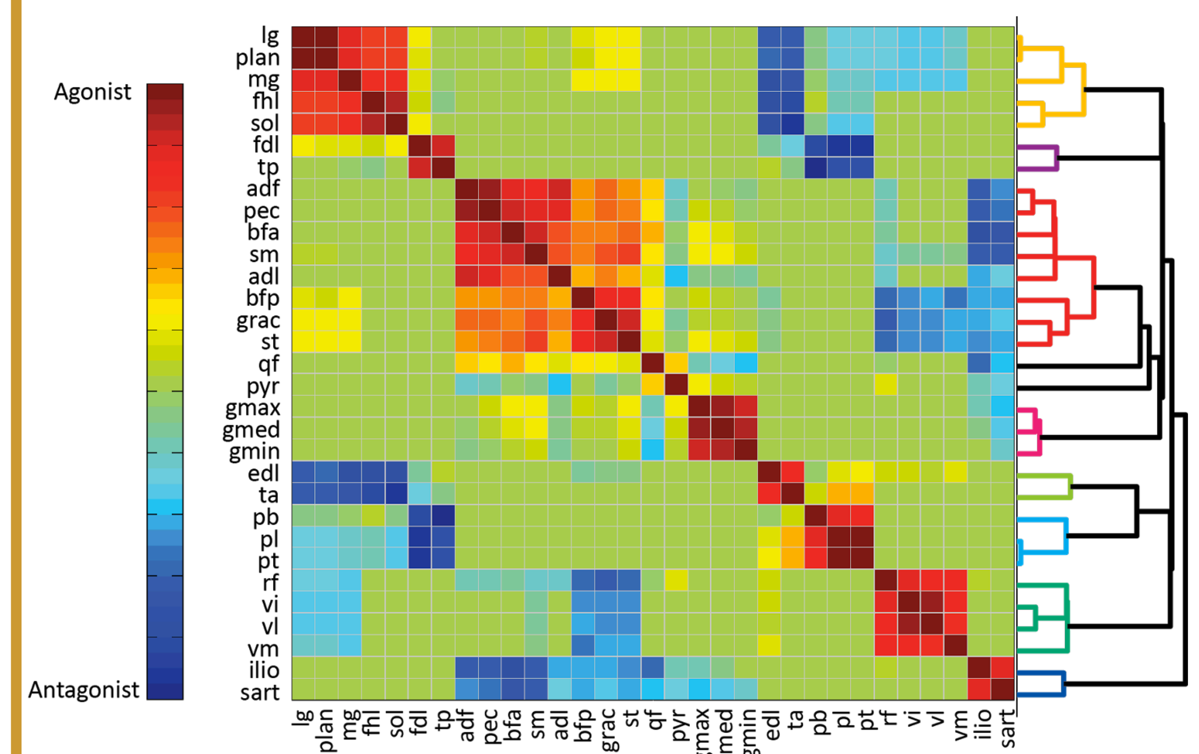

Figure 3. Mechanical interaction matrix

The model has seven degrees of freedom (three hip, two knee, two ankle). The value of each cell corresponds to the cosine of the angle between the moment arms of the corresponding muscles.

Project Goal

These matrices represent the strength of the intermuscular length(left) and force(right) feedback obtained from experimental data. The project is to evaluate how these proprioceptive circuits will influence the mechanical properties

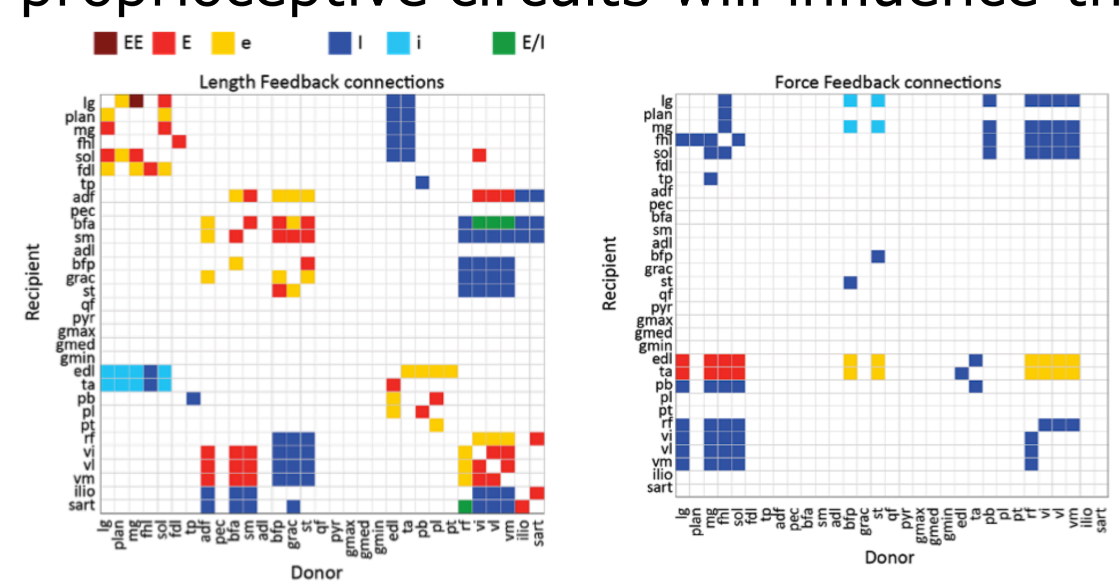

Figure 4. Intermuscular length and force feedback

We will compare the influence of these pattern of feedback observed experimentally with those observed in condition such as spinal cord injury.

Reference

1. Nichols, T. Richard. "Receptor mechanisms underlying heterogenic reflexes among the triceps surae muscles of the cat." J. Neurophysiol. 81: 467-478,1999
2. Nichols, T R, "A technique for measuring the mechanical actions of heterogenic (intermuscular) reflexes in the decerebrate cat" J Neurosci Methods.21: 265-73, 1987
3. Nichols, Bunderson & Lyle, Neural regulation of limb mechanics, Ch 4, In: Neuromechanical Modeling of Posture and Locomotion, Prilutsky BI & Edwards DH, (eds), New York: Springer