

## CAT HINDLIMB MUSCLE RESPONSE TO SLOW MOVEMENT SHOWS POOR RELATIONSHIP TO LENGTH-TENSION PROPERTIES

<sup>1</sup> Thomas G Sandercock, <sup>1</sup> Aaron Daub, and <sup>2</sup> Eric J. Perreault

<sup>1</sup>Dept. Physiology and <sup>2</sup>Biomedical Engineering; Northwestern University; email: [t-sandercock@northwestern.edu](mailto:t-sandercock@northwestern.edu)

### INTRODUCTION

The ultimate goal of our research is to determine the contributions of individual muscles and muscle combinations to whole limb endpoint stiffness in 3 dimensional space. Initially we are examining the intrinsic muscle properties without reflex contributions. For this particular task, i.e. characterizing endpoint stiffness, a central consideration is how a muscle's force changes when a small change in joint angle is imposed on it. This particular study examines tetanic activation with relatively slow movement (short range stiffness properties are ignored). Several well known contractile properties play a role in the total response. They include: length-tension-frequency, force-velocity, and persistent tension excess or deficit properties. Muscle models often use the tetanic length-tension and force-velocity curves but the results here show this leads to substantial errors, and false estimates of endpoint stability.

The purpose of this study is to test the hypothesis that within the physiological range of a muscle, slow stretch of a tetanically active muscle will always result in more force, and slow shortening of a muscle will always result in less force, irregardless of the position on the length tension curve.

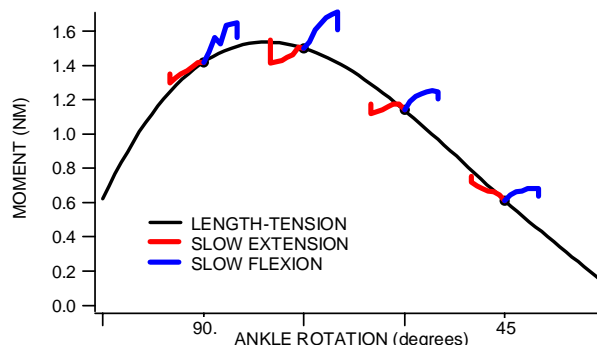
### METHODS

Data were collected from 3 cats (2-3kg) under deep anesthesia (pentobarbital). Three muscle groups, accessible with minimal disruption of the surrounding connective tissue, were examined: the medial gastrocnemius (MG), the lateral gastrocnemius and soleus (LG/S), and the Tibialis Anterior and Extensor Digitorum Longus muscles (TA/EDL). Muscles were stimulated in pairs when nerve separation would have caused an undesired level of connective tissue disruption. During all measurements, muscles were maximally stimulated (100Hz) using peripheral nerve cuff electrodes. Reflex activation was eliminated by cutting the ipsilateral dorsal roots.

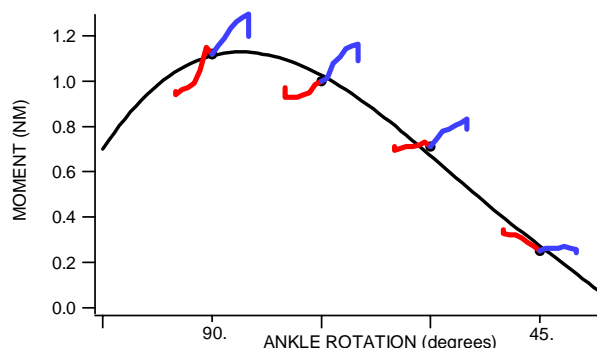
The cat foot was rigidly attached to a 6 degree-of-freedom load cell (JR3) coupled to a 6 degree-of-freedom robotic manipulator (Staubli RX60). Each trial (Fig. 1) consisted of an initial isometric stimulation period (0.25 sec), followed by a robot-controlled joint rotation (5 degrees in 0.37 or 0.75 s) around the ankle. Isometric muscle force was measured immediately prior to the imposed movement and fit with a polynomial to determine the static length-tension properties.

### RESULTS AND DISCUSSION

Figure 1 shows typical results from the combined LG/S muscles. The cat's knee was extended allowing the LG to be studied on the descending limb of the length-tension curve. The dark line shows the static moment-angle properties. The superimposed traces show moments measured during



**Figure 1:** Torque-Rotation (flexion-extension) curve for combined LG and SOL muscles.



**Figure 2:** Torque-Rotation (flexion-extension) curve for MG.

extension (blue) and flexion (red) movements (5 degree rotations over .75s) followed by a .25 isometric hold. The movement is slow so force-velocity properties play a trivial role. Note that the hypothesis is supported at all but the longest muscle length.

Figure 2 shows typical results from the MG. Similar results were obtained for the TA/EDL which was primarily on the ascending limb of the length-tension curve for the same leg position. The results shown here were supported by data from the other 2 cats.

### CONCLUSIONS

The hypothesis was disproved at the longest muscle lengths. However, over a wide range of muscle lengths, muscle force increased during slow stretch and decreased during slow shortening, irregardless of the position on the static length-tension curve. This suggests muscle is intrinsically stable, even in the absence of reflex mechanisms.

### ACKNOWLEDGEMENTS

Supported by NIH R01 AR041531.