RECRUITMENT ORDER HAS LITTLE EFFECT ON THE SHORT-RANGE STIFFNESS OF FELINE MEDIAL GASTROCNEMIUS MUSCLE

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INTRODUCTION

The ultimate goal of our research is to determine the contributions of both individual muscles and muscle combinations to whole limb endpoint stiffness in 3 dimensional space. A computer muscle model, capable of predicting whole muscle short-range stiffness (SRS) based on anatomical properties, is believed to be necessary for accomplishing this goal. Knowledge of the effect of motor unit composition and muscle architecture on SRS is essential for developing such a muscle model.

Slow motor units have been shown to be 1.3 times stiffer than similar fast motor units [2]. In spite of this difference muscle architecture—fiber length and tendon properties—may be the principle determinants of whole muscle SRS.

The goal of this study is to test the hypothesis that the recruitment order of motor unit types has little effect on the SRS versus force characteristics of a muscle. Preliminary results are reported here.

METHODS

The hypothesis was tested in 5 cat medial gastrocnemius (MG) muscles. The cats were mounted in a rigid frame with all muscles in the left hindlimb denervated except for the MG. The MG was partially freed from surrounding tissue with its nerve and blood supply left intact. The calcaneous was cut and attached to a muscle puller allowing force to be measured during step changes in length (1.2 mm in 7 ms). The cats were decerebrated allowing activation of the MG using normal recruitment via the crossed extension reflex (CXR). A laminectory exposed the ventral roots, which were cut after the CXR measurements were complete, and stimulated with hook electrodes.

SRS was measured during three types of muscle activation: 1) CXR activation; 2) Rate modulation; and 3) Partial muscle activation. CXR modulation preserves the normal recruitment order and rate modulation of slow and fast motor units. Rate modulation was achieved by dividing the ventral roots into 4 to 6 bundles, and stimulating the bundles asynchronously to keep whole muscle force smooth, even at low frequencies [1]. Thus the whole muscle was active but at a low frequency. Partial muscle activation was achieved by stimulating part of the ventral roots at 100 Hz.

RESULTS AND DISCUSSION

The most complete results from as single cat are shown in Figure 1. Total force from CXR activation was limited and never exceeds 20% of maximum tetanic force. In contrast, steady low force is difficult to achieve with rate modulation, so these two protocols were not studied over the same force

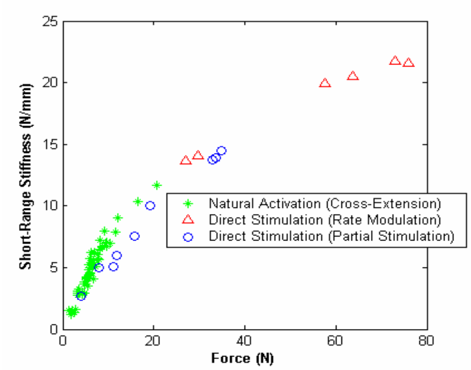

Figure 1: Results from one cat showing SRS plotted against Force (mean value 50 milliseconds before perturbation) using three different types of activation (see text).

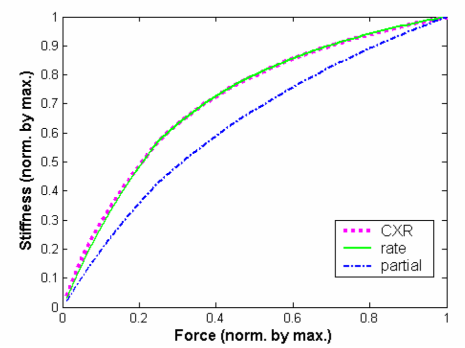

Figure 2: Normalized SRS plotted against normalized Force based on the common tendon model simulation.

range. Still, rate modulation seems to closely match the CXR data, even thought rate modulation does not employ normal recruitment. Similar results were obtained in the other cats.

Figure 2 shows predictions made using a simple common tendon model [3]. Slow units were assumed to comprise 25% of the muscle fibers and were fully recruited by 25% of muscle force. The model provides a reasonable fit to the experimental data.

CONCLUSIONS

Recruitment order of motor units has little impact on SRS of cat MG muscle. If these preliminary results are supported, it suggests recruitment order can be ignored in the hind limb models of stiffness.

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