IN VIVO FASCICLE VELOCITY OF CAT GASTROCNEMIUS AND SOLEUS MUSCLES DURING THE PAW-SHAKE

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INTRODUCTION

During the paw-shake (PS) in the cat a differential activation of ankle extensor synergists, the two-joint gastrocnemius (GA) and the one-joint soleus (SO), occurs: the GA demonstrates very high activation, whereas SO is either inactive or its activation is substantially reduced [1,5]. The two muscles are activated during the lengthening phase of the muscle-tendon complex (MTC) [1,4], in which substantial activation of SO and GA Ia- and Ib-afferents has been reported [4]. Thus, both velocity-dependent (Ia) and force-dependent (Ib) feedback might be used to regulate the differential activation of the two muscles.

The velocity-dependent feedback is related among other factors to muscle fascicle velocity rather than to MTC velocity. Therefore, the role of MTC and fascicle velocity in the regulation of muscle activity in the PS remains unclear. High shortening velocity in muscle fascicles during PS can also be a limiting factor in muscle force production. The aim of this study was to determine fascicle and MTC velocities of the cat medial gastrocnemius (MG) and SO during the PS.

METHODS

Four cats were surgically instrumented with EMG electrodes in SO and MG [2]. Selected cats were also instrumented with sonomicrometry crystals to measure fascicle length [3]. After recovery, the PS was elicited by attaching a sticking tape to the paw and allowing the animal to walk on a walkway. Reflective markers on the animals were video-filmed using high-speed (120 Hz) motion capture system (Vicon, UK) with simultaneous recordings of EMG or sonomicrometry signals. The recorded kinematics and a geometric model of the hindlimb were used to calculate the origin-to-insertion (MTC) lengths of MG and SO. Joint velocities, moments and powers were also calculated for the major hindlimb joints.

RESULTS AND DISCUSSION

During the PS, MTC shortening velocity peaks of MG and SO were up to 0.2 m/s (Fig.1) or 80 and 120% of their in-situ MTC V_{max} [6], respectively. Fascicle shortening velocity peaks reached much smaller values of 0.1 and 0.05 m/s for MG and SO, respectively, (Fig. 1) which corresponded to 40 and 27% of V_{max} expressed in fiber lengths of each muscle [6]. The above results may be explained, in part, by in-series compliance of the tendons and aponeuroses of MG and SO.

MG fascicle and MTC velocities changed in phase during steady state PS cycles (Fig.1), whereas SO fascicle velocity changes were delayed with respect to the MTC velocity (Fig. 1). These results suggest that velocity-dependent feedback from the two muscles during the PS might be different and thus could contribute to their differential activation.

Stretch velocity peaks of MG fascicles typically coincided with the switch of joint moment directions: from ankle flexion/knee extension/hip flexion to ankle extension/knee flexion/hip extension (Fig. 1). Thus, signals from MG velocity-sensitive afferents might be involved in phase regulation between the flexors and extensors during the PS.

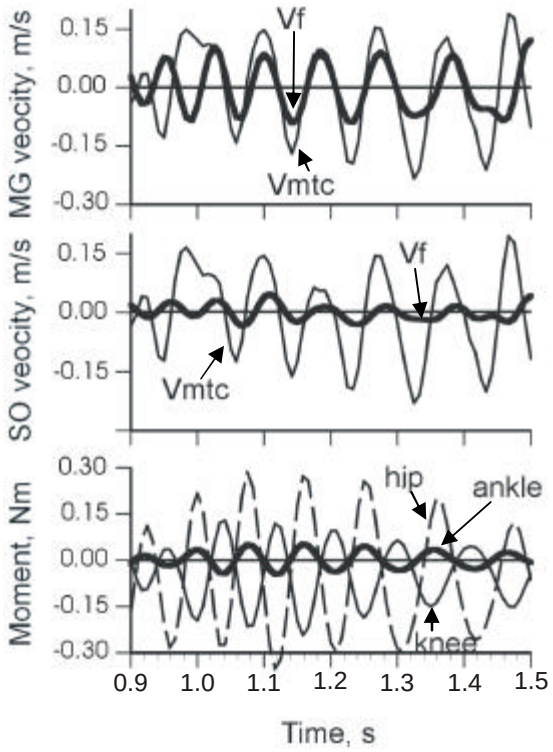

Figure 1: Velocity of muscle fascicle and MTC of MG (top panel) and SO (middle panel) and moments at the hindlimb joints (bottom panel) during a paw-shake. Positive velocities correspond to muscle shortening, positive joint moments correspond to extension.

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