IN VIVO FASCICLE LENGTH OF CAT MEDIAL GASTROCNEMIUS AND SOLEUS MUSCLES DURING SLOPE WALKING

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INTRODUCTION

By changing the slope of a walking surface, mechanical variables (e.g. muscle fascicle length, tendon force) related to proprioceptive feedback can be manipulated. It has been suggested that length-dependent feedback from muscle spindles is more important for limb control during downslope walking compared to level or upslope walking [1]. Such a conclusion is based on length changes of the whole muscle-tendon complex (MTC). However, muscle spindle strain is directly related to changes of muscle fascicle length (L_{fas}).

Fascicle length changes of medial gastrocnemius muscle (MG) have been reported for level walking as well as for modestly sloped surfaces only, i.e. 10% [2]. Therefore, the **aim** of this study was to quantify fascicle length changes of MG as well as soleus (SO) muscles during walking on a level surface as well as on substantially sloped surfaces (i.e. + and −50%, 26.6°).

METHODS

Joint kinematics and kinetics of the hindlimbs, muscle activity patterns, MTC length and L_{fas} were assessed for three walking conditions in the cat: downslope, level and upslope. Four out of six cats were surgically implanted with EMG electrodes in SO and MG [3]. Selected muscles were also instrumented with sonomicrometry crystals to measure L_{fas}. The distance between the sonomicrometry electrodes (fractional L_{fas}) was ≈65% and ≈80% of the total fascicle length of SO and MG, respectively. Resting fascicle [4] and MTC length, as calculated based on a geometrical model, at ankle and knee angles of 90° were used as reference lengths (L_{ref}). For sonomicrometry, 6 step cycles were analyzed for level walking, 10 for the downslope and 13 for the upslope condition.

RESULTS AND DISCUSSION

For all cats, biomechanical gait parameters as well as muscle activity patterns were similar. Significant ($p < 0.05$) differences between changes of MTC length and total L_{fas} were found in early stance of all slope conditions (Figure 1, Table 1). During upslope walking, MTC lengthening of MG occurred in the presence of substantial L_{fas} shortening. For both muscles, fascicle lengthening in early stance during downslope walking was significantly ($p < 0.05$) higher than during level and upslope walking. This suggests a potentially higher contribution of length-dependent feedback for regulation of muscle activation, assuming contant activation of intrafusal fibers. Different muscle-tendon interactions (ΔL_{fas} / ΔL_{MTC}) between muscles and slope conditions can be explained partially by the magnitude of muscle activity [3]:

SO: EMG level < EMG downslope < EMG upslope
MG: EMG downslope < EMG level < EMG upslope.

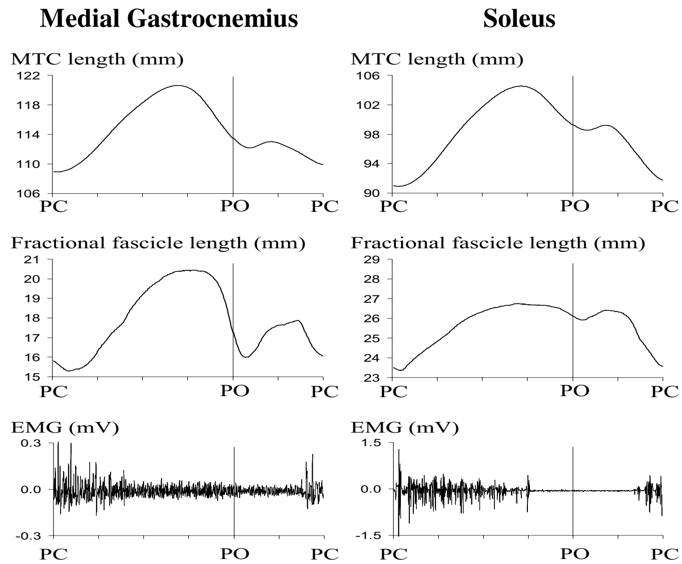

Figure 1: Typical example of MTC and fractional fascicle length as well as EMG recordings during downslope walking.

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Table 1: Mean (SD) MTC and total fascicle lengthening (+ mm) in early stance for MG and SO muscles. Note that in upslope walking the fascicles of MG are shortening (− mm). * Significantly different from ΔL MTC, † significantly different from ΔL level walking.

Muscle		Downslope		Level		Upslope	
		ΔL (mm)	$\Delta L/L_{ref}$ (%)	ΔL (mm)	$\Delta L/L_{ref}$ (%)	ΔL (mm)	$\Delta L/L_{ref}$ (%)
Soleus	*Fascicle*	4.8 (0.43) *†	11.5 (1.0)	1.4 (0.3) *	3.3 (0.7)	0.27 (0.12) *†	0.6 (0.3)
	MTC	13.6 (0.02) †	12.9 (0.02)	3.2 (0.9)	3.0 (0.8)	2.8 (1.1)	2.6 (1.1)
MG	*Fascicle*	6.2 (0.43) *†	29.5 (2.1)	1.1 (0.2) *	5.0 (1.0)	−3.6 (0.6) *†	−17.2 (2.8)
	MTC	11.6 (0.11) †	9.7 (0.1)	2.4 (0.8)	2.0 (0.7)	2.3 (0.8)	1.9 (0.7)