

BEHAVIOR OF APONEUROSIS AND EXTERNAL TENDON OF MEDIAL GASTROCNEMIUS MUSCLE DURING DYNAMIC PLANTAR FLEXION EXERCISE

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INTRODUCTION

Pennate muscles have aponeuroses and external tendons, both of which have been regarded as elastic materials. However, limited information is available on the behavior of each of the two tissues of human muscles during contractions. Some attempts have been made to determine mechanical properties of these structures in vivo [1, 2], but the data have been obtained in a 'static action' of the muscle-tendon complex, not in a 'dynamic action' in which most human movements are performed. The purpose of this study was to investigate the differences between the behavior of the aponeurosis and external tendon of the medial gastrocnemius muscle (MG) in dynamic actions. We determined the length changes of the aponeurosis and external tendon of MG during concentric and eccentric actions of the ankle joint using ultrasonography.

METHODS

Nine male subjects (23.5 ± 1.4 yr, 171.5 ± 6.6 cm, 64.1 ± 6.1 kg, mean \pm SD) performed concentric (CON) and eccentric (ECC) plantar flexion exercises preceded by an isometric action (Pre-iso) on an isokinetic dynamometer (CON-TREX, CMV AG, Switzerland) with pre-set velocity of 5°/s. The range of motion of the ankle was set from 100° to 60° (90° was the neutral anatomic position; positive values for dorsiflexion). Each of concentric and eccentric exercises was performed at three contraction intensities; maximal voluntary contraction (CONmax, ECCmax), and 30 and 60% of MVC (CON30%, CON60%, ECC30%, ECC60%). From Pre-iso to the end of joint motion, the subjects kept the pre-set level of contraction intensity through a visual feedback of the exerted torque. In addition, the subjects performed static ramp actions with the ankle positioned at 100° and 60°.

During the exercises, ankle joint angle and torque were measured, and simultaneously length changes of the aponeurosis and external tendon of MG were determined using two ultrasound apparatuses (SSD-5500, SSD-6500SV, Aloka, Japan) with electronic linear array probes of 10 MHz and 7.5 MHz wave frequency, respectively. The Achilles'

tendon force was calculated by dividing the torque by the moment arm of MG, estimated with a procedure described in a prior study [3].

RESULTS AND DISCUSSION

In CON, the length of external tendon significantly shortened from the level of Pre-iso in all test conditions, with decreasing Achilles' tendon force. However, those change of aponeurosis was significant only in CONmax (Table 1). In ECC, the external tendon was elongated in all test conditions with increasing Achilles' tendon force, while aponeurosis was not elongated even in ECCmax (Table 1, Fig. 1). In static action at 60°, the lengths of both aponeurosis and external tendon increased across force level. However, the length of aponeurosis did not change in static action at 100°.

The present results indicate that, in concentric and eccentric actions, the behaviors of the tendon tissues of MG differ between aponeurosis and external tendon. From the findings obtained here, it may be assumed that the external tendon of MG plays a role of storing and releasing elastic energy. On the other hand, it is suggested that the aponeurosis of MG releases the pre-stored elastic energy in concentric actions, while it acts just for transmitting the muscle force in eccentric actions.

CONCLUSIONS

The present study provides evidence that there is a difference between the length changes of aponeurosis and external tendon in dynamic actions. In addition, the present results indicated that the elastic behavior of aponeurosis differ depending on the types of exercises (concentric or eccentric).

REFERENCES

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2. Magnusson SP, et al. *Acta Physiol Scand* **177**, 185-195, 2003.
3. Grieve DW, et al. *Biomechanics VI-A*, University Park Press, Baltimore, MD.

Table 1 Length changes of aponeurosis and tendon (mm)

	Aponeurosis	Tendon
CONmax	-2.5 \pm 1.2 [†]	-11.3 \pm 3.3 ^{†*}
CON60%	-0.6 \pm 2.0	-9.3 \pm 3.7 ^{†*}
CON30%	-0.8 \pm 2.2	-7.4 \pm 2.9 ^{†*}
ECCmax	0.6 \pm 1.5	10.3 \pm 3.3 ^{†*}
ECC60%	0.6 \pm 2.0	9.9 \pm 2.4 ^{†*}
ECC30%	0.9 \pm 1.8	8.2 \pm 2.7 ^{†*}

Values are mean \pm SD. † indicates that the length change significantly ($p < 0.01$) differs from Pre-iso. * indicates that the length change in tendon significantly ($p < 0.01$) differs from that in aponeurosis.

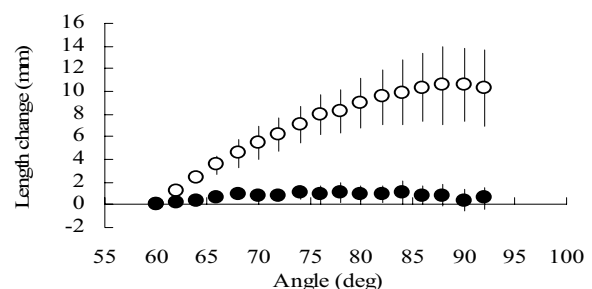


Figure 1 Length changes of the aponeurosis and external tendon from Pre-iso as a function of ankle joint angle during ECCmax. Values are mean \pm SD. ● and ○ indicate aponeurosis and tendon respectively.