FORCE TRANSMISSION FROM SOLEUS MUSCLE IN THE CAT. IS M. SOLEUS AN INDEPENDENT ACTUATOR?

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INTRODUCTION

It has been shown that muscle fiber force can be transmitted via connective tissues surrounding the muscle and that this is affected by changes in muscle relative position (e.g. Huijing and Baan, 2003; Maas et al., 2004). However, the extent of such myofascial force transmission for normal muscle function *in vivo* is still unclear. Myofascial pathways may also serve to transmit force in conditions of muscle or connective tissue injury. Therefore, the purpose of the present study was to assess the mechanical interactions between the one-joint soleus muscle (SO) and its two-joint synergists in physiological muscle-tendon unit (MTU) lengths and relative positions as well as following tenotomy.

METHODS

Deeply anesthetized cats (n = 7, 2.8-4.6 Kg) were mounted in a rigid frame with the left foot secured to a 6 degree-of-freedom load cell (JR3) coupled to a robotic arm (Staubli). The load cell was used to calculate ankle moments exerted in the sagital plane. The robotic arm was used to impose isolated rotations of the knee joint. The SO nerve bundle was isolated, but all nerves to its synergists and antagonists were cut. Ankle moment at the ankle upon tetanic activation of SO was measured for various knee angles (70-140°), changing the length of the two-joint gastrocnemius (GAS) and plantaris (PL) muscles and hence their passive force and relative position to the SO. Ankle angle and, thus, SO MTU length, was kept constant (~90°).

In addition, ankle moment was assessed after cutting the distal SO tendon (tenotomy), which prevented any myotendinous force transmission to its insertion (the calcaneus). Connective tissues at the muscle belly level were minimally disrupted. Subsequently, the distal tendon of SO was attached to a force transducer. The muscle was lengthened distally from the length it obtained after tenotomy to its physiological length. Both ankle joint moment and tendon force were measured.

RESULTS AND DISCUSSION

SO ankle moment was not significantly affected by changes in knee angle (Fig. 1), despite the fact that this involved substantial changes in length and relative position of GAS and PL muscles. Also half-relaxation time and the maximal rate of relaxation of SO muscle contraction, which varied strongly with ankle angle, were insensitive to changes in knee angle. These results suggest that changing the length of the passive two-joint synergists and, consequently, the position relative to the one-joint SO, does not affect force transmission from SO muscle fibers.

Following tenotomy, SO ankle moment decreased substantially (by ~60%) but did not reach zero (Fig. 2). SO muscle shortened to a much greater extent during contraction than in the intact case, which resulted in a major position shift relative to its synergists (16.3 mm, SD 0.3). These results indicate force transmission from SO muscle fibers to the achilles tendon and calcaneus, likely through intermuscular connective tissues linking the muscle belly to GAS and PL. The shortening of the SO fibers along the ascending limb of the length-tension curve probably explains the decreased moment.

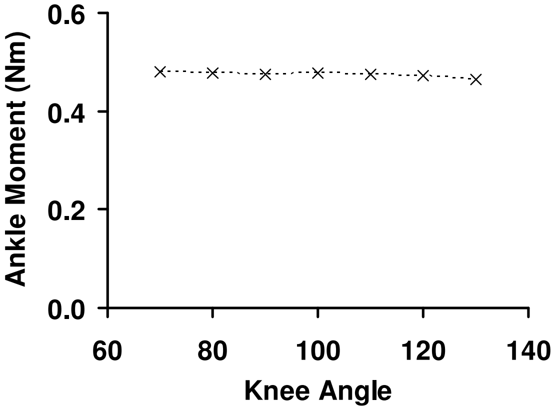

Figure 1: SO Ankle moment plotted as a function of knee angle for one cat.

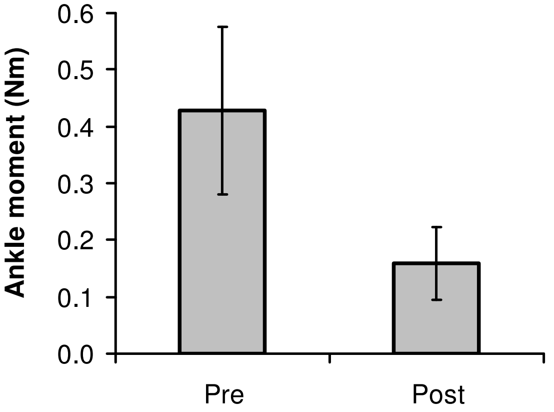

Figure 2: Ankle moment exerted upon activation of SO muscle before and after tenotomy of the distal tendon (n = 3).

Measuring SO ankle joint moment and tendon force at several MTU lengths of SO muscle yielded a clearly linear relationship (Fig. 3). This indicates a partitioning of muscle fiber force between two pathways: (1) via the distal tendon of SO and (2) via the connective tissues linking SO muscle to its synergists. At the physiological length, SO activation did not yield an ankle moment.

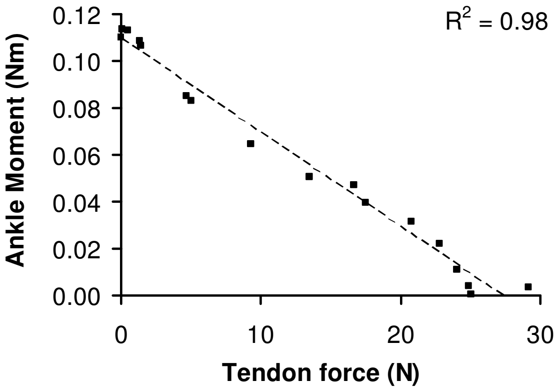

Figure 3: Relationship between force exerted at the SO tendon and ankle moment generated by SO muscle fibers (n = 1).

SUMMARY/CONCLUSIONS

In physiological conditions of the ankle plantar flexors, SO force appears to be predominantly transmitted to bone via its tendons. This suggests that in the intact cat SO muscle acts as an independent actuator.

However, strong mechanical connections between SO and synergistic muscles exist. Such intermuscular connective tissues may bear muscle forces after traumatic events in muscle or tendon.

REFERENCES

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Maas, H., Baan, G. C. and Huijing, P.A. (2004). *J Biomech*, **37**, 99-110.

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