

INTRAMUSCULAR PRESSURE IS A GOOD PREDICTOR OF ISOMETRIC STRESS AT LONG LENGTHS IN RABBIT TIBIALIS ANTERIOR MUSCLE

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Introduction

Electromyography (EMG) and joint kinematics are the most widely-used methods to assess muscle function during gait. However, the ability of EMG to provide an accurate prediction of relative muscle force is restricted to active conditions that are close to isometric, which may limit its practical use in gait analysis. Due to the redundancy in the musculoskeletal system, moment calculations combined with anatomical models yield estimates of muscle tension but the solutions are indeterminate. Although there are direct methods for measuring muscle force *in vivo* (Komi *et al.*, 1996) they are highly invasive and not applicable to use in children. Based on encouraging preliminary measurements of intramuscular pressure (IMP) to predict muscle force (Baumann *et al.*, 1979, Sutherland *et al.*, 1989), IMP may prove a useful adjunct in the assessment of active and passive muscle force during gait. The purpose of this study was to quantify the relationship between IMP and muscle stress during well-defined isometric muscle contractions of the rabbit tibialis anterior (TA).

Methods

The experimental model was the TA of the New Zealand White rabbit (mass=2.5 ±0.5 kg, n = 12). The knee was fixed in a custom jig with 3.2 mm Steinman pins placed in the proximal tibia and distal femur. The TA was exposed and the distal tendon attached to a servomotor (Cambridge Model 300B, Aurora Scientific Inc.). A cuff electrode was placed around the peroneal nerve for

muscle activation (Pulsar 6Bp Stimulator FHC Inc.). A 400 µm fiber optic pressure sensor (Luna Innovations Inc.) was inserted via an 18-gauge angiocatheter at a 10° angle in line with the long axis of the fibers. Optimal length (L_0) and maximum tetanic tension (P_0) were defined with tension measured at 5, 10, 20, 40, 60, 80, and 100 Hz. The length-tension curve was created using 40 Hz isometric contractions with 2 minutes of rest between each contraction to minimize the effects of fatigue. Measurements began at $L_0-50\%$ and progressed to $L_0+50\%$, changing the length-tension in 5% L_0 increments after each contraction. Length, tension, pressure, and temperature were recorded simultaneously using a data acquisition board in the LabView environment (National Instruments). Tension was converted to stress by dividing force by the muscle's calculated physiological cross-sectional area.

Results

Qualitatively, the length-tension curve for isometric contractions (Fig. 1) was mimicked by the length-pressure curve (Fig. 2) for both active and passive contractions. To quantify the correlation between stress and pressure, each data set was broken into groups for the ascending and descending limbs of the length-tension curve. Linear regression was performed individually for each animal for each portion of the length-tension curve and for active and passive conditions. Pressure-stress coefficients of determination ranged from .139-.963 (mean=.69±.23) for active contractions and

from .045-.982 (mean=.70±.32) for the passive condition (Table 1). Correlations were higher for the descending limb of the length-tension curve compared to the ascending limb.

Discussion

This study quantified the relationship between IMP and muscle stress during isometric muscle contractions. Our goal was to investigate the relationship for both active and passive conditions over a range of lengths. The positive correlation between IMP and muscle stress was strong for lengths on the descending limb of the length tension curve for both active and passive muscle contraction. For the ascending limb,

however, a weaker relationship was observed that may be in part due to sensor movement near slack lengths ($L_0-50\%$ to $L_0-35\%$). These data are encouraging under the conditions of static contractions. Further experiments are required to determine similar correlations during dynamic contractions.

References

Baumann *et al.* (1979). *Clin. Orthop. Rel. Res.* **145**:292-299.
 Sutherland *et al.*, (1989). *Orthop. Trans.* **34**:319.
 Komi *et al.* (1996). *Eur. J Appl. Physiol.* **72**:278- 280.

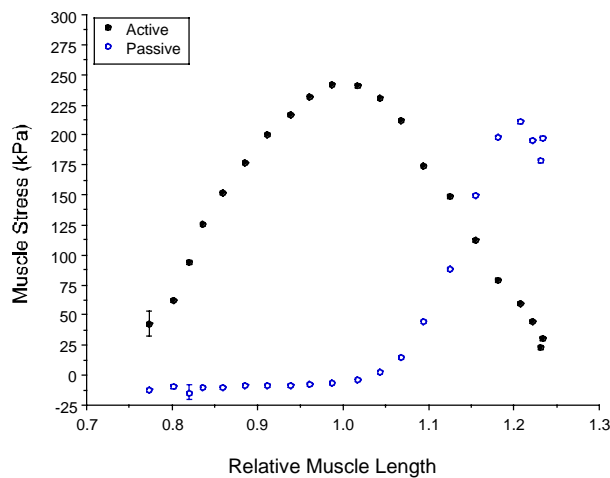


FIGURE 1: Relationship between isometric muscle stress and muscle length, relative to optimal length. The average SEM is shown as a single error bar for each graph for clarity of presentation.

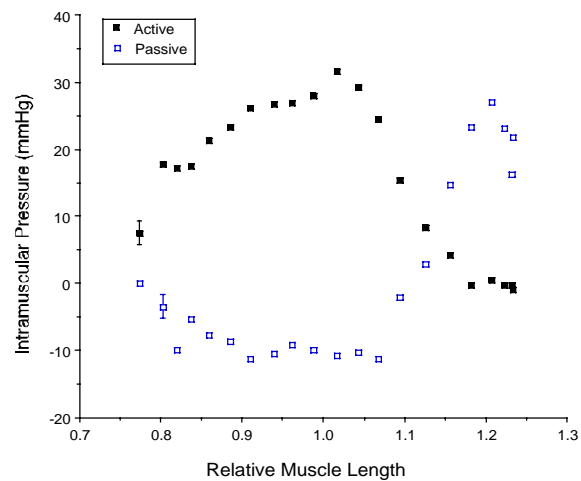


FIGURE 2: Relationship between intramuscular pressure and muscle length, relative to optimal length. The average SEM is shown as a single error bar for each graph for clarity of presentation.

	Active Pressure Coefficients of Determination	Passive Pressure Coefficients of Determination
Ascending Limb	.60 ± .25	.53 ± .38
Descending Limb	.77 ± .16	.86 ± .11

Table 1: Average active and passive pressure coefficients of determination split by limb on the length-tension curve.