SMALL CHANGES IN THE TIMING OF ACTIVATION AFFECTS FIBER LENGTHS AND SERIAL SARCOMERE NUMBER ADAPTATIONS IN RABBIT TIBIALIS ANTERIOR EXPOSED TO ECCENTRIC EXERCISE

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INTRODUCTION

Eccentric exercise has been shown to increase serial sarcomere number (Koh and Herzog, 1998). These adaptations have often been associated with the amount of strain in the muscle-tendon unit (MTU). However, MTU strains may not relate well to fiber strains (Griffiths, 1991), and the timing of activation may greatly affect fiber strain for a given MTU strain. Fiber strain has not been systematically studied in adaptive models of skeletal muscle. The purpose of this study was to measure fiber adaptations for a given cyclic MTU strain in the rabbit tibialis anterior (TA) that was activated exactly at the onset of the eccentric phase, or 100 ms offset to the eccentric phase. We hypothesized that the100ms offset would result in different fiber strains, and that fiber length and serial sarcomere number adaptations would be different for contractions of identical MTU strain, but different timing of activation.

METHODS

Nerve cuff electrodes were implanted bilaterally on the peroneal nerves of 13 adult New Zealand white rabbits. The left nerve cuff electrode was attached to a custom made subcutaneous electrical interface that allowed for temporary connections to an external stimulator (Koh and Leonard, 1996). The anesthetized rabbits were placed supine in a sling with their left foot attached to a plate connected to the cam of a servo motor. Supra-maximal stimulation was determined (voltage 3x α-motoneuron threshold, 150Hz). An eccentric exercise bout of 5 sets of 10 repetitions was performed (stimulus train duration = 500 ms) from a tibiotarsal joint angle of 70^{o}-105^{o} at 70^{o} sec^{-1}. ***Protocol 1*** (n=7) consisted of plantar flexion (eccentric TA action) beginning at the onset of activation, through a range of motion of 35^{o} from 70^{o}-105^{o} at $70^{o}\cdot sec^{-1}$. Afterwards, the foot was returned to the start angle passively. The entire eccentric protocol consisted of five sets of ten repetitions with a two minute rest between sets. ***Protocol 2*** (n=6) was identical to the first, however the timing of activation was offset by 100 ms. This resulted in a 100ms isometric contraction prior to stretch, and deactivation of the TA 100 ms prior to the end of plantar flexion.

For each protocol, the eccentric exercise was repeated 3 times per week for 6 weeks, with at least 48 hours rest between bouts. Nine days after the last exercise bout, the rabbits were euthanized. Left and right hind-limbs were fixed at 90^{o}. TA were excised, weighed and processed. Six fascicles were teased from the superficial layers of the central third, and placed on glass slides. Fascicle and sarcomere lengths were measured using digitization and laser diffraction, respectively.

RESULTS

Although the mechanical strain of the MTU was the same for both groups (~5.0%), the adaptive cellular response varied between protocols. Fiber lengths increased significantly more in the superficial central region of the TA (p=0.006) for protocol 2 compared to protocol 1 (9.1% compared to 3.3%, Fig. 1). These increases in fiber lengths were associated with increases in serial sarcomere number, however, these increases were not significantly different between protocols (p<0.15, table 1).

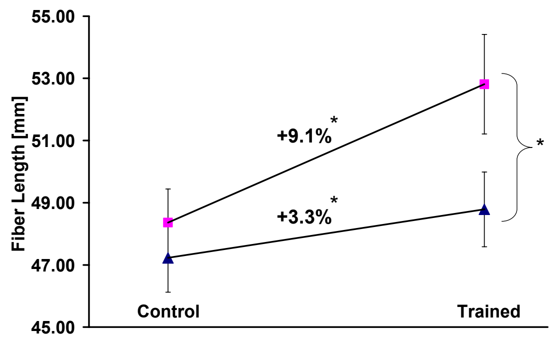

Figure 1: Central-superficial fiber lengths for control and trained TA for protocol 1 (▲) and protocol 2 (■). Means ±SE.

DISCUSSION

We have previously sown that a small shift in the timing of activation (i.e.100ms) affects fiber strain dramatically, even for identical MTU strain protocol (Butterfield and Herzog, 2004). For example, total fiber strain was shown to increase by 50% when activation was adjusted by 100ms from the start of the eccentric phase. Thus, we conclude that the changes in fiber strain resulted in the differential adaptation in fiber lengths and the observed trend in increased serial sarcomere number in the superficial central portion of the TA, and that fiber strain is a more potent factor in dictating the adaptive response of skeletal muscle than the MTU strain.

SUMMARY

Timing of activation appears to be a potent factor influencing muscle adaptation. Here we have shown that a shift in the activation of the muscle by 100ms resulted in significant sarcomere number and/or fiber length adaptations in the superficial and deep regions of the central TA. We believe that this increased adaptive response is due to the increased fiber strains achieved through the alteration of activation timing, while keeping MTU strain constant. Thus, fiber dynamics may be more valuable than MTU strain in understanding potential muscle injury and subsequent adaptation.

REFERENCES

Butterfield, T.A., Herzog, W. (2004) in: *XI Conf Can Soc Biomech, Halifax.* 2004.

Griffiths, R.I. (1991) *J Physiol*, **436**, 219-236

Koh, T.J., Herzog, W. (1998) *J Biomech*, **31**, 499-501.

Koh, T.J., Leonard, T.R. (1996) *J Neurosci Methods*, **70**, 27-32.

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Table 1. Serial sarcomere numbers. Values are Mean ± SD

	Protocol 1	**Protocol 2**
	TA Superficial	TA Superficial
trained	23084 ± 2732	23939 ± 2547
control	22377 ± 2599	22394 ± 2486
difference	+3.2%	+6.9%
P- value	.015*	.000*