MODULATION OF PASSIVE FORCE IN SKELETAL MUCLE FIBERS

Eun-Jeong Lee, Dilson E. Rassier and Walter Herzog
Human Performance Laboratory, Faculty of Kinesiology
University of Calgary (AB), Canada; email:walter@kin.ucalgary.ca

INTRODUCTION

When skeletal muscle is stretched while activated, the passive force following deactivation is higher than that produced by passive stretches with the same characteristics (amplitude, initial length), and following isometric contractions at the corresponding lengths [1]. The mechanism behind this phenomenon, referred to as "passive force enhancement", is unknown. Recent evidence shows that increasing Ca^{2+} concentration enhances the force produced by titin [2], suggesting that the passive force enhancement may be caused by modulation of titin upon muscle activation. If that was true, the entire passive force-length relationship would be affected by activation. In this study, we evaluated if the passive force-sarcomere length relationship following active stretches was different from that following isometric contractions and following passive stretches.

METHODS

Single fibers (n = 6) were dissected from lumbrical muscles of the frog (R. Pipiens) and suspended between a motor arm and a force transducer inside an experimental chamber (temperature: 9°C). Sarcomere length was measured using the laser diffraction technique, with a He-Ne laser beam (633nm wavelength) projected perpendicular to the axis of the fiber. Fibers were pre-stretched to different sarcomere lengths along the descending limb of the force-length relationship, activated and stretched ~0.22 μm per sarcomere. Passive stretches were performed with similar characteristics, and isometric contractions were performed at the corresponding final lengths. Experiments were performed in Ringer solution (pH=7.5), and with the addition of 5 and 20 mM of BDM, which inhibits active force production [3].

RESULTS AND DISCUSSION

Passive force measured after stretch of activated fibers was higher than the force measured after passive stretches, and higher than the passive force measured after an isometric contraction at the corresponding length (Figure 1). This result was confirmed statistically in all fibers investigated in this study. The passive force enhancement was length-dependent, as it increased with increasing sarcomere lengths, causing an upwards shift in the passive force-sarcomere length relationship along the Y-axis. Adding BDM to the Ringer solution did not decrease the degree of passive force enhancement after stretches. Therefore, it seems that the increase in passive force observed during an active stretch is not due to cross-bridge kinetics, but due to the engagement of a passive element upon activation and stretch. Based on previous studies [2], we suggest that this passive element is titin, which would be activated by Ca^{2+} when muscle contraction starts.

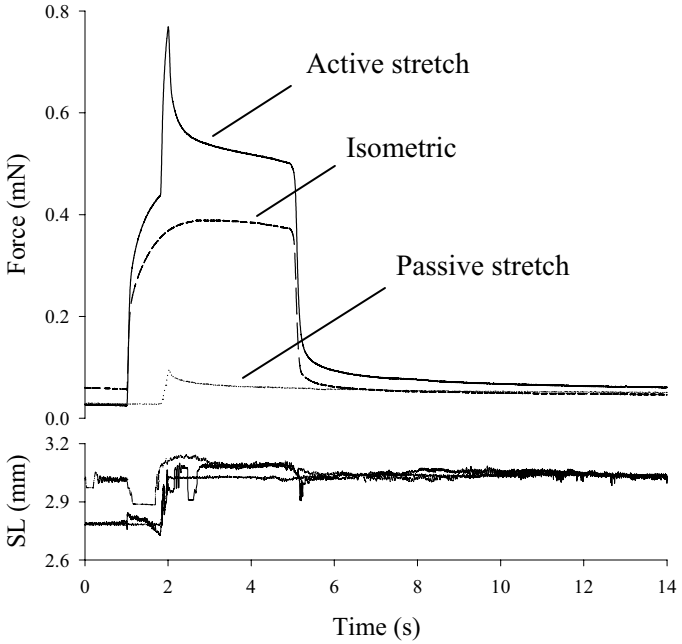

Figure 1: Typical experiment performed with a single fiber in Ringer solution. Force–time traces (top) and sarcomere length -time traces (bottom) are shown for an isometric contraction, an active stretch and a passive stretch. Note that the sarcomere lengths after contractions are similar, but forces following an active stretch are higher than those in the other conditions.

CONCLUSIONS

The passive force-length relationship is shifted upwards along the force axis when fibers are stretched while simultaneously activated. These results might account for the passive force enhancement observed recently in skeletal muscles.

REFERENCES

1. Rassier, et al. *J.Biomech.* **36**, 1309-1316, 2003.
2. Labeit, et al. *Proc.Natl.Acad.Sci.U.S.A* **100,** 13716-13721, 2003.
3. Regnier, et al. *Am.J.Physiol.* **269,** C1532-C`539, 1995.

ACKNOWLEDGEMENTS

Canada Research Chair Program and NSERC of Canada.