Energy Consumption After Active Stretch in Single Skinned Muscle Fibres

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Summary

The increase in steady-state force following active stretch compared to the purely isometric reference contraction is known as residual force enhancement (rFE). Though the mechanism causing rFE remains unknown, it is thought to be related to the passive structural protein, titin. Research on muscle energetics following active stretch is rare but might provide crucial information about the mechanisms underlying rFE. We aim to evaluate the energy cost at steady-state following active stretch compared to purely isometric reference contractions in skinned rabbit psoas muscle fibres. The purely isometric contractions were performed at average SLs of 2.8, 3.0 and 3.2µm. Fibres were then activated at an average SL of 2.4µm and stretched to SLs of 2.8, 3.0 and 3.2µm. ATP cost was measured simultaneously with force using photospectroscopy. Our preliminary results indicate that ATP cost per unit of force is lower following active stretch compared to the isometric reference state.

Introduction

The isometric force produced by a skeletal muscle at steady-state following active stretching is greater than a purely isometric contraction at the same final muscle length and activation. This property is referred to as residual force enhancement (rFE) [1]. Despite an abundance of studies on rFE, the mechanism underlying rFE remains elusive. There is increasing evidence that an increase in stiffness of the passive structural protein titin may cause rFE [2]. If so, the increase in force associated with rFE should occur with little or no increase in the energetic cost (ATP use). However, there is little work on ATP use following active stretch. A study has been published on the ATP use following active muscle stretching [3]. Even though this study provided important insight regarding energetics, the ATP use could only be measured following the mechanical testing rather than simultaneously with the force measurements, thus limiting interpretation of the results.

The purpose of this study is to measure the rate of ATP use and force simultaneously following active stretch and compare it to the corresponding isometric reference state. Experiments are performed using skinned rabbit psoas muscle fibres. We hypothesize that ATP use per unit of force will be lower following active stretch compared to the purely isometric reference contraction, supporting the idea that rFE is primarily caused by a passive non-cross-bridge element.

Methods

Skinned rabbit psoas muscles were used to compare energy cost per unit force following active fibre stretching and during purely isometric reference contractions at the same length and activation level. The purely isometric contractions were performed at average sarcomere lengths (SLs) of 2.8, 3.0 and 3.2µm. For the active stretch trials (rFE), fibres were set at an initial average SL of 2.4µm, then activated and stretched to SLs of 2.8, 3.0 and 3.2µm (Fig 1.). ATPase activity was measured once steady-state isometric force has been reached for both the isometric reference and the rFE condition. ATP use is measured using NADH absorbance of 340 nm light with photospectroscopy.

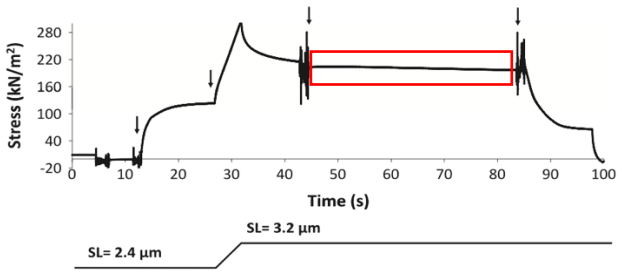

Fig. 1. Stress-time history of a fibre that was activated at an average SL of 2.4µm, stretched to an average SL of 3.2µm, and then deactivated. Arrows from left to right along the time axis indicate the time of activation (initial SL of 2.4µm), beginning of the active stretch (to a final SL of 3.2µm), when the fibre is transferred to a bath wherein the ATPase activity is measured simultaneously with force (red box), and when the fibre is deactivated. A fibre is activated by adding a washing solution (free of EGTA and calcium) and then an activating solution (high in calcium). The noise in the force trace indicates when activating and relaxing solutions were changed.

Results and Discussion

Our preliminary results indicate that the ATP cost per unit of force is lower following active stretch compared to the isometric reference state, supporting the idea that the extra force following active stretch (rFE) comes from a passive element and not from increased cross-bridge activity.

Conclusions

Preliminary results led to the conclusion that the energetic cost of isometric force following active muscle stretching is more efficient than that required for purely isometric contractions.

Acknowledgments

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References

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