Rabbit psoas sarcomere length range of operation: preliminary findings

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Summary

Although the force-length and torque-angle relationship of many muscles have been described in the literature, little is known about the corresponding range of physiological sarcomere lengths. This project was aimed at measuring the sarcomere lengths at different joint angles. Rabbit psoas muscle samples were extracted at four different hip joint positions and stored in 10% neutral buffered formalin, then transferred to 30% nitric acid, and maintained in glycerol for two weeks. Samples were separated into fascicles and the sarcomere lengths measured using laser diffraction. Sarcomere lengths ranged from 2.18µm to 2.66µm from full hip flexion to full hip extension. Plotting these data using the theoretical force-length relationship, based on rabbit contractile filament lengths, showed that psoas operates near the optimum length.

Introduction

The sarcomere force-length relationship is a well-studied property that relates the maximal, active, isometric force of a muscle uniquely to its length [1]. To determine the force-length relationship, a wide range of sarcomere lengths (SL) are typically measured and plotted against the theoretically predicted curve [1]. However, even though a muscle's force-length relationship may be determined readily, typically little is known about the SL range that occurs physiologically during everyday joint range of motion.

Here, we determined the SL of the rabbit psoas muscle ranging from full hip flexion to full hip extension and plotted the measured SL against the theoretically predicted curve [1], considering actin and myosin lengths specific to the rabbit psoas [2].

Methods

The project was approved by the local ethics committee. Three New Zealand rabbits were euthanized with sodium pentobarbital. Five muscle samples were collected using a plastic clamp at four hip angles (fully flexed, 90º, 170º and 180º) measured by a goniometer. Samples were placed in a 10% neutral buffered formalin for 7 days, then in 30% nitric acid for approximately 12 hours, transferred to a phosphate buffered saline solution for 8 hours, and finally kept in glycerol for two weeks.

Fascicle strips were isolated and placed on slides, where the mean SL was determined using a laser diffraction system, from six measurements along each fascicle's length. The average of the six measures of the five samples for each joint angle was calculated to represent the sarcomere operating range. Furthermore, the predicted force-length relationship was calculated using a thin filament length as 1.09µm [2], Z-disk width of 0.1µm, and bare zone width of 0.2µm, resulting in the plateau occurring between 2.28-2.48µm.

Results and Discussion

Normalizing muscle force to its maximum and SL to its optimum, the sarcomere operating range of rabbit psoas straddled the optimal length (Figure 1), slightly reaching the ascending and descending limb when in full flexion (SL = 2.18µm) and full extension (SL = 2.66µm), respectively.

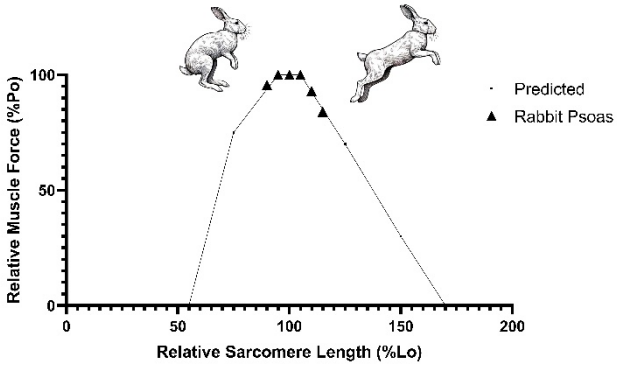

Figure 1: Predicted rabbit psoas sarcomere force-length relationship and observed sarcomere lengths for the full range of hip joint motion.

These data suggest that rabbit psoas muscle develops maximal isometric force at about 90º of hip flexion, which agrees with the generally accepted notion that maximal force is produced with the joint in a mid-range position.

Conclusions

The rabbit psoas muscle operates near optimum length of the force-length relationship for sarcomere lengths measured in the passive muscle. Rabbit psoas fibres, myofibrils and sarcomeres are commonly used to test muscle contraction mechanisms [e.g., 3]. This novel information allows experiments within the muscle's physiologically relevant range.

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