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The effect of prior shortening on residual force enhancement after stretch

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The mechanism of muscle contraction was first explained by the sliding filament theory. However, several muscle properties are poorly explained by this theory such as: enhancement of force with stretch; and depression of force with shortening. Recently, a new theory of muscle contraction, the "winding filament" hypothesis, has been suggested. This hypothesis explains how titin acts in conjunction with sliding filament theory. This theory resolves many unexplained muscle properties. If activation of a passive elastic element is responsible for residual force enhancement, then shortening prior to stretch should reduce or eliminate the extra force upon stretch. Edman and others have performed experiments in which active muscles were shortened prior to stretch. However, they observed no reduction in residual force enhancement due to pre-shortening. They concluded that, if an elastic element is formed in muscle during activation, it is not slackened by shortening. Later studies showed that, as the delay between shortening and stretch increased the effect of shortening on force enhancement decreased. The purpose of this study was to evaluate the effect of the delay between shortening and stretching on mouse muscles. Muscles were placed initially on the descending limb of the force-length relationship. The muscles were first shortened and then stretched at a fixed amplitude and speed (10% fiber length and at 40% fiber length/s), either immediately following shortening, or 100, 200, 300, 400, or 500 ms following shortening. As the interval between shortening and stretch increased, residual force enhancement increased. The observations are consistent with the idea of a passive structural elastic element in vertebrate skeletal muscle that develops upon muscle activation. Further this element has a time-dependent mechanism that is dependent on cross bridge cycling. These findings are consistent with the predictions of the winding filament hypothesis.