# The Effect of Muscle Length on Fatigue Rate:

## Accounting for muscle mechanical response using a motor unit fatigue model

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## References

[1] Caillet, A. H., Phillips, A. T., Carty, C., Farina, D., & Modenese, L. (2022). Hill-type computational models of muscle-tendon actuators: a systematic review. bioRxiv, 2022-10.

[2] Hill, A. V. (1938). The heat of shortening and the dynamic constants of muscle. Proceedings of the Royal Society of London. Series B-Biological Sciences, 126(843), 136-195.

[3] Potvin, J. R., & Fuglevand, A. J. (2017). A motor unit-based model of muscle fatigue. PLoS computational biology, 13(6), e1005581.

## Introduction

**Muscle fatigue models** are algorithms and equations which predict the change in muscle strength capacity from work.

These algorithms are leveraged in **ergonomics** to predict the decline in muscle strength or the maximum endurance time (ET) of an exertion using a simulated force-time history from a job.

Modern industrial work requires **dynamic movements**. However, fatigue rates are only validated against empirical data collected from **isometric research** [1].

## Purpose

To expand on a motor unit-based muscle fatigue model so that simulated force demand accounts for changing muscle mechanical properties and predictions can be made for dynamic work.

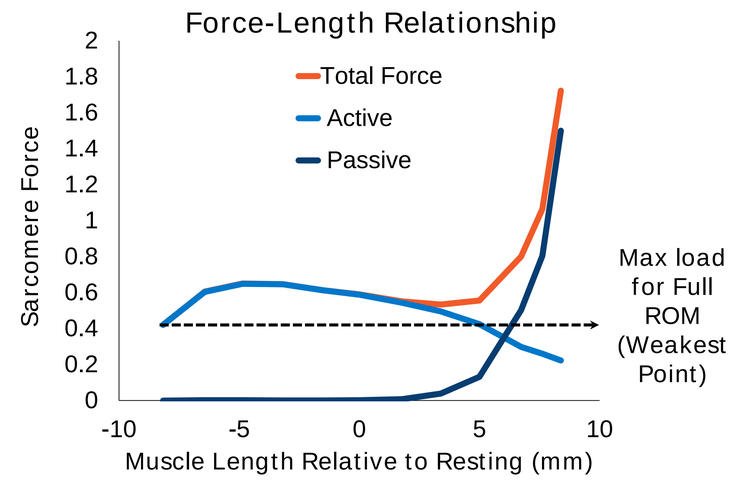


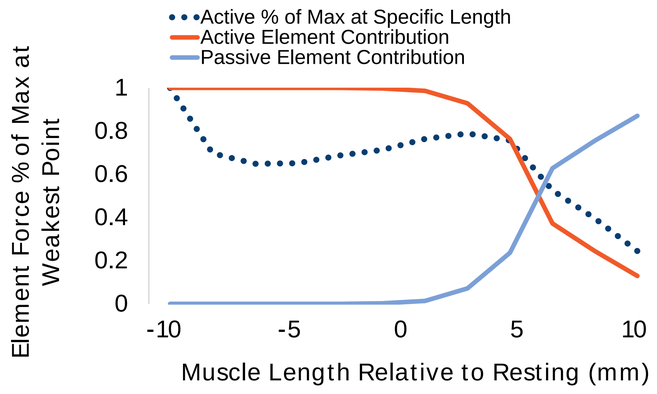

**Figure 1:** Change in active and passive element force as a function of muscle length.

## Methods

Using a **Hill-type model** [2] of muscle-tendon (MT) mechanics, active and passive element force contributions will be calculated. The input **force level** to the Potvin & Fuglevand [3] fatigue model will be **adjusted to account for muscle length**.

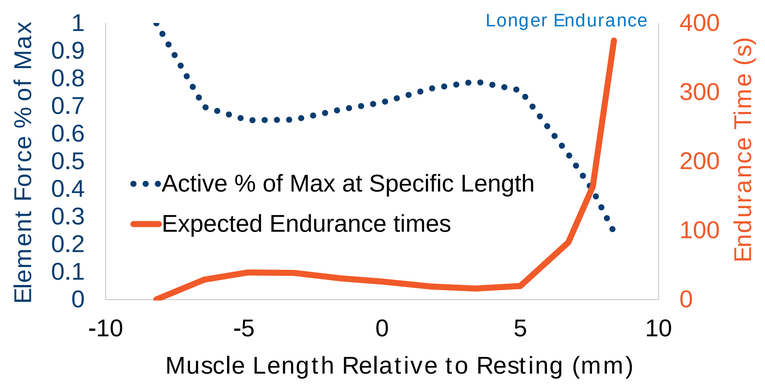
Muscle Length = *l*
Force = *F*

$$\text{Active \%Max}(l) = \frac{\text{Active Element Capacity}(l) * F}{\text{Active Element Capacity}(l)}$$

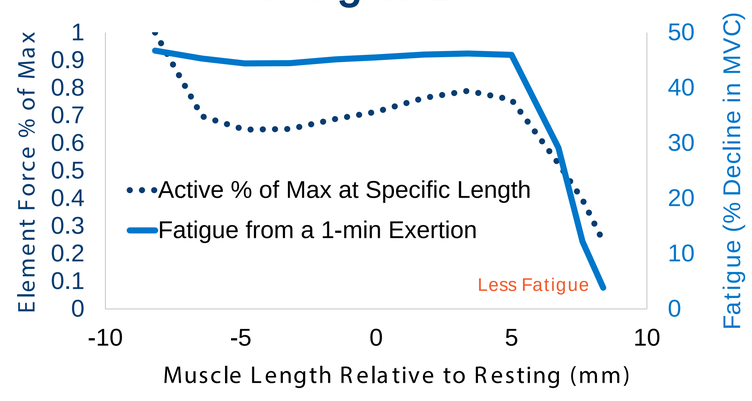



## Analysis & Results

### Endurance Time




### Strength Loss




## Discussion

The muscle is near maximum capacity and has little endurance at very short muscle lengths. At longer muscle lengths there is a large increase in ET.

Fatigue from a 1-min exertion is reduced at longer muscle lengths compared to the rest of the range.

Workers may have **only brief endurance at short muscle lengths**; they also may preferentially work at **long muscle length postures** to take advantage of the passive force contributions to reduce effort.

**Future** work will include the **force-velocity relationship** so a fatigue model can be used dynamically.

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