The practical considerations when quantifying the force-velocity relationship in whole skeletal muscle

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Summary

The mechanical performance of skeletal muscle during cyclical contractions is underpinned by both a shortening (concentric) and a lengthening (eccentric) force-velocity (F-V) relationship. The eccentric F-V relationship has been understudied, possibly, due to the complex behaviour of active muscle during lengthening. Lengthening muscles exhibit a dynamic biphasic response, that depends on both active cross-bridge dynamics and non-crossbridge parallel elastic elements (e.g. titin). Here we modified: (a) the muscle temperature (17, 27 and 37°C) and (b) the lengthening strain (10, 20 and 30 % of optimum length) to investigate their effects on the eccentric F-V relationship. We show that the both active cross-bridge and the non-cross bridge parallel elastic elements are sensitive to the changes in temperature, and the lengthening strain imposed upon them. Consequently, these experimental parameters can have a significant impact on the experimental eccentric F-V relationship and upon the assessment of mechanical performance during cyclical contractions.

Introduction

The capacity of skeletal muscle to generate power is underpinned by the F-V relationship, which comprises two distinct components: a concentric and an eccentric F-V relationship. The eccentric portion of the F-V relationship is mechanically complex, presenting with a dynamic biphasic response (Figure 1). It is thought that the initial rapid phase-1 profile is a response to elevated strain of attached cross-bridges, after which the detachment of myosin heads leads to the transition into a shallower phase-2 force response [1]. While the phase-2 force response is thought to be linked to increased strain of non-crossbridge parallel elastic elements [1]. This dynamic phenomenon presents a unique opportunity to explore the mechanisms of physiological perturbations, for example how does manipulation of skeletal temperature and muscle strain amplitude impact this biphasic response?

Methods

Here, we use the extensor digitorum longus and soleus muscles from the mouse to investigate the impact of (a) temperature (17, 27 and 37°C) and (b) lengthening strain (10, 20 and 30 % of optimum length) on the eccentric mechanical response. We quantified changes in the rate of force development across phase-1 and phase-2, in addition to the relative force at which the transition between these two phases occurs (Figure 1) [2].

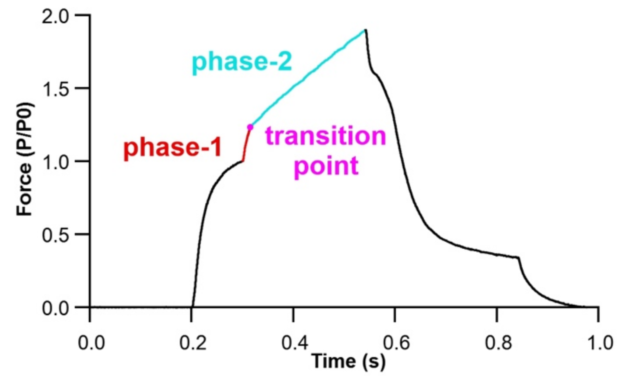

Figure 1. Eccentric lengthening of muscle. The initiation of stretch during an isometric tetanic contraction results in a rapid rise in force (phase-1), followed by a lower rate of force development (phase-2).

Results and Discussion

Here we present data that highlight the significant impact experimental parameters used can have on the derived F-V relationship. The phase-1 portion is highly sensitive to changes in temperature which has a significant impact on plateau height of the F-V relationship. Further, the lengthening strain has a significant impact on when the transition point between phase-1 and phase-2 occurs, significantly impacting the F-V relationship.

Conclusions

There is currently no standardized approach to quantifying the eccentric F-V relationship, and yet this relationship underpins much of our understanding of muscle function, where for example, musculoskeletal models are highly sensitive to changes in the eccentric portion of the F-V relationship [3].

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