Muscle Action Dependence on the Damkohler Number

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Abstract

Muscle action is the mechanical response of a soft biological material to stimulus. It occurs as a consequence of membrane depolarization allowing Ca+2 ion to flux into the intra-fibrillar space from the T-tubule system. Binding of this ion to the acto-myosin protein complex changes the catalytic activity of the complex for ATP hydrolysis. This form of ATP hydrolysis supplies energy to the protein complex which allows it to undergo a mechanical action that causes displacement under load. A model has been developed to link the mechanical action to the ATP hydrolysis. This model enables one to compute the mechanical efficiency of action as a function of the velocity of contraction in the muscle. The model links mechanical action at the nano-scale to macro-scale response. Some aspects of the model depend on consideration of ion transport versus chemical reaction. Responses in muscle are in the millisecond time scale range. The steady state model response has been published (Long and Phoonsiri, 2006, Chem. Eng. Comm.). A transient response model has been submitted for publication. Damkohler number dependence affects the transient response and the relative significance of reaction time versus transport time can be estimated from published kinetic data considered together with T-tubule dimension data.

A distinguishing feature of this model is that allows ADP release from both a high strain and a low strain state, though at different rates. This means that ADP is released both pre and post power stroke, which is consistent with recently published data on analog systems. To date difficulties remain in making reliable measurements of these nano-scale events.

keywords: mechano-chemical energy transduction, cross-bridge kinetics, calcium binding kinetics, ATP hydrolysis, force-velocity relation, muscle power

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