A mathematical model of myocyte contraction based on discrete representations of individual sarcomeres

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Abstract: Mathematical models of contracting muscle cells have been developed over several decades, and have given important insight into the mechanisms of muscle contraction. However, most models are focused on a single scale, such as the sarcomere or the complete cell, and are not capable of modeling interactions between individual sarcomeres or other functional units. Sub-cellular heterogeneities in ion concentrations and contractile mechanics have been studied experimentally, and suitable computational models could shed new light into the results of these experiments.

We present a computational model of cell contraction which is based on a discrete representation of individual sarcomeres. The sarcomeres are modeled as separate contractile units, which are connected into bundles of myofibrils connected by linear springs. The model framework is generic and can be combined with different dynamic and static models of sarcomere force development, to describe different muscle cell types and experimental conditions. In the present study the model was adapted to experimental data from cardiac myocytes, using a widely used model of cardiac force development. The dynamics of each sarcomere is described by eight ordinary differential equations (ODEs), which for a complete cardiomyocyte would result in a coupled system of tens of thousands of ODEs to describe a complete cardiomyocyte. Initial model results were based on a smaller array of sarcomeres, and showed good agreement with experimental observations of sarcomere contraction and interaction.