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Biophysics: Order in chaos

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The process of skeletal muscle contraction is based around protein filaments sliding inside sarcomeres — the structural units of muscle fiber. Inside each sarcomere is a set of filament motors, which appear in different densities in different areas. Scientists previously thought that the motor force would change according to the filament load in the muscle, but recent studies have shown that the motor force actually maintains a constant level during the muscle contraction. Despite such breakthroughs, however, it remains unclear exactly how this constant force is maintained in an otherwise chaotic system.

Bin Chen of the A*STAR Institute of High Performance Computing and Huajian Gao at Brown University, US, have now built a model to illustrate the process of skeletal muscle contraction and show how a constant force can be sustained by the protein motors.

The two key proteins in muscle contraction are actin and myosin. Myosin drives the system, forming a thick filament made up of numerous motors which ‘grab’ onto, bind to and slide past the thinner actin filaments during contraction. This ‘grabbing’ and sliding motion has been shown to be fairly chaotic in nature, with attachment and release happening at random. When the weight of an object exerts a load on the filaments — for example, when you try to lift something up — the muscles must contract, requiring the protein motors to generate a force opposite to the load.

Chen and Gao have created a new skeletal muscle fiber model to demonstrate how contraction forces work. “Our model is designed for the sarcomere,” Chen explains. “We consider the thin filament as an elastic rod under a filament force, which is driven by multiple stochastic myosin motors that convert the chemical energy of adenosine-5'-triphosphate (ATP) hydrolysis into stored elastic energy and then function like swinging arms.”

The results show that the unique way in which the myosin motors randomly attach and release from actin, coupled with the elastic properties of the motors, generate a consistent force across the whole sarcomere. When there is a higher filament load, more myosin motors are attached to the actin, but the overall motor force remains constant.

“This regulation mechanism may exist in various biological processes and dramatically induces order within a chaotic system,” explains Chen. “Our modeling framework can also be further adapted to study the behaviors of other actomyosin complex structures, which is part of our plan for future work in this area.”

More information: Chen, B. et al. Motor force homeostasis in skeletal muscle contraction. *Biophysical Journal* 101, 396–403 (2011) doi:10.1016/j.bpj.2011.05.061

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