Fast, cheap and out of control: dynamic interactions of elastic structures and muscle motors

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It is now well established that the elastic function of tendons has a profound influence on locomotor function. Tendons and other elastic structures can reduce the energy cost of locomotion, amplify muscle power output for ballistic movements, and provide passive dynamic responses to perturbations. Research in my lab uses the tools of comparative biomechanics to explore these mechanisms in a variety of animals and locomotor modes. For example, we study running turkeys to understand the influence of elastic structures on the metabolic cost of locomotion, and we investigate frog jumping to understand how biological springs help to power rapid movements. One consistent lesson from this work is that the interaction between elastic elements and muscles influences the force, velocity and power of virtually all muscle contractions. Several results from our lab indicate that a model of a spring in series with a muscle fails to capture the mechanical significance of these muscle-tendon interactions. For example, we find that elastic structures influence muscle shape changes during contraction, and these shape changes in turn influence muscle force and velocity. Shape changes in muscle likewise result in tendon loading along more than one axis, resulting in a dynamically variable tendon stiffness. These observations have implications for motor control that are not yet fully explored. On the one hand, changes in muscle force and velocity mediated by muscle-spring interactions can provide rapid adjustments in mechanical output independent of nervous control. On the other hand, motor commands for prescribed motions must account for these complex dynamics.