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State of the science: Musculoskeletal tissue biomechanics enjoys a rich history of inquiry traditionally involving materials testing approaches to structures of interests. More recently, testing has incorporated considerations for physiological conditions of the tissue which may mean revising testing protocols to provide appropriate tissue geometry, testing strains, strain rates, strain histories and stresses. As a result, there has been a tremendous proliferation of data describing muscle, tendon, ligament and bone biomechanical properties under physiologically relevant conditions. Adopting the comparative approach to biomechanics has revealed major design features of musculoskeletal tissues. In comparative studies, tissue properties are measured in animals that demonstrate extreme adaptations in locomotor style or performance. Such lessons, while obtained in the context of animal locomotion, even of lower animal classes, clarify the key features of tissue that can easily be applied to humans.

Of course, the wealth of biomechanical data available necessarily lead to biomechanical modeling of these tissues. The purposes of the models vary but often are used to simulate conditions that cannot easily be reproduced experimentally. This is especially true with locomotion studies where implanted transducers cannot reasonably be used to make the number of measurements required to understand the entire system. Models are produced at both the macro- and micro-level using similar approaches albeit on different scales. At the macro-level, the approaches involve finite element modeling which can predict regional variation in tissue properties. Such regional variations often provide insights into injury mechanisms. At the micro-level, modeling approaches may provide insight into cellular mechanisms responsible for creating and maintaining tissue properties. These approaches may lead to microscopic biomechanical investigation of tissue adhesive properties, mechanotransductive structures, signaling pathways that are biomechanically sensitive and ultimately will be used to understand the general mechanisms for maintaining tissue properties.

Vision for the future: The field of tissue biomechanics is vast and complex. It is necessarily interdisciplinary, which creates barriers of communication among scientists, clinicians and engineers. Significant energy and grace is required for these fields to merge and create productive, insightful collaborations. Many times, “interdisciplinary” simply means involving multiple investigators in different Departments. However, true interdisciplinary research only leads to progress when the various parties take time, learn the relevant vocabulary, and spend the energy needed to understand the issues from the perspective of the other. The field of tissue biomechanics has traditionally been addressed primarily using engineering tools. Only recently have sophisticated biological tools been implemented to study the living tissues. This is absolutely critical, as any discussion of tissue healing, tissue adaptation and tissue aging necessarily requires an understanding of “rules” that govern such changes. In this area it is important to study living systems noninvasively, or at least without significant disruption, to develop models in which biological processes and mechanical condition can be studied simultaneously. Finally, global movement studies require thoughtful integration of information obtained on studies of muscle, tendon, ligament, bone, and cartilage. These fields largely exist independently and there are very few literature reports that cross the tissue boundaries. Such crossings are crucial to create reasonable large-scale models of human or animal movement. Similar to the human genome project, there may need to be a concerted effort to create a large database of tissue material properties in an organized fashion that permits integration and sharing among investigators. Standards may have to be developed in which the testing and reporting environments are carefully controlled and consistent among investigators. There is no question that the field of tissue biomechanics is at a crossroads in which the explosion of transgenic animals and molecular tools make possible experiments of unprecedented significance and impact.