Functional Skeletal Muscle Imaging

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IMAGING TO TEST MODELING ASSUMPTIONS

We tested the assumption that muscles transmit force only to their own tendons by measuring the motion (using cine phase-contrast MRI) of the rectus femoris in control subjects and subjects with cerebral palsy who had undergone a surgical transfer of the distal tendon of the rectus femoris to one of the knee flexors [1]. If muscle force were transmitted from the rectus femoris muscle solely to the rectus femoris tendon the rectus femoris would move in the same direction as the knee extensors in control subjects and in the direction of the knee flexors in subjects who had undergone surgery. We acquired one anatomical and three velocity images during a knee flexion-extension cycle. The images were interpolated into 24 evenly spaced time frames that represented the motion cycle. Regions of interest were defined in the tissue of the rectus femoris, vastus intermedius (a knee extensor), and semitendinosus (a knee flexor). For each time frame, the superior-inferior velocities within in each region were calculated. We found that the rectus femoris moved in the direction of the knee extensors, not the knee flexors, in the surgical subjects. This suggests that force generated by the rectus femoris is not transmitted only to its distal tendon but may also be transmitted laterally to the surrounding muscles, presumably due to adhesive scar tissue that develops between the rectus femoris and vasti after surgery.

We tested the assumption that muscle fascicles shorten uniformly by using cine phase-contrast MRI to measure the shortening along anterior and centerline fascicles of the biceps brachii muscle during elbow flexion [3]. Shortening of muscle in the direction of its fascicles was estimated by measuring the displacements of tissue regions prescribed along the muscle fascicles. We found that shortening along the anterior fascicles of the biceps brachii was approximately uniform along the length of the muscle. In contrast, shortening along the centerline of the biceps brachii was highly non-uniform. This invalidates the assumption that muscle fascicles shorten uniformly along their length. These results emphasize the need to make *in vivo* measurements of muscle motion to test assumptions about muscle contraction, improve the accuracy of muscle models, and further our understanding of muscle function.

IMAGING AND MODELING CHALLENGES

MR imaging of skeletal muscle has inspired the development of a new generation of muscle models [2] that account for the complex contraction mechanics observed in dynamic imaging studies. Conversely, advanced biomechanical models of the musculoskeletal system are motivating the development of new MR imaging techniques. Breakthroughs in two areas will be particularly valuable. First, the development of realtime MR imaging methods and associated image analysis techniques is needed to accurately measure the motions of muscles, tendons, and bones under physiologic loads. Second, the application of diffusion tensor imaging to characterize the complex arrangement of muscle fascicles in healthy subjects and persons with neuromuscular diseases is needed to better understand muscle architecture, function, and disease. These challenges provide fruitful directions for imaging research.

REFERENCES

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