Velocity Encoded-Phase Contrast MRI Reveals *in vivo* Tissue Dynamics of the Human Medial Gastrocnemius During Isometric Contraction

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Introduction: Fibers in skeletal muscle attach to tendinous tissue (tendon and/or aponeurosis). In pinnate muscle such as the medial gastrocnemius (MG), the aponeroses are located on both sides of the muscle. It has been reported that superficial and deep aponeuroses of the MG are stretched homogenously along their lengths by isometric contraction. However, it is impossible to elongate the entire aponeuroses, because the proximal edge of each aponeurosis attaches to the femur. Velocity encoded-phase contrast (VE-PC) MRI has been widely used to investigate the motion of musculotendinous tissue. The VE-PC MRI has the advantage that a considerably large area can be visualized in a single image with excellent soft tissue contrast and resolution.

Hypothesis and Purpose: We hypothesized that by isometric contraction, only certain locations in each aponeurosis shorten rather than stretching homogenously along their entire lengths. This hypothesis was tested by comparing the velocity and displacement between superficial and deep aponeuroses during isometric plantarflexion using VE-PC MRI.

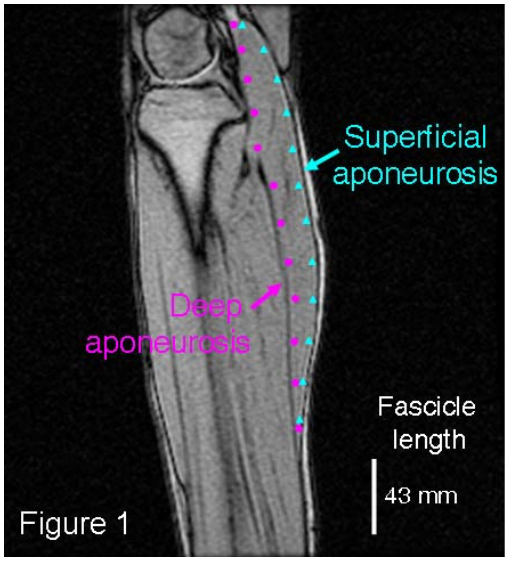

Figure 1

Materials and Methods: 4 male subjects were scanned using 3-Tesla Trio (Siemens). VE-PC MR images were acquired using gated gradient echo 2D phase contrast sequence (TR 13.3 ms; TE 7.5 ms; FA 20°; FOV 320 × 160 mm; pixel matrix 256 × 512; phase FOV 50%; slice thickness 3 mm; bandwidth 290 Hz/pixel; views per segment 3; 2 averages, 1 slice; scan time 1.5 min). Encoding velocity was set at 10 cm/s in the superior inferior direction. A total of 22 phases were acquired in the sagittal plane. The temporal resolution of each phase was approximately 80 ms. Subjects performed at two different force levels: 20% and 40% of the subject's maximum voluntary contraction. The plantarflexor force was projected along with the target force onto the scanner face, as a feedback to the subject, allowing him to produce target force accurately and consistently. Trajectories of 12 seed ROIs (Fig.1) uniformly placed along each aponeurosis were tracked using an in-house MATLAB-based algorithm (Fig.2), from which velocities and displacement of each aponeurosis were determined.

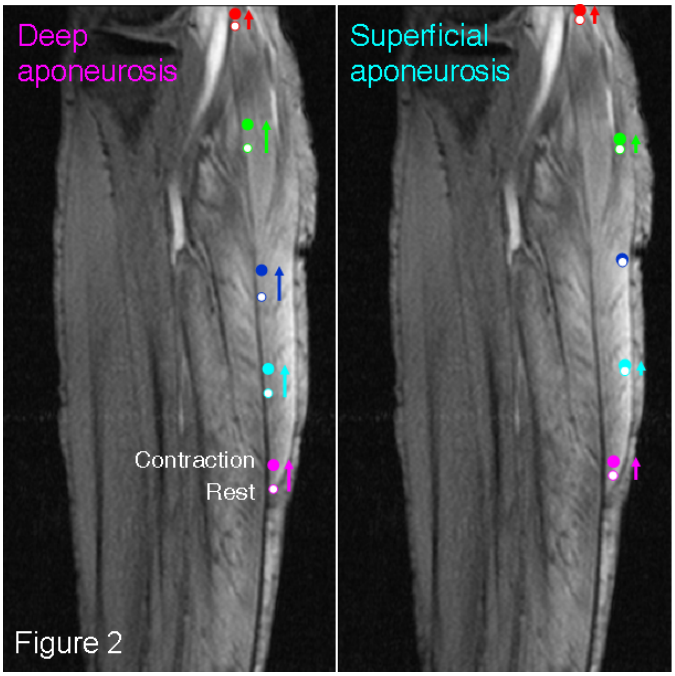

Figure 2

Results and Discussion: The velocities of each aponeurosis increased and was positive during the contraction phase, declined to zero at peak torque, and then became negative during relaxation phase, suggesting both moved proximally during contraction and moved distally during relaxation. The displacement moved the least in middle region of the superficial aponeurosis and proximal region of the deep aponeurosis along its length (Fig.3). This means that the superficial aponeurosis lengthened in the proximal region and shortened in the distal region, and the deep aponeurosis shortened in the proximal region. However, the displacement of the distal region may have been overestimated since the length of this region was of the same order as the fascicle length.

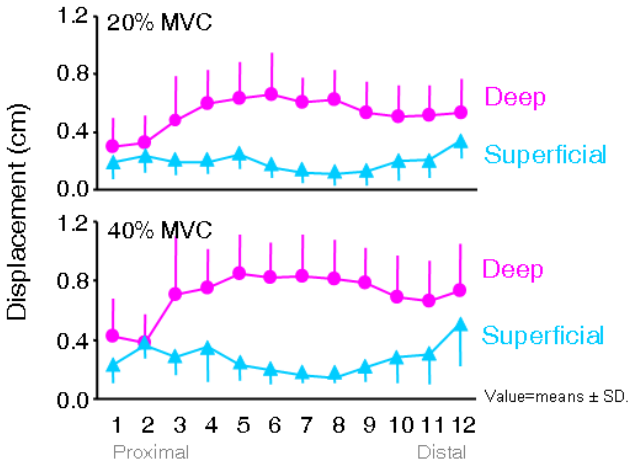

Figure 3

Conclusion: Both aponeuroses moved in a similar direction during contraction, but the displacement variations along their lengths were markedly different between the two. VE-PC MRI is able to very effectively elucidate the biomechanics of movement realistically over the entire FOV of the MSK structure, unlike Ultrasound, which has a limited window of FOV.