Skeletal Muscle Motion Maps from Post-Contraction Gradient Echo Spin Saturation Effect

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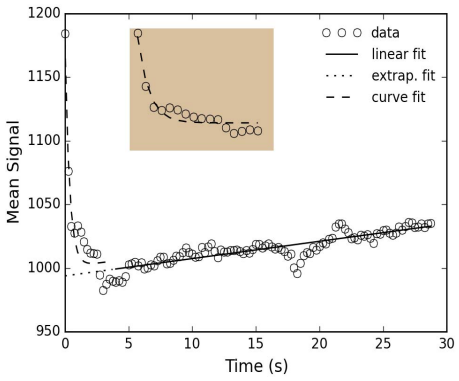

Fig. 1: ***Saturation signal fit method****. Fit to post-exercise data from mean of fit map voxels of MG from one trial in the superior direction. Shown are the linear fit (solid line), extrapolation to early points (dotted line), and mono-exponential decay curve fit (dashed line). Inset shows expanded view of de-trended fit.*

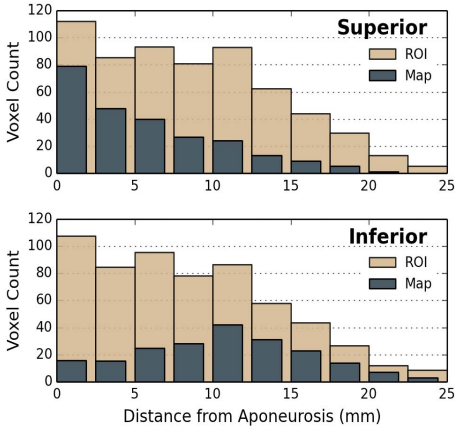

Fig. 3: ***Voxel proximity to deep aponeuroses****. Mean voxel counts from all trials in triceps surae muscle ROIs (lighter bars) and fit maps (darker bars), plotted against proximity to the deep aponeuroses of the triceps surae.*

Target Audience: Musculoskeletal researchers interested in functional imaging of muscle.

Purpose: Muscle functional imaging using gradient echo echo planar imaging (GRE-EPI) shows increasing promise in evaluating skeletal muscle under a variety of conditions [1], especially during exercise [2]. Such studies have not assessed the utility of GRE-EPI for evaluating biomechanics. This study sought to test whether muscle displacement maps could be generated using only a standard time series of images produced using GRE-EPI MRI.

Methods: Data was collected from six male subjects using a 3T GE HD Signa MRI scanner with a single receive channel flex coil. Following localization and routine T1-weighted anatomical imaging, single shot GRE-EPI datasets were acquired axially through right leg calf muscles, during and after isotonic plantar flexion exercise (3×10mm thick slices, TE/TR=35/250ms, α=33°, FOV=16cm @ 64×64). Only post-exercise data was used; an image post-processing scheme was developed to exploit the post-contraction saturation effect evident in the signal upon muscle relaxation **(Fig. 1)**. The effect, which has been noted previously [3], occurs when muscle tissue leaves and re-enters the imaging plane during exercise. The post-processing scheme operates voxel-wise to remove the (locally linear) BOLD trend from the data and fit a mono-exponential decay curve to post-exercise points. Maps are generated based on thresholding the voxel fits to be a true decay with reasonable time constant and R^2>0.5.

Results: Through-plane motion maps were generated for each trial using the image processing scheme **(Fig. 2)**. The maps were processed to determine proximity of inferior and superior motion to the deep aponeuroses of the triceps surae **(Fig. 3)**.

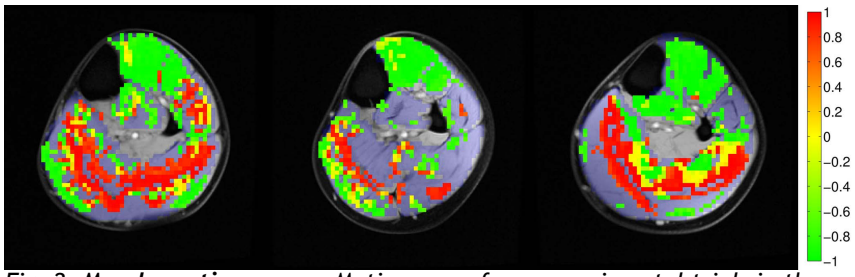

Fig. 2: ***Muscle motion maps****. Motion maps from experimental trials in three subjects. Values represents R^2 values, with positive or negative sign indicating voxels from superior or inferior slice, respectively.*

Discussion: Inferior motion is especially prevalent in the anterior compartment and areas of the triceps surae distant from the deep aponeuroses, while superior motion occurs mostly near the deep aponeuroses of the soleus and gastrocnemius. This result is expected, since plantar flexion occurs by moving the deep aponeuroses, and ultimately the achilles tendon, in the proximal direction to rotate the foot about the ankle [4].

Conclusion: The method successfully mapped muscle displacement in accordance with prior studies. Although the established methods for muscle motion mapping using ultrasound and phase contrast MR imaging provide more subtle quantitative information, this novel method provides researchers who are already doing functional GRE-EPI imaging of muscle with valuable complementary information.

References: **[1]** Carlier et al. NMR Biomed 2006; 19:954–967. **[2]** Noseworthy et al. Semin Musculoskelet Radiol 2010; 14:257-268. **[3]** Meyer et al. NMR Biomed 2004; 17:392–398. **[4]** Shin et al. J Appl Physiol 2009; 107:1276–1284.