Temporal Diffusion Differences between Slow-twitch and Fast-twitch Skeletal Muscle following Mild Exercise

Conrad Rockel[1], Alireza Akbari[1], Dinesh Kumbhare[2,3], and Michael Noseworthy[1,4]

[1]*School of Biomedical Engineering, McMaster University, Hamilton, Ontario, Canada,* [2]*Physical Medicine and Rehabilitation, McMaster University, Hamilton, Ontario, Canada,* [3]*Department of Medicine, McMaster University, Hamilton, Ontario, Canada,* [4]*Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada*

Target audience: Researchers and clinicians interested in post-exercise skeletal muscle physiology as assessed using diffusion tensor imaging (DTI).

Purpose: This work was done to investigate the temporal DTI response immediately following exercise in fast and slow twitch skeletal muscles. Furthermore, our goal was to demonstrate that active muscles show larger changes in diffusion following exercise than do proximate inactive muscles.

Methods: *Subjects:* Three healthy male volunteers (mean age 33.6 yrs) were scanned prior to and immediately following mild exercise (repeated dorsiflexion/eversion of the foot at 1Hz for 5 minutes.). *MRI:* Scanning was done using a GE 3T (GE Healthcare, Milwaukee WI) and an 8-channel lower extremity coil. DTI data was acquired using a dual echo spin echo EPI sequence (b=400s/mm², TR/TE=4000/70ms, 6 directions, 16 slices 4mm thick, 16cm FOV, 64x64) prior to (4 volumes) and immediately following the exercise (13 volumes). The DTI volumes were collected every 35s from the thickest cross-section of the calf of the volunteer's dominant leg. *Analysis:* Regions-of-interest (ROIs) were drawn on tibialis anterior (ATib), extensor digitorum longus (Ext), peroneus longus (Peron), soleus (SOL), and gastrocnemius lateralis (LG), and subsequently spatially and temporally registered using FSL[1] to create a time course of diffusion behaviour. ROIs were drawn separately for pre- and post-exercise volumes to prevent misregistration due to bulk movement during exercise. ROIs consisted of two 2x2 squares across 5 slices placed to avoid fascia, blood vessels, or artifacts from chemical shift. Mean diffusivity (MD) was then calculated for each volume using FSL[1]. Percentage MD change from baseline was calculated for each post-exercise time point, and the slope of percentage change was assessed for time points 1 to 3 and 3 to 13. Baselines and slopes of post-exercise change of each muscle were compared to published percentages of individual muscle content of slow- and fast-twitch fibers[2].

Results: At baseline, no correlation between baseline MD and slow-twitch fiber percentages was noted [**Fig.1**]. Immediately following exercise, muscles involved with dorsiflexion/eversion of the foot (ATib, Ext, Peron)[3] showed a notable increase in diffusion (~10 %) [**Fig.2**]. For uninvolved muscles (Sol, LG), there was less than 1% change in diffusivity. None of the involved muscles returned to baseline during the period of data collection (~7.5 minutes). Within active muscles, slow-twitch dominated muscles (ATib, Peron) showed different rates of post-exercise diffusion change than fast-twitch dominated muscles (Ext).[2,3]. For time points 1 to 3, there was a *negative correlation* between percentage of slow-twitch fibers and amount of diffusion **[Fig3; red=involved muscles]**, while for time points 3 to 13, the slope of MD in Ext became steeply negative **[Fig4; red=involved muscles]**,

Discussion: Although there was no apparent relationship between baseline MD values and muscle fiber percentage, differential diffusion behaviour between muscles was noted following mild exercise. Muscles involved in the exercise exhibited a rise in diffusivity, while uninvolved muscles did not stray from baseline measures. Furthermore, a negative relationship was noted between the percentage of slow-twitch fibers and the rate of diffusion change in the first three time points following diffusion, during which time diffusion in the slow twitch muscles began to decline, yet diffusion in the fast-twitch muscles continued to increase. This differential pattern has previously been noted between the fast-twitch gastrocnemius and slow-twitch soleus[4]. It is thought that diffusion changes within skeletal muscle following exercise reflect alterations in interstitial fluid levels and blood flow induced by the exercise. Because vascularization is greater around slow-twitch muscle fibers, it is possible that diffusion through these tissues is held relatively steady during and following exercise. However, fast-twitch fibers may exhaust nutrients during exercise due to their limited blood supply, resulting in a greater post-exercise demand for blood flow, and thus diffusion patterns of higher magnitude for longer periods of time.

Conclusions: The behaviour of diffusion changes following mild exercise differed between muscles of mostly slow-twitch vs fast twitch fibers. The fast-twitch-dominated muscles exhibited delayed diffusion increases following exercise. Therefore, DTI is sensitive to differences between muscles with differing fiber types following mild exercise.

References: [1] http://fsl.fmrib.ox.ac.uk/fsl/; [2] Johnson MA, et al. *J Neurol Sci*. 1973; 18: 111-129.; [3] Snell RS. Clinical Anatomy for Medical Students, 3rd ed. Toronto: Little, Brown & Co, 1986. [4] Rockel C, et al. *Proc Int Soc Mag Reson Med. (ISMRM)* 2012;20:1425.

Fig1

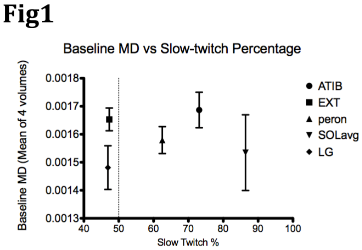

Fig2

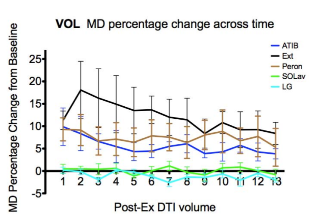

Fig 3

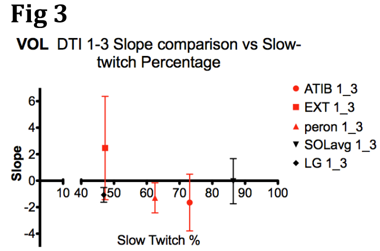

Fig 4