Phosphocreatine and Acetylcarnitine in Skeletal Muscle During Exercise at 7T by Interleaved 31P and 1H-MRS

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INTRODUCTION

Exercise results in a massive increase in muscle metabolic rate. ^{31}P-MRS provides insight into pH, [ADP] and phosphorylation potential, and ^{1}H-MRS offers direct measurement of intramyocellular lipid concentration, and the concentration of acetylcarnitine, a critical buffer required to balance fuel oxidation with the needs of the citric acid cycle. These studies are traditionally performed separately.

The objective of this pilot study was to evaluate the feasibility of interleaved ^{1}H and ^{31}P-MRS measurements in human skeletal muscle during exercise in a 7 Tesla whole body magnet.

METHODS

2 to 5 minutes of exercise at 50% of maximal voluntary contraction (MCV) were performed in the magnet using a custom built isometric plantar flexion dynamometer. 2D FID CSI ^{31}P with matrix 8x6 was acquired in calf muscle during rest and exercise with resolution of 17.5x17.5 mm, slice thickness 40 mm, TR 1.5 s, BW 4000 Hz, number of samples 1024, averages 2, using 1s NOE composed of train of pulses with 9uT B1 and duty cycle 2%. Total scan time 112 s. PCr recovery curves were acquired during rest, exercise and recovery with TR 1s, using single shot FID acquisition with the same spectral resolution as above. Acetylcarnitine recovery curves were acquired with time resolution 2 min 16 s, using LASER sequence with TR 2s, TE 280 ms, averages 64, and spectral resolution of 0.97 Hz/sample.

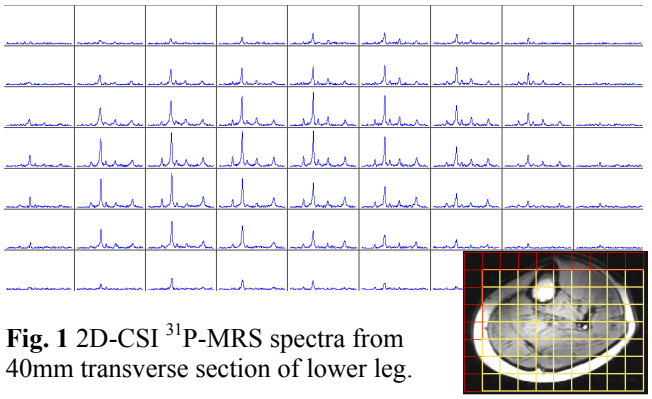

Fig. 1 2D-CSI ^{31}P-MRS spectra from 40mm transverse section of lower leg.

RESULTS AND DISCUSSION

2D CSI ^{31}P spectra were acquired successfully during rest and exercise enabling regional visualization of PCr and Pi signals (Fig. 1). Pi was elevated in spectra acquired during exercise, however the rapid changes in high energy phosphates combined with poor time resolution of the 2D CSI prevent visualization of the full extent of PCr depletion. At the end of exercise, PCr concentration was reduced to ~0.5 times resting levels but recovered rapidly upon exercise cessation ($T_{1/2}$ = 21.6s, TR 1s, Fig. 2). Acetylcarnitine was elevated after a 2 minute contraction at 50% MCV then returned to baseline concentrations by 7 min after exercise cessation (Fig. 3). This study demonstrates that, at 7 Tesla, it is possible to obtain consecutive high resolution ^{1}H-MRS and ^{31}P-MRS spectra in response to exercise. The rate of recovery of high energy phosphates in skeletal muscle post exercise is much faster than recovery of acetylcarnitine.

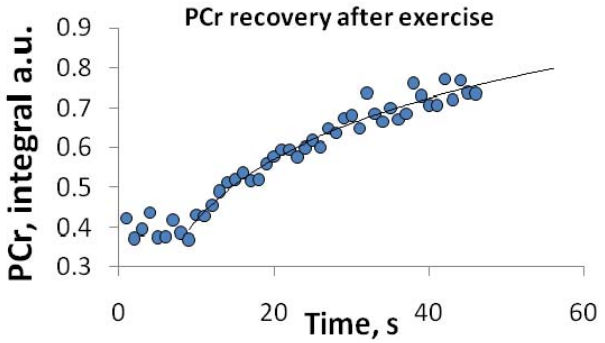

Fig. 2 Recovery of PCr after exercise.

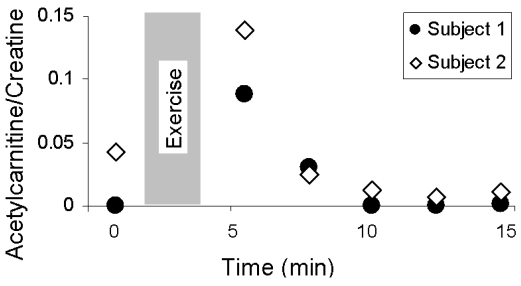

Fig 3. Acetylcarnitine/creatine during rest and recovery.