Metabolic response to exercise of gastrocnemius and soleus muscle characterized by localized dynamic 31P MRS, using a three-channel RF coil at 7T

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Introduction, Purpose: The increased sensitivity of high field MRS allows to augment spatial and temporal specificity of the metabolic information acquired [1-3]. This work demonstrates the feasibility of localised dynamic ^{31}P MRS with high time resolution in two distinct muscles, gastrocnemius medialis (GM) and soleus (SOL), during exercise.

Methods: A pneumatic ergometer was used to impose a constant force at 30 % of the individual maximum voluntary contraction force during a 5 min aerobic plantar flexion exercise in the MR scanner, in two equivalent bouts spaced by 40 min. Data available at the time of writing of the abstract were acquired from one healthy subject (female, 30 yrs).

An in-house-built novel three-channel TX/RX ^{31}P surface coil [4], optimised for MRS in human calf muscle, was used in a 7 T whole-body MR scanner (Siemens, Erlangen, DE). The voxels in the respective muscles were excited using a semi-LASER sequence with $T_R = 6$ s, $T_E = 25$ ms, VOI = 38 cm^3 [3]. Spectral quantification was done in AMARES, pH was calculated via the chemical shift of PCr and Pi, with a minimum of SNR(Pi) = 1.3 as criterion for pH calculation.

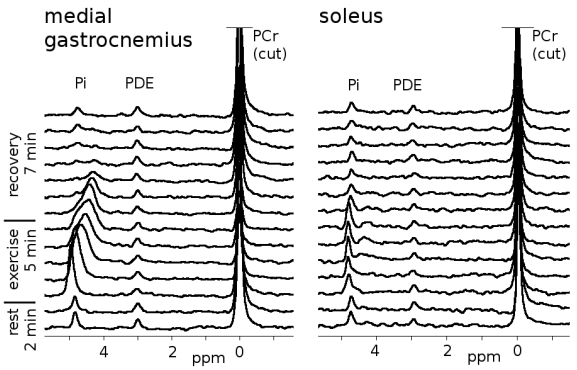

Fig 1: Stack plot of spectra acquired in GM and SOL exercise under rest, plantar flexion exercise and recovery. (10 time points averaged for display)

Results: Quantification of PCr and Pi was possible in GM and even in the deeper SOL from single acquisitions. Spectra in Fig. 1 were averaged in blocks of 10 for display only, PCr time courses (Fig. 2) represent single acquisitions. The PCr line width was 6.8 ± 0.3 Hz and only 4.5 ± 0.2 Hz in SOL. PDE and ATP quantification (not shown) is also feasible with 6 s time resolution. The precision of the Pi fit was sufficient to calculate pH from single acquisitions at both voxel positions (Fig. 3).

PCr depletion and recovery half times are given in Tab. 1, along with pH values at rest and end exercise and the minimum of pH after exercise.

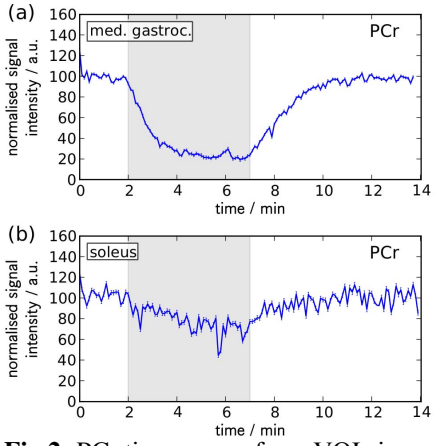

Fig 2: PCr time course from VOIs in (a) GM and (b) SOL localised with semi-LASER, in single shots during rest, exercise (grey area) and recovery.

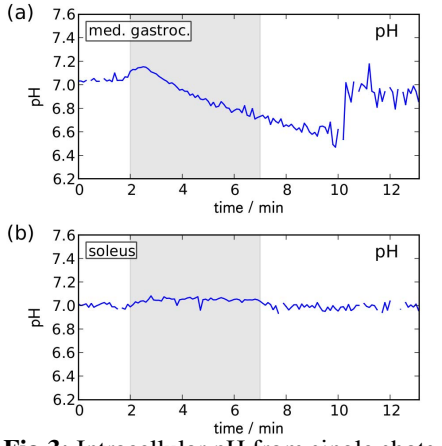

Fig 3: Intracellular pH from single shots (TR = 6 s, VOI = 38 cm^3).

Discussion: PCr depletion and pH changes in gastrocnemius are consistent with published data [5], while PCr recovery rate of the subject in these preliminary data shown was relatively long. SOL, which is less active than GM, shows a moderate pH increase during exercise and lower, but still detectable PCr depletion at end of exercise, with a slightly faster relaxation rate, as would be expected due to the higher post-exercise pH.

Pi remains detectable throughout the experiment at high time resolution, even during recovery. Note that the step in pH at $t = 10$ min is due to the Pi peak re-emerging at ca. 4.75 ppm, corresponding to pH ≈ 7.

Tab. 1: Tab 1: Dynamic PCr exercise- and recovery data and pH.

	PCr depletion	$t_{1/2}$	pH resting	pH end ex	pH_{min} post ex.	$t(pH_{min})$ post ex.
GM	83 ± 2 %	67 ± 3 s	7.03 ± 0.00	6.74 ± 0.03	6.57 ± 0.09	2.9 min
SOL	28 ± 3 %	56 ± 14 s	7.01 ± 0.01	7.05 ± 0.00	6.97 ± 0.03	0.3 min

Conclusion: It is possible to acquire metabolically relevant ^{31}P MRS data localised to deeper muscles. To our knowledge the data presented here are the first PCr exercise/recovery time courses and pH curves to be shown from soleus muscle with such high time resolution (6 s throughout). The increased sensitivity and specificity of the methods (an optimised sensitive array coil employed at high field, in combination with a robust full-signal single-shot localisation sequence) has the potential to increase the soundness of conclusions derived from bio-energetic data based on in vivo ^{31}P MRS.

References: [1] Parasoglou, P., et al. NMR Biomed, 2012.(Epub). [2] Forbes, S. C., et al. NMR Biomed, 2009. 22(10):1063.

[3] Meyerspeer, M., et al. MRM, 2011. 65(5):1207. [4] Laistler et al. Submitted to ISMRM13, #5092. [5] Meyerspeer, M., et al. MRM, 2012. (Epub).

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