Natural abundance of glycogen and lipids in human calf muscle measured before and after exercise by ^{13}C MRS at 7T

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Introduction Natural abundance ^{13}C MRS provides information specific to investigate metabolism in vivo while it can detect a wide range of ^{13}C signals, such as glycogen C_1 in the human calf muscle [1]. In particular, the energy required for muscular contraction during exercise can be assessed by dynamic ^{13}C MRS while monitoring the degree of glycogen content [2, 3]. In addition, physical activity may influence the degree of fatty acids from adipose tissue [4]. The simultaneous assessment of glycogen and lipid content by ^{13}C MRS at high field requires symmetric ^{13}C excitation and broadband ^{1}H decoupling. Therefore, the aim of this study was to evaluate changes of glycogen and lipid levels in the human calf before and after exercise by ^{13}C MRS at 7T, using an implemented pulse sequence with symmetric ^{13}C excitation [5] and broadband ^{1}H decoupling.

Methods MR experiments were performed on a 7T human scanner (Siemens Erlangen/Germany). A ^{13}C-linear/ ^{1}H-quadrature RF surface coil [6] was built for use at 7T. A sphere (Ø = 7 mm) filled with 99% ^{13}C-enriched formic acid was placed in the centre of the ^{13}C coil as an external reference. A pulse sequence was implemented for ^{13}C MRS with symmetric ^{13}C adiabatic excitation [5] and broadband ^{1}H decoupling using WALTZ16 scheme [7]. In vivo natural abundance ^{1}H decoupled ^{13}C MR spectra were acquired on the human calf of a healthy volunteer who gave informed consent according to the procedure approved by the local ethics committee. The duration of the main 90° pulse of the WALTZ16 scheme used for ^{1}H decoupling was 0.5ms, resulting in a decoupling bandwidth of 1kHz. The total decoupling duration was adjusted relative to the acquisition time for efficient and simultaneous decoupling of ^{13}C signals, while respecting the limits for power deposition in tissue. ^{13}C MR spectra were acquired before and after exercise (1 hour run), using glycogen C_1 resonance at the centre of the spectrum (TR = 1.1s, BW = 20 kHz, 300 scans, vector size = 2048, Gaussian filter with width = 20ms, acquisition time = 102ms, decoupling duration = 48ms). Intensity levels of the ^{13}C signals obtained before and after exercise were compared.

Results Natural abundance of glycogen C_1 from gastrocnemius muscle was detected at 100.5 ppm, as well as lipids from adipose tissue including glycerol C_1, C_3 (62ppm) C_2 (73 ppm), saturated and unsaturated lipids (30 and 130 ppm) (Figure 1). Methyl peak was detected (15ppm) but not fully enhanced due to the limited decoupling bandwidth (1kHz) which was shorter than the ^{1}H chemical shift in vivo (~1.5kHz). Glycogen C_1 level was degraded after exercise by ~40%, as well as clustered glycogen C_2-C_5 (~75ppm). No significant changes were observed on glycerol peaks, while unsaturated and saturated lipid levels were increased by a factor of ~1.2 after exercise.

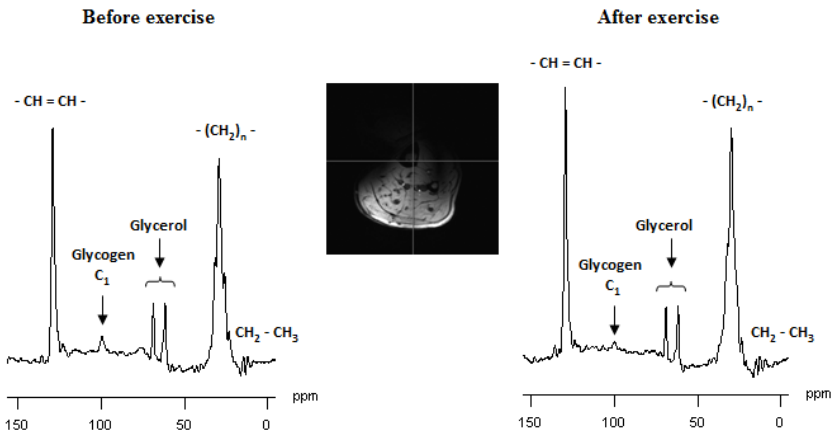

Figure 1: In vivo natural abundance ^{1}H decoupled ^{13}C MR spectra obtained from the calf muscle of a healthy volunteer before (left) and after (right) exercise (1 hour run). Spectra was acquired using a pulse sequence with symmetric ^{13}C adiabatic excitation [5] and broadband ^{1}H decoupling using WALTZ16 scheme [7] (TR = 1.1s, adiabatic pulse duration = 2ms, decoupling duration = 48ms, BW = 20kHz, 300 scans, vector size = 2048, Gaussian filter with width = 20ms, acquisition time = 102ms). Spectra are shown with the same vertical scale.

Conclusion It is feasible to assess glycogen and lipid content in human muscle at 7T using a pulse sequence with symmetric ^{13}C excitation and broadband ^{1}H decoupling. The obtained changes of glycogen and lipid levels after exercise are in agreement with the literature [2, 3, 4], and this will allow further extension of this technique for an improved assessment of metabolite concentrations by ^{13}C MRS in humans at 7T.

References [1] M.J. Avison et al, 1988; [2] A. Heerschap et al, 1989; [3] T.B. Price et al, 1991; [4] N. Beckmann, 1995; [5] Serés Roig et al, ISMRM 2014; [6] G. Adriany et al, 1997; [7] A. J. Shaka et al, 1983.

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