Relaxation Times of Human Skeletal Muscle Metabolites at 7T

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Introduction: Single-voxel proton MR spectroscopy (SV-^{1}H-MRS) of human skeletal muscle at ultra high fields provides accurate quantitation of muscular metabolite concentration due to improved spectral resolution and high signal to noise ratio. Quantitative evaluation of relaxation times is extremely important for accurately quantifying metabolite concentration, optimizing measurement protocols in MR spectroscopy, and in quantitative spectroscopic imaging (1). Although previous studies have measured ^{1}H relaxation times of skeletal muscle metabolites at clinical field strengths (1-7), there have been no quantitative measurements of T_1 and T_2 relaxation times of skeletal muscle metabolites at ultra high field (7T) in the literature. Therefore, the aim of this study was to demonstrate the feasibility of *in vivo* human tibialis anterior muscles and evaluate the T_1 and T_2 relaxation times of metabolites.

Methods: Model lipid phantom (corn oil) and healthy volunteers (n = 3, mean age 35.6 years) were scanned at 7T MRI system (Siemens Medical Solutions, Erlangen, Germany) utilizing a transmit-receive 18-cm inner-diameter quadrature birdcage knee RF coil (In Vivo Corp., Gainesville, FL). A voxel of 10X10X10 mm^3 was positioned in the oil phantom and right calf tibialis anterior (TA) muscles (Fig.2 (a)) using the single voxel STEAM sequence. For comparison, the lipid phantom was also scanned at 3T clinical MR scanner (MAGNETOM Trio, Siemens Medical Solutions, Erlangen, Germany), and an 18-cm diameter, transmit-receive quadrature knee coil was employed for T_1 and T_2 measurement of lipid phantom. At 3T, for T_1 measurement of lipid phantom, TE = 10ms, TR = 500, 600, 700, 800, 900, 1000, 1500, 2000 ms; for T_2 measurement, TR = 6s, TE = 25, 50, 75, 100, 150, 200, 250, 300 ms. At 7T, for T_1 measurement of lipid phantom, TE = 10 ms, TR = 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 10 s; for T_2 measurement, TR = 6s, TE = 15, 25, 35, 45, 55, 75, 100, 150, 200 ms. At 7T, for T_1 measurement of human tibialis anterior (TA) muscles, TE = 10 ms, TR = 0.5, 1, 2, 3, 4, 5, 6, 7 s; for T_2 measurement, TR = 6s, TE = 25, 35, 45, 55, 75, 100, 150, 200 ms. All MRS data were processed with JMRUI (8) using HLSVD filtering for removal of the residual water signal.

Results and Discussion: Representative stacked T_1 (variable TR), T_2 (variable TE) spectra recorded from lipid phantom and TA of a male volunteer at 7T are depicted in Fig.1 and Fig.2. In lipid phantom, the T_1 shows a steady increase while T_2 shows a slight decrease with B_0 (Table.1). The spectra from lipid phantom at 7T show larger spectral resolution than at clinical fields (7) (Fig.1 (a), Fig.1 (b)). In TA, the T_1 values are in the range of 1188 ms and 3672 ms with the highest value of =CH-CH2-(CH2)n at 2.24 ppm and the lowest value of EMCL-CH3 at 1.1 ppm. The T_2 values are in the range of 20.5 ms and 62.4 ms with the highest value of TMA at 3.2 ppm and the lowest value of -CO-CH2-CH= at 2.4 ppm (Table.2). Similarly, the T_1 values are higher at 7T than at 3T, while the T_2 values are slightly lower at 7T than that of 3T when compared with reported results in Ref.(1). At 3T, the T_1 values of TMA, Cr-CH3, IMCL-CH2, and EMCL-CH2 for TA muscle are 945, 1096, 413, and 420 ms (1), respectively, while the T_1 values of the corresponding metabolites at 7T are 1310, 1516, 1605, and 1479 ms (Table.2), respectively. The maximum percentage of increase is about ~74%. At 3T, the T_2 values of TMA, Cr-CH3, IMCL-CH2, and EMCL-CH2 for TA muscle are 78.6, 132, 90.9, and 77.5 ms (1), respectively, while the T_2 values of the corresponding metabolites at 7T are 62.4, 56.81, 57.9, and 58.5 ms (Table.2), respectively. The maximum percentage of decrease is about ~57%.

Conclusion: In this study, for the first time we obtained the spin-lattice and spin-spin relaxation times of several metabolites in human skeletal muscle under in vivo condition at 7T. The preliminary results will be used for calculating the relaxation correction factors required for absolute quantitation of metabolite concentrations. The calculated relaxation times are also used for protocol and sequence optimization for follow-up investigations on human skeletal muscle.

Fig.1

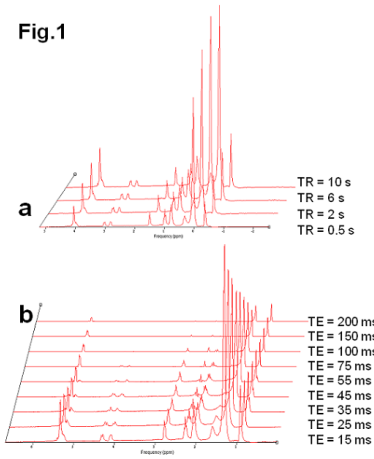

Fig.2

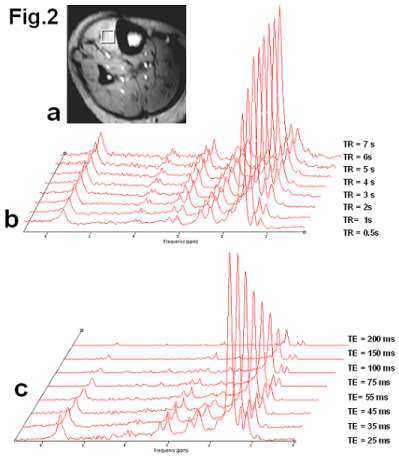

Table.1

Corn Oil	-(CH2)n- (1.3ppm) 3T	-(CH2)n- (1.3ppm) 7T
T_2 (ms)	76	51
T_1 (ms)	450	713

Table.2

T_1 and T_2 Relaxation Times in Human Tibialis Muscle (ms) at 7T									
TA	IMCL-CH3 (0.9ppm)	EMCL-CH3 (1.1ppm)	IMCL-CH2 (1.27ppm)	EMCL-CH2 (1.5ppm)	=CH-CH2-(CH2)n (2.24ppm)	-CO-CH2-CH= (2.4ppm)	Cr-CH3 (3.03ppm)	TMA (3.2ppm)	-CH=CH- (5.4ppm)
T_1	N/A	1188	1605	1479	3672	1805	1516	1310	1750
T_2	N/A	54.2	57.9	58.5	23.2	20.5	56.81	62.4	44.5

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