Dependence of Quantitative MRI Indices on Age, Gender, and BMI in Healthy Thigh Muscles

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Target Audience: Musculoskeletal radiologists, and imaging scientists interested in quantitative MRI methods for skeletal muscle.

Purpose: Muscle deterioration associated with aging has presentations of decreased muscle mass and muscle functions, including muscle strength and power. At a microscopic level, losses of muscle function may be explained by decreases in muscle fiber number, fiber atrophy, denervation, and a decrease in the production of anabolic hormones[1]. Thus aging may be a factor that introduces bias into the parameter estimates for quantitative MRI studies of muscle disease. The purpose of this work is to develop a multi-parametric MRI protocol to characterize skeletal muscle and correlate these quantitative indices to demographic factors, such as age, gender, and body-mass-index (BMI). The protocol includes Dixon fat/water imaging, quantitative T_1 and T_2, quantitative magnetization transfer (qMT) imaging, and diffusion-tensor imaging (DTI).

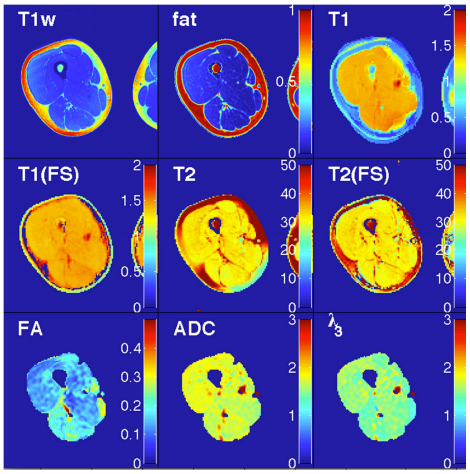

Figure 1. Example parameter maps. Units: fat, fractional units; T_1 and T_1(FS), s; T_2 and T_2(FS), ms; ADC and λ_3, $\times 10^{-3}$ mm^3/s. FA is dimensionless.

Methods: Subjects: Sixteen healthy volunteers (age=19-65 (44±15), BMI 24.8±4 kg/m^2, 7 males) participated in this study, with written informed consent. Data acquisition: Data were collected on a 3.0 T Philips Achieva MR scanner, with a two-channel body coil for excitation and a six-channel SENSE cardiac coil for signal reception. Images were acquired in the center of one thigh, with the subject lying in a supine position. Dixon fat/water imaging was performed using a six-echo gradient echo sequence[2] with $TE_1/\Delta TE$ = 1.34/1.53 ms. T_1 was measured using an inversion-recovery sequence, with a 1-ms block pulse for inversion and a single-shot 3D FLASH readout. T_2 was measured with a multi-echo sequence with composite refocusing pulses[3], ΔTE = 14 ms, TR = 4 s, and 22 echoes. The T_1 and T_2 measurements were repeated with fat-signal suppression (FS). QMT MRI used a MT-weighted spoiled gradient echo sequence[4], with frequency offsets of 1, 2, 5, 10, 20, 50, 100 kHz, nominal saturation flip angles of 360° and 820°, TR = 50 ms, and MT pulse width of 20 ms. B_1 maps were acquired using an actual flip angle method[5]. B_0 maps were acquired using a dual-echo gradient echo sequence. Water-only excitation was performed by using a 121 binomial excitation pulse for T_1(FS) and qMT sequences. DTI data were acquired with b-value = 450 s·mm^{-2} in 15 directions and one b = 0 image. All images had FOV of 256 × 256 mm^2, slice thickness = 7 mm, and matrix size = 128 × 128. High-resolution T_1-weighted (T1w) images were acquired for anatomical reference. Data analysis: All data were fitted to corresponding models on a voxel-by-voxel level. Regions of interest (ROIs) were drawn on each parameter map along the edge of muscles. Mean quantitative values within each ROI were used to represent one muscle. The quantitative indices studied in this work include muscle fat fraction (f_{Fat}), T_1, T_1(FS), T_2, T_2(FS), PSR, FA, ADC, and λ_3. Statistical analysis: All analyses were performed with Matlab 2013a. The mean values of eight muscles in the thigh were determined. To test for gender effects, an unpaired Student's t-test was used. Initially, each variable was regressed on age and separately on BMI. Where significant regression effects occurred, a multiple linear regression model by forward stepwise regression was used to investigate the dependence of these indices on age and f_{fat} and separately for BMI and f_{fat}.

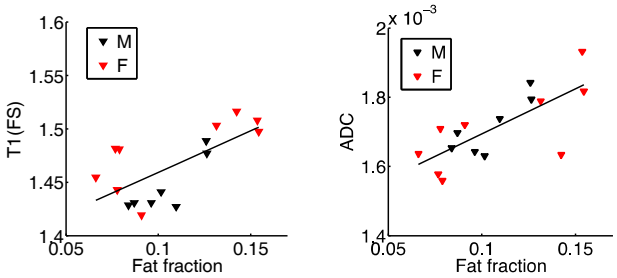

Figure 2. Univariate regression of T1(FS) and ADC vs. fat fraction.

Table 1. Multiple linear regression of quantitative muscle MRI indices on age and f_{fat} and BMI and f_{fat}. Abbreviations: β_0, intercept estimate; β_{Fat}, slope estimate. Slopes are expressed per fractional unit of fat content (u_{Fat}). Parentheses enclose the SE of the parameter estimate.

	β_0 (s or $\times 10^{-3}$ mm^3/s)	β_{Fat} (s/u_{Fat} or $\times 10^{-3}$ mm^3/s/u_{Fat})
T_1(FS)	1.381(0.025)	0.776 (0.226)
λ_1	1.78 (0.064)	2.62 (0.58)
λ_2	1.28 (0.10)	3.34 (0.90)
λ_3	1.24 (0.068)	1.83 (0.61)
ADC	1.43 (0.071)	2.60 (0.64)

Results: Figure 1 shows example parameter maps. No significant differences were observed between male and female groups for any parameter. In univariate regression analyses, T_1(FS) increased with age and λ_1, λ_2, λ_3, and ADC increased with BMI. Table 1 lists the intercepts and slope coefficients obtained in the multiple regression analysis. When T_1(FS) was regressed on both f_{Fat} and age, only f_{Fat} was a predictor of T_1(FS). Likewise, when the diffusivities were regressed on both f_{Fat} and BMI, only f_{Fat} was a predictor of T_1(FS).

Discussion: For a sample of both genders having an age range of 19-65, neither age nor BMI contributed substantially to the variations in the quantitative MRI indices that we measured in the thigh muscles. Also, no effects of gender were observed. The variations that did occur were much smaller than the potential 30-50% percent changes that may occur for some of these parameters in muscle diseases. Comparing this work to a previously reported study of age, fat fraction, and MTR[4], this work investigated more quantitative indices and provides additional insights into sources of the dependence of quantitative MRI indices at 3.0 T on subject demographic parameters. Future work includes increasing the sample size, increasing the age range, and investigating muscle-specific effects with more advanced statistical models.

References: [1] Deschenes M., et al. *Sports Med*, 34:809 (2004); [2] Berglund J et al, Magn Reson Med, 67:1684 (2012); [3] Poon CS et al, *J Magn Reson Imaging*, 2:541 (1992); [4] Ramani A et al, *Magn Reson Imaging*, 20:721 (2002); [5] Yarnykh VL, *Magn Reson Med*, 57:192 (2007); [6] Morrow J. et al, ISMRM 2013, p0314.