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 hormones1. 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 T1 and T2, quantitative magnetization transfer (qMT) imaging, and diffusion-tensor imaging (DTI).

Methods: Subjects: Sixteen healthy volunteers (age=19-65 (44±15), BMI 24.8±4 kg/m², 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 sequence2 with TE1/ΔTE = 1.34/1.53 ms. T1 was measured using an inversion-recovery sequence, with a 1-ms pulse block for inversion and a single-shot 3D FLASH readout. T2 was measured with a multi-echo sequence with composite refocusing pulses, ΔTE = 14 ms, TR = 4 s, and 22 echoes. The T1 and T2 measurements were repeated with fat-signal suppression (FS). QMT MRI used a MT-weighted spoiled gradient echo sequence3, 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. B1 maps were acquired using an actual flip angle method4. B0 maps were acquired using a dual-echo gradient echo sequence. Water-only excitation was performed by using a 121 binomial excitation pulse for T1(FS) and qMT sequences. DTI data were acquired with b-value = 450 s/mm² in 15 directions and one b = 0 image. All images had FOV of 256 × 256 mm², slice thickness = 7 mm, and matrix size = 128 × 128. High-resolution T1w-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 (fFat), T1, T1(FS), T2, T2(FS), PSR, FA, ADC, and λ. Statistical analysis: All analyses were performed with Matlab 2013a. The mean values of eight muscles in the thigh were determined. To test for gender differences on age and fFat and BMI and fFat. Abbreviations: β, intercept estimate, βF, slope estimate. Slopes are expressed per fractional unit of fat content (uFat). Parentheses enclose the SE of the parameter estimate.

Results: Figure 1 shows example parameter maps. No significant differences were observed between male and female groups for any parameter. In univariate regression analyses, T1(FS) increased with age and λ, and ADC increased with BMI. Table 1 lists the intercepts and slope coefficients obtained in the multiple regression analysis. When T1(FS) was regressed on both fFat and age, only fFat was a predictor of T1(FS). Likewise, when the diffusivities were regressed on both fFat and BMI, only fFat was a predictor of T1(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 MTR2, 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.