Comparison of multiple acquisition sequences for exercise-induced skeletal muscle MR contrast shifts at 0.7T

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Introduction

MR imaging is commonly used for anatomic visualization of soft tissue, but recent developments enable the acquisition of functional measurements. Of interest to neuromuscular physiology is the observation that exercise elicits contrast shifts in T2 relaxation times of skeletal muscle (1) that correlate with iEMG activity (2) and torque development (3). Traditionally these measurements have relied on spin-echo imaging at 1.5 T. Little work investigating exercise-induced contrast shifts using alternative sequences and at lower field strengths has been performed, which limits the utility of this technique. Therefore, the purpose of this study was to examine exercise-induced contrast shifts in skeletal muscle using various acquisition sequences at 0.7 T.

Methods

Five recreationally active medical residents (4 males, 1 female) with no history of neuromuscular disorders or orthopedic limitations served as subjects (mean age 31.7 y). After orientation, the heaviest load each subject could lift for three sets of 10 repetitions, or the 3 x 10 repetitions maximum (3 x 10 RM) was determined for the biceps dumbbell curl for the right and left arms. Images were obtained immediately after the completion of the exercise bout and did not extend beyond 5 minutes following completion of the last set. Sequences included fast-spin echo proton density (FSEPD), fast-spin echo T2 (FSET2), T2 weighted gradient recalled echo (GRE), short-tau inversion recovery (STIR), and magnetic transfer (MT). Sequences were randomized for order and arm dominance. All imaging was performed using a SignaOpenSpeed 0.7T magnet (General Electric, Milwaukee, WI). Images were analyzed for signal to noise (SNR) and contrast ratio (post exercise SNR – pre exercise SNR) over three slices of the belly of the biceps brachii. Data were analyzed with a two-way analysis of variance (sequence x time) with repeated measures over time. Tukey-Kramer analyses were performed to determine specific differences among sequences and means contrast analysis for specific differences over time (pre and post-exercise). The level of significance was set at $p<0.05$.

Results

There was a significant sequence x time interaction for SNR ($p<0.05$). All sequences demonstrate a significant increase in SNR post-exercise ($p<0.05$). The mean $\pm$ SE for percent increase in SNR post-exercise for each sequence were as follows: PD (9.3 ± 1.7), GRE (16.4 ± 1.5), STIR (49.8 ± 4.3), MT (61.7 ± 9.3), and FSET2 (86.9 ± 8.7). Specific significant differences existed for PD and GRE when compared to STIR, MT, and FSET2 ($p<0.05$). A significant difference also existed between STIR and FSET2 ($p<0.05$) and approached statistical significance between MT and FSET2 ($p=0.1$). The mean $\pm$ SE for contrast ratio were: FSEPD (4.4 ± 0.7), GRE (4.7 ± 0.5), STIR (6.7 ± 0.8), MT (1.2 ± 0.1), and FSET2 (5.3 ± 0.6). A significant difference was found between MT and all other sequences ($p<0.05$), but there were no other significant contrast ratio differences.

Discussion

The results demonstrate the feasibility of evaluating exercise-induced contrast shifts in skeletal muscle using a mid-field strength, 0.7 T magnets. This may allow for further studies investigating skeletal muscle function to utilize open MRI units which have advantages in terms of range of motion that permit imaging active muscle with improved temporal relation to the exercise bout. The results also suggest that a variety of non spin-echo sequences are capable of demonstrating exercise-induced contrast shifts, however the extent of the signal change can vary markedly, especially when analyzing percent change in SNR, which appears to be more sensitive than contrast ratio. Exercise-induced contrast shifts are of greater magnitude in sequences considered to be “fluid sensitive,” further supporting a role of water redistribution in the underlying mechanism (4).

References
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