A novel artifact reduction strategy for retaining and detecting changes in muscle activity in the MR environment

J. B. Dougherty[1], C. J. Conklin[2], K. Moxon[1], S. Faro[2], and F. Mohamed[2]
[1]Drexel Univesrity, Philadelphia, Pa, United States, [2]Temple University, Philadelphia, Pa

Background and Objectives

Detecting changes in muscle activity associated with changes in cortical activity can greatly improve our understanding of neuroplastic changes and the effects of treatments in neuromuscular conditions. Current methods for reducing artifact in electromyography (EMG) signals collected during fMRI impose some restrictions in data collection [1], and none have been validated for assessing changes in muscle activity in the MR environment. The purpose of this work is to introduce a flexible and robust wavelet-based artifact reduction strategy that allows for the distinction between two muscular conditions in an MR environment; unfatigued and fatigued.

Methods and Materials

This study included 10 right handed adult subjects (mean age; 27) with no known neuromuscular abnormalities. Subjects performed a basic motor task of ankle dorsiflexion and plantarflexion in a block design with periods of rest (6 blocks) and activity (6 blocks). A second task included a sustained contraction (6 blocks) to induce a fatigued state. Both tasks were performed with and without scanning to obtain baseline EMG measures inside the scanner. A Magnetom Verio 3T with TIM technology was used to obtain images (45mT/m, rapid switching gradients). Functional images were obtained with echo planar free induction decay (EPI-FID, T2* weighted) sequence. The functional imaging parameters were a 64*64 matrix; FOV = 210mm; slice thickness = 5mm; TR = 3 s; and TE = 21 ms. The size of the imaging voxel was 3.28 mm x 3.28 mm x 5 mm. A 12-channel brain phased array coil was used for imaging. Each block consisted of 10 measurements covering the entire brain. FMRI data was processed in SPM8. Images were aligned, normalized, smoothed, and second level analysis was performed for both fatigued and unfatigued conditions. One subject, with head movement greater than 3 mm was excluded from further analysis. To better refine our fMRI analysis one of the EMG parameters, the median frequency was used as a covariate during the second level group random effects (RFx) analysis. For EMG measurements, MR-compatible Ag/AgCl EMG electrodes (Biopac) were placed on the right anterior tibialis and extended out of the MR environment using MR-compatible cables (Biopac). All EMG data was processed in Matlab. A bandpass filter was applied excluding frequencies below 15 Hz to eliminate movement artifact and frequencies above 350Hz as the primary power of EMG is well below 350 Hz. All EMG collected during scanning was deconstructed to 8 levels with the stationary wavelet transform and custom thresholds optimized to EMG activity were applied. The signal was then reconstructed and analyzed traditionally for amplitude by root mean square, median frequency, and power. Corrected EMG was evaluated in comparison with EMG collected with no scanning and the effects of fatigue were assessed with the use of median frequency as a fatigue index [2].

Results & Conclusion

Wavelet-based artifact reduction was found to remove nearly all visible artifact from EMG signals (Figure 1). A dampening effect was present in the amplitude, but dampening was consistent within the subject. Seven of the nine subjects showed no significant change in median frequency from no scanning EMG to corrected EMG. In the evaluation of two muscular conditions, fatigue was correctly identified in all subjects. Significant changes in median frequency and power were identified correctly for all subjects. Analysis of functional images showed consistent cortical activations in the left motor cortex and a decrease in volume active with fatigue. When the fatigue condition was analyzed with the inclusion of median frequency as a covariate, the analysis was refined, showing a slight decrease in the volume active during the fatigue condition (Table 1). The work demonstrates a flexible and robust method for reducing artifact in EMG collected during fMRI. Additionally, this work validates this methodology for use in reliably identifying changes in muscle activity.

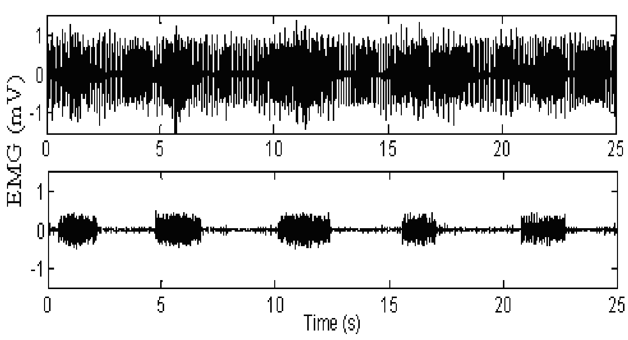

Figure 1:EMG pre (top) and post (bottom) artifact correction

	Location (MNI)			Z score	Volume (mm^3)
	x	y	z		
Typical	-8.71	-29.60	73.40	4.09	408
Fatigue	-11.20	-23.20	69.40	3.53	144
Fatigue with Δ Median Frequency	-11.40	-22.90	70.10	3.44	122

Table 1: Cortical activation results for the typical condition, fatigue condition, and the fatigue condition when the fatigue index was included as a covariate

References: [1] Laufs et al. "Recent advances in recording electrophysiological data simultaneously with magnetic resonance imaging," *NeuroImage,* vol. 40, pp. 515-528, 4/1. 2008. [2] De Luca, C.J. "The use of surface electromyography in biomechanics," *Journal of Applied Biomechanics,* vol. 13, pp. 135-163, 1997.