EMG Methods and Results

Methods

The problem with acquiring EMG signals in the MR environment is that although the EMG system introduces no artifacts in the fMRI or image data, the switching gradients of the MR system introduce significant artifact in the EMG signal. Figures 1A and B shows raw EMG recordings obtained outside of the MRI scanner and EMG signals obtained in the MRI scanner, respectively.

Insert Figure 1 about here

The large magnitude peaks in voltage are due to the slice selection z-gradient, and the low magnitude noise is generated by the x readout and the 'blipped' y-gradient k-space sampling. Moreover, the PACE navigator and the trigger pulse contribute additional noise. Gradient-related noise was digitally removed through a process of windowing and filtering. Hanning windows were used to pass the EMG signal embedded in low-magnitude, high frequency noise. The signals were then bandpass filtered with a 2^{nd} order, digital elliptic filter with physiological cutoff frequencies of 20 Hz and 500 Hz. Figure 1C shows the recovered EMG signal from a single subject for all four springs. The processed signals were then rectified and normalized. In order to correlate the EMG signals with the fMRI time-series, the EMG signal was down-sampled to the fMRI time-series, the sliding window mean of the EMG signal at each TR obtained, and correlation analysis performed using Pearson' correlation coefficient.

Results

Although statistically significant correlation was observed between the EMG and fMRI clusters identified for each of the four springs (data not shown), there was no statistically significant correlation between the EMG and the fMRI clusters identified for the mean effect of the springs. These data suggest that there is no significant association between neural activity related to differences in dexterity requirements and EMG activity, and importantly, that muscle co-contraction does not account for the neural correlates of dexterity index. Thus these results are in agreement with other evidence that the task of compressing springs is likely a sensorimotor integration task that does not rely on stiffening the fingers (Venkadesan et al. 2007).

Overall, for the effect of task, there was statistically significant correlation between the EMG time-series and activity in the contralateral dorsal premotor and prefrontal areas (superior and middle frontal gyrus), left caudate and right thalamus. Specifically, correlation of EMG time-series with fMRI series was observed in the contralateral precentral gyrus, middle frontal gyrus and right inferior frontal gyrus for both sustained and cyclic compression tasks. However, the EMG was also correlated with the right postcentral gyrus (SI) and right culmen of the cerebellum in sustained compression tasks. In contrast, for the cyclic compression task, correlation was identified with activity in the right inferior parietal lobule. Due to the slow time course of the fMRI signal, the correlation between the EMG time-series and the fMRI time-series reflects temporal covariation in activity and not a stimulus response or stimulus coupling effect. Thus, the correlation between the EMG signal and activity in premotor, sensory and parietal cortex or other subcortical or cerebellar sites likely reflects motor output modulation of the dynamical regulation of fingertip forces and on-line error correction. Notably, other studies have suggested that EMG activity in the hand or arm is associated with premotor activity due to facilitatory input to M1 from ventral premotor cortex and SMA (Cerri et al. 2003; Boudrias, 2006). Our findings suggest that EMG activity is associated with task stability requirements primarily in motor planning areas. However, the requirements for stability control in the single compression task result in co-variation of hand muscle activity and activity in sensory input networks, whereas the cyclic compression tasks reflect processing in parietal sensorimotor integration or planning areas. Lastly, in interaction effects, EMG activity was correlated only with activity in the insula.

Discussion

We compared the time-series of EMG activity with the fMRI time-series to determine whether EMG activity correlated with activity in specific brain regions. We found that for sustained compression tasks, EMG activity was highly correlated with activity in SI and the cerebellum lending further support to the hypothesis that control of fingertip force direction in sustained compression involves increased sensorimotor integration. Furthermore, in the cyclic compression task, EMG activity was highly correlated with activity in the inferior parietal lobule supporting the idea of coordination of fingertip force direction across multiple joints or effectors involve sensorimotor integration in the parietal cortex. Finally, in interaction effects, EMG activity was correlated with activity only in the insula, supporting the idea that the insula may act to select the appropriate sensory model in sensorimotor integration.

References

1. Venkadesan, M., Guckenheimer, J., Valero-Cuevas F.J. (2007). Manipulating the edge of instability. J. Biomech. 40(8): 1653-1661.

2. Boudrias, M-H, Belhaj-Saif, A., Park, M.C. et al. (2006) .Contrasting Properties of Motor Outputfrom the Supplementary Motor Area and Primary Motor Cortex in Rhesus Macaques. Cerebral Cortex 16: 632-638.

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Figures

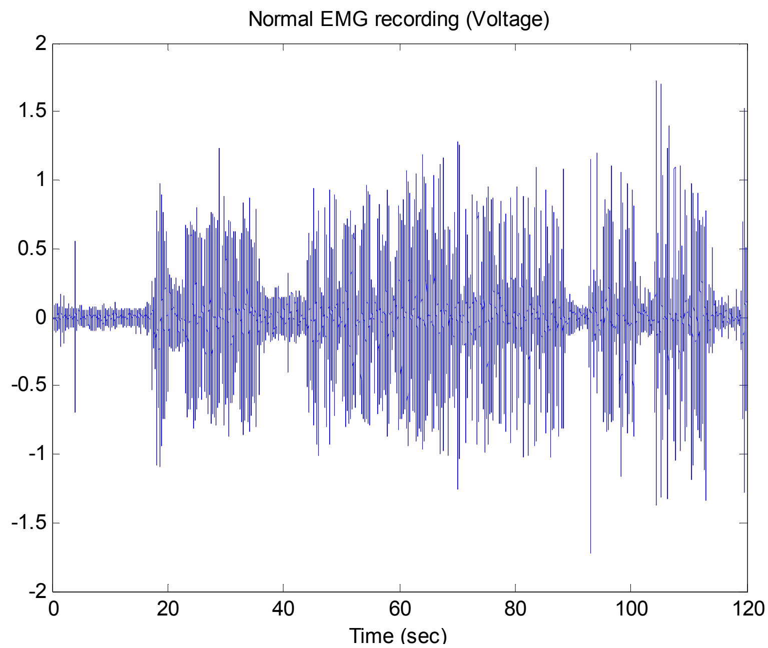

Figure 1A: Raw EMG signals recorded during sustained and cyclic precision grip outside of the MRI scanner.

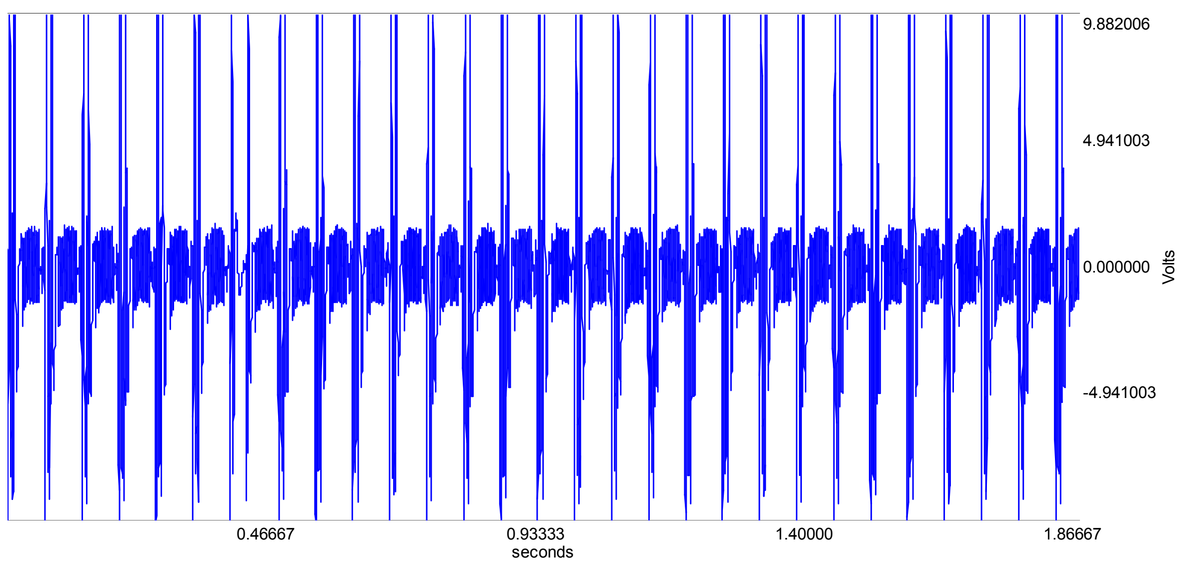

Figure 1B: Raw EMG signals from a single subject recorded during sustained and cyclic precision grip of spring #4 in the MRI scanner while acquiring images with the EPI pulse sequence used for the fMRI data acquisition.

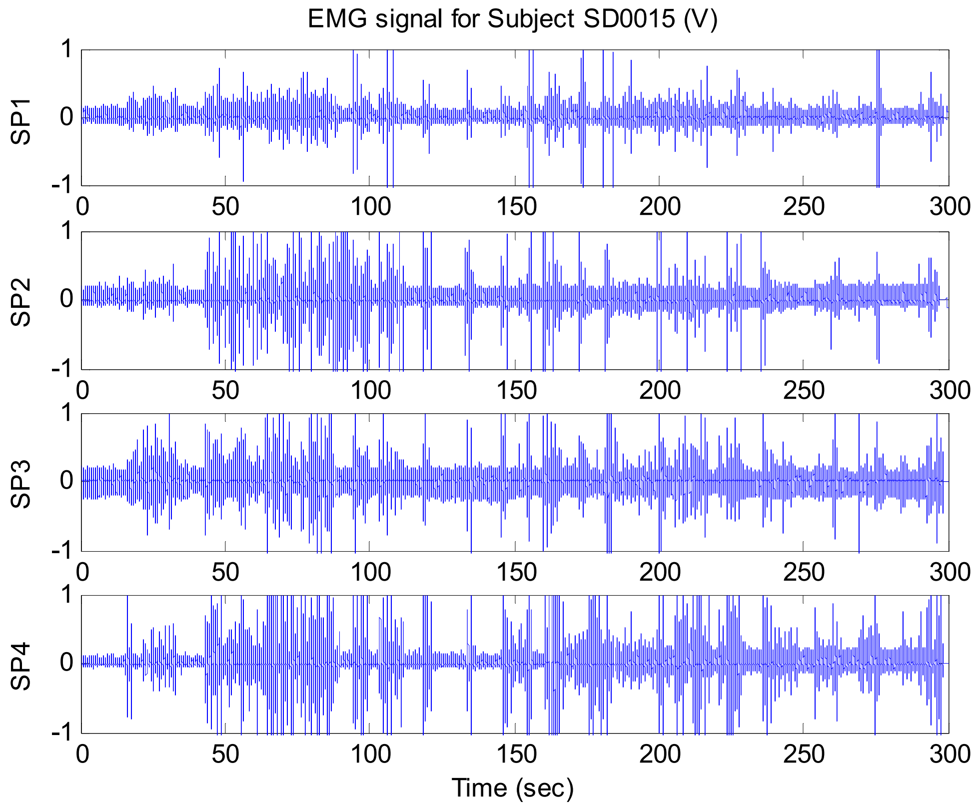

Figure 1C: Raw EMG signals for a single subject recorded during sustained and cyclic precision grip of the four springs in the MRI scanner after post-processing and filtering.