Long-term Motor Training Induced Changes in Resting State Brain

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INTRODUCTION

Functional activation often only reflects differentiated involvement and temporal relationship of brain regions compared between the task performance and the control states on a transient level. However, lasting changes in metabolic and hemodynamic physiology and synaptic plasticity induced by motor skill learning common to both states have not been elucidated. Animal studies have shown that extensive motor skill training can induce angiogenesis, synaptogenesis, and chronic changes in metabolic rate. Brain anatomical studies of musician's reveal an enlarged primary motor cortex (M1) and associative areas. We believe that long-term neuronal and physiological changes are critical for our understanding of the mechanism of motor skill training and should not be omitted. To address this issue, we explored long-term motor training induced neuronal and physiological changes in normal human subjects during task performance and resting state (a commonly used control states) using functional magnetic resonance imaging (fMRI) and positron emission tomography (PET).

METHODS

Ten normal right handed subjects were trained to perform the Karni finger movement task using their left hands [2] for 4 weeks. Three sets of task performance fMRI images (240 volumes, 16-slice with 72 × 72 voxels, TR = 33 ms, TE = 12 ms, flip angle (α) = 60°, slice thickness = 5 mm, interslice gap = 0 mm) were acquired at pre-training, Week 2, and Week 4. Two sets of resting state PET images were acquired at pre-training and Week 4. Two sets of PET images were also acquired at the same test times when the subjects performed the task. Twelve $[^{15}O]H_2O$ PET images were acquired for each PET session. Sixty-three contiguous slices in a transaxial field of view of 30 cm were acquired. Water labeled with oxygen -15 ($[^{15}O]H_2O$, half-life 122 second) were used as a blood-flow tracer. Data acquisition began at the time of arrival of the tracer bolus in the brain (15-20 second after tracer injection) and continued for 40 seconds. For both types of images, a cluster analysis method was used to create the SPI image. A threshold of t = 2.5 was used to isolate significant areas.

RESULTS

Statistical analysis revealed that the subjects' skill improved much more significantly in the first half of training than in the second half. The rate improvement reached a plateau at about Day 20. The fMRI activation volumes in the right M1/S1 and SMA appear to increase on Week 2 and return to the pre-training level on Week 4 (Figure 1A). The PET activated volumes for these two regions are essentially the same for pre-practice and Week 4 (Figure 1B). This agrees well with the fMRI activation maps. The regional cerebral blood flow (rCBF) in the right M1 area significantly increased in both task performance and resting state (Figure 2). By contrast, the changes in the rCBF in the left M1 area did not reach statistical threshold in both task and resting state.

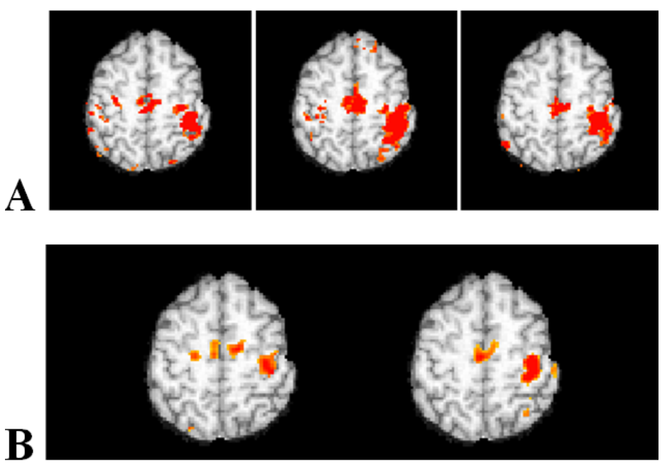

Figure 1: A: The fMRI activation maps at pre-training, Week 2, and Week 4. B: The PET activation maps at pre-training, Week 2, and Week 4.

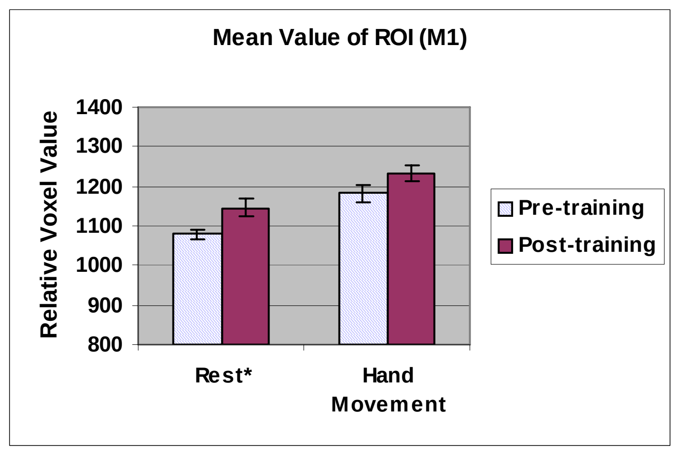

Figure 2: Mean value of an ROI in the right M1 region detected by PET. Motor skill training induced significantly greater increases in regional blood flow in both task and resting state.

CONCLUSION

We have observed long-term motor training induced changes in rCBF. The changes in rCBF may reflect changes in metabolic rate, enzymatic capacity, angiogenesis, or synaptogenesis. Current neuroimaging data analyses focus on the differentiated involvement of brain in the task and control state and are insensitive to control changes. Current activation data are sufficient for explaining mechanisms of adaptive changes in motor skill learning only if the control state does not change (often assumed) or the control state changes are deemed unimportant. In this study, we have observed long-term learning induced hemodynamic changes in the resting human brain (control state changes). The finding may have profound effects on interpretation of functional activation obtained using fMRI and PET. The control state changes, we believe, may reflect more fundamental changes in the brain. Combining control state changes with activation data should greatly enhance our understanding of the mechanisms of motor-skill learning.

REFERENCE

1. Karni, A, Meyer G, Jezzard, P, Adams, MM, Turner, R and Ungerleider, LG, 1995. Nature 377, 155−158.