Effects of physical exercise on working memory and prefrontal cortex function in post-stroke patients

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Abstract: Recent studies found that moderate exercise enhanced prefrontal cortex activity associated with improved performance of working memory in older adults. However, it is unknown about the exercise effect on the prefrontal cortex activity in post-stroke patients. The aim of this study was to examine the acute effect of physical exercise on prefrontal cortex activity in post-stroke patients using near-infrared spectroscopy (NIRS). We studied 11 post-stroke patients. The patients performed Sternberg-type working memory tasks before and after moderate intensity aerobic exercise (40 % of maximal oxygen uptake) with a cycling ergometer for 15 min. We measured the NIRS response at the prefrontal cortex during the working memory task. We evaluated behavioral performance (response time and accuracy) of the working memory task. We found that physical exercise improved behavioral performance of the working memory task compared with control condition（$p<0.01$）. In addition, NIRS analysis found that physical exercise enhanced the prefrontal cortex activation, particularly right prefrontal cortex（$p<0.05$）, during the working memory task compared with control condition. These findings suggest that the moderate intensity aerobic exercise enhanced the prefrontal cortex activity associated with working memory performance in post-stroke patients.

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Relation between prefrontal cortex activity and respiratory rate during mental stress tasks: near infrared spectroscopy study

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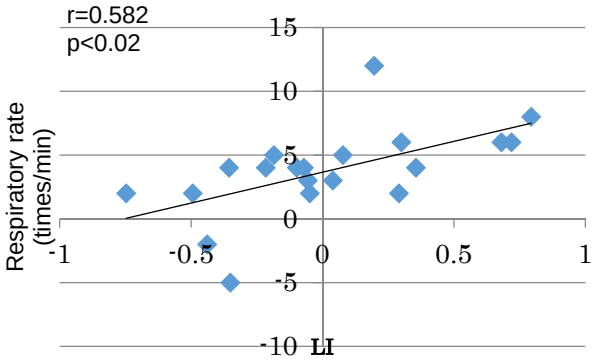
Abstract: Near infrared spectroscopy (NIRS) studies have demonstrated that mental stress tasks causes activation of the prefrontal cortex (PFC) associated with increases of heart rate (HR) [1-3]. Interestingly, the subject with right dominant activity of the PFC exhibited larger increases of HR compared with that with left dominant activity. The autonomic nervous system regulated HR and respiratory rate (RR), however, the relation between the PFC activity and RR during mental stress tasks is not yet known. In the present study, we evaluated the relation between the PFC activity and RR during mental arithmetic (MA) tasks employing NIRS.

We studied 20 normal male adults (20~22 years old). Employing 2 channel NIRS, we measured hemoglobin (Hb) concentration changes in the bilateral PFC during MA tasks. In order to evaluate asymmetry of the PFC activity, we calculated the laterality index (LI); that is, (R-L)/(R+L) of oxyhemoglobin concentration changes. Positive scores of LI indicate right dominant activity while negative scores indicate left dominant activity. For measurements of RR, we employed Kinect, which is a motion sensor made by Microsoft.

The MA tasks increased oxy-Hb in the bilateral PFC and RR ($p<0.001$). In addition, there was a significant correlation between LI and RR ($r=0.582$, $p<0.02$) (Figure).



These results indicate that the MA-induced activity in the right PFC was larger than that in the left PFC activity in the subject with high RR increases, suggesting that the right PFC has a greater role in cerebral regulation of RR during mental stress.

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Effects of antioxidant supplements (BioPQQ™) on cerebral blood flow and oxygen metabolism in the prefrontal cortex

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Abstract: Pyrroloquinoline quinone (PQQ) is a quinone compound identified from methanol-utilizing bacteria as a cofactor for redox enzymes [1]. In ISOTT2014, we reported that PQQ disodium salt (BioPQQ™) improved cognitive functions in human evaluated by Stroop test [2]. However, the physiological mechanism of PQQ on cognitive functions is not yet clear. In the present study, we measured changes of the regional cerebral blood flow (rCBF) and oxygen metabolism in the prefrontal cortex (PFC) before and after administration of PQQ using a time-resolved near infrared spectroscopy (tNIRS). We studied 20 healthy subjects between 50 and 70 years old. Subjects were orally given 20mg of BioPQQ™ per day or placebo for 12-weeks. We measured hemoglobin (Hb) concentrations and oxygen saturation (SO_2) in the bilateral PFC at resting condition using tNIRS. We found that baseline concentrations of oxyhemoglobin and total hemoglobin in the right PFC increased significantly after administration of PQQ ($p<0.05$). In contrast, SO_2 decreased in the bilateral PFC ($p<0.05$). The results suggest that PQQ increased right PFC activity associated with increases of rCBF and oxygen metabolism, resulted in the enhancement of cognitive functions.

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Effects of positive and negative mood induction on the prefrontal cortex activity measured by near infrared spectroscopy

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Abstract The neurophysiological mechanism of positive versus negative emotions is insufficiently understood. In the present study, we examined the effect of event recall tasks on the prefrontal cortex (PFC) using near infrared spectroscopy (NIRS). 9 healthy adults were instructed to recall episodes of their life associated with positive (happiness) and negative (anger) emotion, both silently and verbally. PFC activity was measured during the experiments using 2 channel NIRS. Concentration changes of oxyhemoglobin (oxy-Hb) were analyzed using ANOVA. Heart rate (HR) changes were also measured using an ECG monitoring system. NIRS showed an increased oxy-Hb in the bilateral PFC during silent and verbal recall tasks of both positive and negative episodes. The average changes of oxy-Hb in the right and left PFC during silent recall tasks of negative episodes were larger than those during silent recall tasks of positive episodes ($p=0.01$). There was no difference in average changes of oxy-Hb between silent and verbal recall tasks of negative episodes ($p=0.95$), while average changes of oxy-Hb during verbal recall tasks of positive episodes were larger than those during silent recall task of positive episodes ($p=0.02$). Interestingly, silent recall tasks of negative episodes tended to cause larger changes of oxy-Hb in the right PFC than those of positive events ($p=0.07$). Finally, both verbal and silent recall tasks of positive and negative episodes increased HR; however, verbal recall tasks caused larger increases of HR than silent recall tasks ($p=0.01$). HR changes in negative episodes were slightly larger than those in positive episodes; although there was no statistical significance. The present results suggest that recall of negative episodes affect neuronal activity of the PFC, which plays a key role in cognitive control of emotions, more than positive episodes. Autonomic results goes in the same direction, suggesting a trend of major activation during negative episode recall.

Correlation between NIRS and EEG Signals during Mental Arithmetic Task Evaluated by Self-Organizing Map

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Abstract: Simultaneous monitoring of brain activity by near-infrared spectroscopy (NIRS) and electroencephalography (EEG) allows the spatio-temporal reconstruction of the hemodynamic response in terms of the concentration changes in oxy-hemoglobin (HbO) and deoxy-hemoglobin (HbR) associated with recorded brain activity such as cognitive functions. However, the results obtained by EEG-NIRS measurements are often different depending on granularity of time frame to capture snapshot of NIRS and EEG signals such as mental arithmetic task in a minute and a deep breath for a few seconds. This study approach compares indices of mental workload in between NIRS and EEG by analysis of self-organizing map (SOM) and correlation between changes in oxy-Hb of NIRS and event-related de-synchronization and synchronization (ERD/ERS) of EEG. SOM is used for selection of indices in NIRS and EEG signals by visualization of high-dimensional data and classification of states during mental arithmetic task. We conducted an experiment for identification of transition between mental arithmetic task and being at rest with 10 participants. We found the highest correlation ($p < 0.01$) at transition of tasks between temporal changes of EEG power spectra in the range of 8Hz-9Hz and difference between oxy-Hb on the left prefrontal area and right prefrontal area in 2 minutes of time frame. Each state of mental arithmetic task can be found using NIRS and EEG.

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