Effect of a moderate-intensity one-leg pedaling exercise on prefrontal cortex oxygenation and executive function

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[Introduction]

Moderate-intensity two-leg pedaling exercises improve the color-word Stroop task (CWST) performance and executive function. Additionally, the activity of the left prefrontal cortex (PFC) during these exercises is related to this improvement. The American Heart Association and American Stroke Association guidelines have recommended aerobic exercises for relapse prevention in patients with stroke, and one-leg pedaling exercises may be used for patients with hemiplegia in clinical situations. However, whether or not the use of the left or right leg affects the PFC executive function and oxygenation changes has not been clarified. Near-infrared spectroscopy can measure changes in oxygenation in the cerebral cortex, thereby making it possible to measure the oxygen supply in response to the cortical activity. Therefore, the purpose of this study was to evaluate the executive function before and after a one-leg exercise and measure changes in oxygenation in the left (L-) and right (R-) PFC during the exercise.

[Method]

A total of 13 right-handed, healthy young men, fully informed of the contents of this study and consenting, participated in this study. Research Ethics Committee of Niigata University of Health and Welfare (Approval number 18126-190123) approved the study. Following recruitment, participants performed a one-leg pedaling exercise with a constant load. The exercise intensity was set at 50% of the maximum oxygen uptake obtained in the cardiopulmonary exercise test performed during the right-leg pedaling exercise, with a pedal rotation speed set at 50–55 rpm. The continuous load exercise was performed for 10 min following a 5-min rest, and CWST was performed before and immediately after the exercise. Subjects randomly performed this task under three conditions: right one-leg pedaling, left one-leg pedaling, and rest on different days (control). To evaluate changes in the executive function resulting from the exercise, the change amount in the Stroop interference time, which indicates the cognitive task processing speed, was calculated and compared under each condition. Moreover, oxygenated hemoglobin (O_2Hb) and deoxygenated hemoglobin levels were measured to observe changes in oxygenation in the L-PFC and R-PFC during the exercise using a multi-channel near-infrared spectroscopy system. The O_2Hb level during the exercise was calculated as the change amount from the average value of a 5-min rest before exercise, wherein the average value for each minute was calculated. The highest value (peak) during the exercise and area under the curve (AUC) of O_2Hb changes were then obtained and compared among conditions. We also analyzed the correlation between the change amount in the Stroop interference time under each condition and O_2Hb values in the L-PFC and R-PFC.

[Results]

The Stroop interference time had significantly decreased after right and left one-leg exercises (right leg before vs. after exercise: 85.3 [34.5–226.6] vs. 35.4 [16.2–111.6] ms, $p < 0.01$; left leg before vs. after exercise: 71.8 [37.5–212.3] vs. 39.4 [19.1–116.4] ms, $p < 0.01$; Figure a). During the exercise, the L-PFC and R-PFC O_2Hb values were significantly higher in both peak and AUC following right and left one-leg exercises than in control conditions (L-PFC peak, right leg vs. control: 0.11 [0.07–0.15] vs. 0.008 [-0.0006–0.01] mM · cm, $p < 0.01$; left leg vs. control: 0.12 [0.06–0.23] vs. 0.008 [-0.0006–0.01] mM · cm, $p < 0.01$; AUC, right leg vs. control: 0.55 [0.13–0.94] vs. 0.01 [-0.07–0.04] a.u., $p < 0.01$; left leg vs. control: 0.71 [0.22–1.03] vs. 0.014 [-0.07–0.04] a.u., $p < 0.01$; R-PFC peak, right leg vs. control: 0.102 [0.05–0.19] vs. 0.01 [0.003–0.01] mM · cm, $p < 0.01$; left leg vs. control: 0.12 [0.07–0.14] vs. 0.01 [0.003–0.01] mM · cm, $p < 0.01$; AUC, right leg vs. control: 0.59 [0.33–1.27] vs. 0.02 [-0.05–0.11] a.u., $p < 0.01$; left leg vs. control: 0.67 [0.34–0.81] vs. 0.02 [-0.05–0.11] a.u., $p < 0.01$). Moreover, the change amount in the Stroop interference time under each condition and L-PFC and R-PFC O_2Hb values correlated significantly (peak, R-PFC: $r = -0.39$, $p < 0.05$; L-PFC: $r = -0.46$, $p < 0.01$; AUC, R-PFC: $r = -0.38$, $p < 0.05$; L-PFC: $r = -0.42$, $p < 0.01$; Figure b).

[Discussion]

This study indicated that single-leg moderate-intensity exercises may shorten the Stroop interference time related to O_2Hb elevation during the exercise. This is the first study to provide the evidence that increasing PFC oxygenation improves the executive function with two- and one-leg exercises. The Stroop interference time decreased in the one-leg pedaling exercise using both the left and right legs. Previous studies showed that moderate-intensity double-leg pedaling exercises improve the executive function and O_2Hb elevation in the L-PFC. The decrease in the Stroop interference time after the exercise was related to the O_2Hb change in the L-PFC rather than in the R-PFC. Similarly, previous studies reported an increase in the left dorsolateral PFC (DLPFC) local cerebral blood flow during CWST following moderate-intensity exercise. Otherwise, the R-PFC might be activated to restrain the other leg during the exercise, playing a role in inhibition of the movement. Therefore, it was considered that the O_2Hb change in the L-PFC during the exercise affected the increase in left DLPFC local cerebral blood flow after the exercise.

[Conclusion]

Executive function improved after one-leg pedaling exercises in relation to oxygenation changes in the L-PFC and R-PFC during the exercise. Moreover, the difference between the left and right leg exercises did not affect oxygenation changes in L-PFC or R-PFC during the one-leg pedaling exercise.

[Figure]