Effects of Acute Moderate Intensity Exercise on the EEG Frontal Alpha Asymmetry

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Abstract. Exercise can improve physical and psychological states efficiently. Previous studies have shown that the frontal alpha asymmetry can be used to express emotional states, while relative activity in the larger left frontal can predict positive effects. In this study, our purpose is to observe the effects of pedalling exercise (PE) on the frontal alpha asymmetry during negative stimulation. The electroencephalograph (EEG) signals obtained are processed by matlab to obtain the frontal asymmetry value. By observing and comparing the frontal alpha asymmetry between two groups, we can find that the frontal alpha asymmetry of the sports group increased significantly, while the control group have no significantly change. The study shows that the acute moderate intensity PE can improve the resistance to negative stimuli and increase positive emotions.

1. Introduction

Questionnaires and EEG have been widely used for assessing emotional state. Through the questionnaire, we can understand the subjective feelings of the subjects, and EEG’s high intensity temporal resolution can help us better capture the emotions of the subjects. Acute aerobic exercise is an effective means to resist and regulate negative emotions [1-3]. According to previous research, alpha (8-13Hz) power is negatively correlated with cortical activation [4-6]. The higher left frontal cortex activation (e.g., lower alpha power) is associated with positive emotion, whereas higher right frontal cortex activation is associated with negative emotion [7-8]. Frontal alpha asymmetry is considered to be an effective indicator of emotional state, with positive values (i.e., relatively greater left activation) indicating positive affect and negative values (i.e., relatively greater right activation) representing negative affect [9-10]. Moreover, James suggested that the larger left frontal electrical activity measured during rest is associated with a tendency to behave as well as a close-to-related expression of emotions [11]. Evidently, frontal alpha asymmetry is not only a reflection of positive/negative emotions, but also an ability to regulate emotion depending on the demands of situation.

The purpose of this study was to observe the effect of acute moderate intensity PE on emotion, and to analyse the power changes in left and right brain regions to find out the mechanism of exercise affecting emotion. We predict that compared with before exercise, moderate intensity PE will have a
positive impact on the picture stimulation after exercise, the negative emotion under negative stimulation will decrease, and the positive emotion under neutral stimulation will increase.

2. Materials and Methods

2.1 Participants and Stimulus pictures

66 healthy, right-handed, normal eyesight, normal Body Mass Index (BMI) undergraduate students are recruited. They are divided into two groups according to the experimental contents: Sports group (30 people) and Control group (36 people). Furthermore, all of the study participants reported that they have no exercise habits for at least 1 year before participating in the experiment. We use International Physical Activity Questionnaire-short (IPAQ-S) [12] to determine whether the subjects meet the experimental requirements of no exercise habit: At least three times a week for moderate intensity (HR > 110 bpm) exercise, each time for more than 30 minutes.

Pictures are selected from the International Association for the Philosophy of Sport (IAPS). According to the difference in valence (1 = very unpleasant, 5 = neutral, 9 = very pleasant) and arousal (1 = clam, 9 = excited), we have selected a total of 32 pictures [13]. The mean and standard deviation of the three type valence pictures are shown in Table 1.

| Table 1. Means and standard deviation of picture valence and arousal |
|---------------------|--------|--------|--------|--------|
|                     | Valence |        | Arousal |        |
|                     | Mean   | SD     | Mean   | SD     |
| Pre-test            |        |        |        |        |
| Negative            | 2.88   | 0.97   | 5.80   | 1.51   |
| Neutral             | 4.99   | 0.04   | 3.68   | 1.11   |
| Post-test           |        |        |        |        |
| Negative            | 2.87   | 0.96   | 5.76   | 0.91   |
| Neutral             | 4.99   | 0.04   | 3.26   | 1.17   |

2.2 Measurements

2.2.1 Experiment flow. First, all participants fill out the basic information and IPAQ-S questionnaire after they arriving laboratory, then the EEG Cap and sports bracelets is attached to collect EEG and HR signals. As we can see in Figure 1, the whole experiment can be divided into three part. 1. The pre-test as Stage 1. In the course of the experiment, the stimulus picture will be presented for 6s, and then 24s will be used to fill in the PAD-P scale to reach valence score of stimulus picture, as can be seen in figure 2. 2. The action part. The control group is asked to sit for a rest 20minutes, while the sports group need to take 20 minutes of PE use the Snode spinning. 3. The post-test as Stage 2. The content of the experiment is consistent with that of the pre-test, except for the stimulation pictures.

2.2.2 EEG pre-processing. Brain activities were continuously recorded at a sampling rate of 250 Hz using 32-channel EEG recorder system (Neuracle, China) referenced to the right and left ear mastoids based on a modified international 10–20 system. EEG preprocessing involved bad channel removal and interpolation, bandpass filtered between 8 and 13 Hz to obtain the alpha band signal, remove electrical noise. Preprocessing was followed by average Power spectral density (PSD) value (Hanning window, 50%) computation for each EEG electrode data epoch.

2.2.3 Calculation of asymmetry. After average PSD value computation, EEG signal is calculated according to the valence. The signal before the mark 1s is called the baseline, and the signal after 1s of the mark is our calculation data. EEG asymmetry score is calculated by subtracting left channel power (F7) from right channel power (F8) [1]. We calculate the asymmetry values of the baseline and the data separately called \( \text{Asym}_{\text{base}} \) and \( \text{Asym}_{\text{info}} \) as equation (1) and equation (2). Finally, the difference of the asymmetry between the baseline and data is calculated as the experimental result called Asym, that is equation (3). We calculated three kinds of Asym, namely, the Asym under negative stimulation, the
Asym under neutral stimulation and the total Asym, in which the total Asym is the negative Asym plus the neutral Asym.

\[
\text{Asym}_{\text{base}} = F8 \text{ power} - F7 \text{ power} (\text{baseline}) \\
\text{Asym}_{\text{info}} = F8 \text{ power} - F7 \text{ power} (\text{data}) \\
\text{Asym} = \text{Asym}_{\text{info}} - \text{Asym}_{\text{base}}
\]

3. Results

3.1 Mood assessment

According to the Chinese reference standard of BMI, the BMI values of the two groups are more than 18.5 and less than 24, which belong to the normal range. There is no significant difference in Age between the two groups, the RPE score of the Sports group is less than 6, which indicates that subjective score is moderate intensity exercise [12]. There is no significant difference in PAD-P scores between the two tests, the PAD-P score in the sports group is slightly larger than the post-test, while the control group is the opposite. Other relevant information is described in Table2.

|                | Sports group (30) | Control group (36) |
|----------------|-------------------|--------------------|
|                | Mean   | SD    | Mean   | SD    |
| Age            | 20.22  | 1.19  | 19.56  | 1.32  |
| Height(cm)     | 167.38 | 8.37  | 169.33 | 8.28  |
| Weight(kg)     | 56.78  | 8.09  | 60.47  | 9.92  |
| BMI            | 20.08  | 1.71  | 21.02  | 2.56  |
| RPE            | 5.57   | 0.77  | None   | None  |
| PAD- Neg1      | 2.55   | 0.93  | 2.66   | 1.10  |
| PAD- Neu1      | 2.63   | 1.00  | 2.63   | 1.04  |
| PAD- Neg2      | 5.64   | 0.64  | 5.85   | 0.66  |
| PAD- Neu2      | 5.66   | 0.62  | 5.83   | 0.73  |

3.2 Mood assessment

We can see the calculation results of Asym in Figure 1 (a)For the sports group, the Asym of negative and neutral stimuli in the Post-test increased significantly compared with that in the Pre-test. (b) For the control group, the Asym is decreased. (c) For the total Asym, the Asym of the sports group increased significantly after exercise, while that of the control group decreased slightly.
3.3 Left and right brain hemispheres analysis
As shown in Figure 2, when the sports group received negative stimulation, the average power values of F8 and F7 in Post-test were higher than those in pre-test, and the average power values of F8 increased more. When the exercise group was stimulated by neutral stimulation, the average power values of F8 and F7 decreased, and the average power values of F7 decreased more.

Figure 1. The Asym of Sports group and Control group.

Figure 2. Average power values of F7 and F8 under negative and neutral stimuli in sports group.
4. Discussion
For the total Asym in Figure 3, the Asym of the subjects in the sports group increased significantly and the positive emotion increased, while the Asym in the control group decreased slightly and the emotion remained basically unchanged. For negative stimulation, the Asym of the subjects in the sports group increased significantly in the post-test experiment, while that in the control group decreased slightly. In the face of negative stimulation with the same valence, the subjects who underwent moderate intensity PE exercise for 20 minutes had higher resistance to negative stimulation and less negative emotion. For neutral stimulation, the Asym of the subjects in the sports group increased, while that in the control group still decreased slightly. In the face of neutral stimulation with the same valence, exercise can increase positive emotion. Therefore, we found that 20 minutes of moderate intensity PE exercise can increase positive emotions and resist negative emotions. For the subjective consciousness of the subjects, we can draw a similar conclusion by observing the PAD-P score in Table 1.

The Asym of the prefrontal lobe is calculated from the average power difference between the prefrontal brain area. The average power values of F7 and F8 channels of sports group increased relatively in the face of negative stimulation with the same valence, and the increased value of F8 is larger, which led to the increase of the Asym. For the negative stimulation with the same valence, the negative emotion produced in the right brain region of the subjects is less in the post-test, and the ability of the subjects to resist negative stimulation increased. When the sports group faced with neutral stimulation in the same valence, the average power values of F7 and F8 channels are relatively decreased, and the left and right prefrontal regions are activated at the same time, and the decrease of F7 channels is more, which led to the increase of asymmetry. Exercise activates the left brain and produces positive emotions to regulate emotions. Therefore, after exercise, the negative emotion produced by the left brain decreased relatively, while the positive emotion produced in the face of neutral stimulation relatively increased, which is the way to increase the resistance of negative emotion and regulate the emotion of the subjects.

In conclusion, the PE exercise can improve resistance to negative sexual stimulation and increase positive emotions. When encountered negative stimulation, the subjects after exercise had stronger ability to resist negative stimulation, which proved the importance of exercise in regulating emotion in daily life. The limitation of this paper is that there is no monitoring of EEG in the process of exercise and the uniformity of the type of sports. In the subsequent study, we will use these two points as a breakthrough for improvement, one is to find the sports items that can analyse the process, the other is to analyse the effects of different kinds of exercise on the emotion.

5. Conclusion
In conclusion, the PE exercise can improve resistance to negative stimulation and increase positive emotions. After being subjected to negative stimuli, the subjects after exercise have a stronger ability to resist negative stimuli, which proved the importance of exercise in regulating emotion in daily life.

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Reference
[1] SatokoOhmatsu, Hideki Nakano, TakanoriTominaga, YuzoTerakawa, Takaho Murata, Shu Morioka. Activation of the serotonergic system by pedaling exercise changes anterior cingulate cortex activity and improves negative emotion [J]. Behavioural Brain Research, 2014, 270.
[2] Yohn Christine N, Gergues Mark M, Samuels Benjamin Adam. The role of 5-HT receptors in depression.[J]. Molecular brain,2017,10(1).
[3] Smith Ezra E,Reznik Samantha J,Stewart Jennifer L,Allen John J B. Assessing and conceptualizing frontal EEG asymmetry: An updated primer on recording, processing,
analyzing, and interpreting frontal alpha asymmetry. [J]. International journal of psychophysiology: official journal of the International Organization of Psychophysicsiology, 2017, 111.

[4] Davidson Richard J. What does the prefrontal cortex "do" in affect: perspectives on frontal EEG asymmetry research. [J]. Biological Psychology, 2004, 67(1-2).

[5] Reznik Samantha J, Allen John J B. Frontal asymmetry as a mediator and moderator of emotion: An updated review. [J]. Psychophysiology, 2018, 55(1).

[6] Quaedflieg C W E M, Meyer T, Smulders F T Y, Smeets T. The functional role of individual-alpha based frontal asymmetry in stress responding. [J]. Biological psychology, 2015, 104.

[7] Klimesch Wolfgang, Sauseng Paul, Hanslmayr Simon. EEG alpha oscillations: the inhibition-timing hypothesis. [J]. Brain Research Reviews, 2006, 53(1).

[8] Ilona Papousek, Elisabeth M, Weiss, Günter Schulter, Andreas Fink, Eva M. Reiser, Helmut K. Lackner. Prefrontal EEG alpha asymmetry changes while observing disaster happening to other people: Cardiac correlates and prediction of emotional impact [J]. Biological Psychology, 2014, 103

[9] Hugdahl K, Davidson RJ. 2003. The asymmetrical brain. Cambridge: MIT Press

[10] Petruzzello S J, Hall E E, Ekkekakis P. Regional brain activation as a biological marker of affective responsivity to acute exercise: influence of fitness. [J]. Psychophysiology, 2001, 38(1).

[11] James A Coan, John J. B Allen. Frontal EEG asymmetry as a moderator and mediator of emotion [J]. Biological Psychology, 2004, 67 (1).

[12] Craig C, M. A L, et al. The International Physical Activity Questionnaire (IPAQ): A comprehensive reliability and validity study in twelve countries [J]. Medicine & Science in Sports & Exercise, 2003.

[13] Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International affective picture system (IAPS): Affective ratings of pictures and instruction manual. Technical Report A-8. University of Florida, Gainesville, FL.