RESEARCH ARTICLE

Effects of aerobic exercise on electroencephalogram in patients with mood disorders

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Emotional disorder is a common psychological disease. The global incidence rate continues to rise, which seriously affects the life quality of patients and may cause serious health problems. Aerobic exercise has been proven to have a positive effect on emotion regulation, but its specific regulatory mechanism on electroencephalogram signals is still unclear. This study explored the mechanism and impact of aerobic exercise on brain electrical signals in individuals with emotional disorders, aiming to help patients develop personalized exercise intervention plans and improve clinical treatment outcomes. The study involved a total of 300 patients with emotional disorders including 150 males and 150 females and were randomly divided into a control group and an experimental group. The control group maintained a sedentary state, while the experimental group underwent moderate intensity indoor spinning training (70% maximum heart rate) three times a week for 8 weeks. According to the international standard 10 - 20 system, the brain was divided into 10 regions including left frontal lobe (L1), right frontal lobe (R1), left central region (L2), right central region (R2), left parietal lobe (L3), right parietal lobe (R3), left occipital lobe (L4), right occipital lobe (R4), left temporal lobe (L5), and right temporal lobe (R5). The results showed that there was only a significant difference in the average power value (APV) corresponding to the alpha rhythm between the APVs of the left-brain region electrical signal data between the two groups in the R5 region ($P < 0.05$). There were significantly differences in the L1, L2, L5, R1, R2, R3, and R5 regions of the β rhythm ($P < 0.05$). In the θ rhythm, only the comparative difference between L1 and L2 regions showed significant difference ($P < 0.05$). There were also significant differences in the comparison of L1, R1, R4, and R5 regions in the δ rhythm ($P < 0.05$). The correlation results demonstrated that there was a positive connection between the APV value and negative emotion (NE) in the R5 region under the alpha rhythm ($R = 0.473$, $P < 0.05$). The L5 and R5 regions of APV values in the β rhythm showed a positive correlation with NE ($P < 0.05$). The APV value of L1 under the θ rhythm was actively related to NE changes ($R = 0.443$, $P < 0.05$). In the δ rhythm, the change in APV value of L1 had an active connection with positive emotion (PE) ($R = 0.678$, $P < 0.05$), and L5 and R5 also showed a positive relation with NE as $R = 0.706$, $P < 0.05$ and $R = 0.547$, $P < 0.05$, respectively. Aerobic exercise significantly improved the emotional state of patients with emotional disorders by regulating the brain electrical activity of alpha, beta, theta, and delta rhythms, especially the alpha rhythm in the R5 and the delta rhythm in the L1, which were closely related to emotional changes. The study clarified the mechanism of the impact of aerobic exercise on brain electrical signals in individuals with emotional disorders, providing strong support for clinical interventions and public health policies.

Keywords: sports aerobic exercise; mood disorders; brain region; electroencephalogram.

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Introduction

Emotional disorders are a common psychological disorder with a continuously increasing prevalence worldwide [1]. As the growth of social pressure and the acceleration of the life pace, the incidence of emotional disorders has gradually increased, which has attracted widespread attention from all sectors of society. It not only has a significant negative impact on an individual's life quality but may also lead to serious health problems such as an increased risk of suicide [2-4]. Sports aerobic exercise (SAE) can have a significant positive impact on emotional regulation as it can not only alleviate depression and anxiety but also improve mental health, enhance self-esteem, and improve sleep quality [5]. In addition, aerobic exercise can significantly improve emotional state and enhance emotional regulation ability by regulating the levels of neurotransmitters such as serotonin and dopamine [6]. Among them, the most important is that sports regulate the neural activity of the brain, and aerobic exercise can enhance an individual's emotional stability and reduce emotional fluctuations. It can promote neural plasticity in the brain, improve cognitive function, and better cope with emotional stress [7].

Numerous scholars have conducted in-depth analysis and exploration of this issue. Marinelli *et al*. aimed to determine the therapeutic effect of resistance training in reducing anxiety and depression symptoms in young people. The study used a random-effects meta-analysis to calculate the combined effect of resistance training before and after intervention compared to the control group. The results showed that resistance training was significantly associated with the reduction of depression and anxiety symptoms, making resistance training an effective intervention for alleviating depression and anxiety symptoms in young people [8]. Wasike *et al*. investigated the effect of aerobic exercise on depression in elderly individuals by evaluating the vital signs, depression severity, and quality of life of 38 sedentary individuals diagnosed with geriatric depression before and after the project. The research showed that, after the implementation of the aerobic exercise program, respiratory rate, clinical depression outcome scale score, blood pressure, and heart rate values all decreased significantly, while the median change in quality of life increased significantly [9]. Xing explored the impact of physical exercise on the anxiety level of college students using a questionnaire survey to collect physical exercise data and anxiety self-assessment results of college students in different grades, genders, and ages from multiple universities in Guangdong, China. The results showed that there was a significant negative correlation between physical exercise and anxiety levels among college students, that was, the more frequent and intense the physical exercise, the lower the anxiety level [10].

There is ample evidence to suggest that aerobic exercise can effectively improve emotional disorders. However, the specific regulatory mechanism of electroencephalogram signal (ES) is still unclear, and there is a lack of objective biomarkers to quantify the direct impact of exercise on brain function. This research aimed to reveal the specific regulatory rules of aerobic exercise on ES in individuals with emotional disorders and clarify the correlation between changes in electroencephalogram (EEG) activity and emotional improvement. The study included 300 patients including 150 males and 150 females with emotional disorders and compared them in both control and experimental groups according to different intervention methods with the evaluation indicators related to ES in brain regions. This study explored the impact of aerobic exercise on emotional disorders in the population, further understood the physiological basis of emotional disorders, encouraged the improvement of mental health through aerobic exercise, and reduced the risk of emotional disorders.

Materials and methods

Selection of patients

A total of 300 patients with 150 males and 150 females, aged from 20 to 65 years old, and diagnosed with emotional disorders from the Affiliated Hospital of the East China Mental Health Research Center (Shanghai, China) was recruited in this study. All participants were divided equally into control group (CG) (n = 150) and experimental group (EG) (n = 150) based on different intervention methods. The inclusion criteria included no gender limitation, aged between 20 and 65 years old, able to engage in sports activities, with a self-rating depression scale (SDS) (https://www.psychologytools.com/) score between 53 – 72 and the scores of the self-rating anxiety scale (SAS) score (https://www.psychologytools.com/) between 55 – 72, and not having the habit of regular exercise. The exclusion criteria were with diseases that were not suitable for physical exercise, having unhealthy lifestyle habits and dietary preferences, having taken psychotropic drugs, having a history of chronic family history, allergies, and other health issues, and unable to complete testing tasks alone. All procedures of this study were approved by the Ethics Committee of the School of Zhumadian Preschool Education College (Zhumadian, Henan, China).

Comparison of different exercise groups

After completing the general information collection, all participants were scored using positive and negative emotion scale (PNES) (https://www.pnes.org) and underwent resting EEG testing before being randomly divided into CG and EG for testing. Repeated PNES and resting EEG testing after intervention were then completed. During the test, the dependent variable was set as the evaluation score of the PNES and the absolute power value of the ES, while the independent variable was set as SAE. The experiment lasted for a total of eight weeks. The beginning, fourth week, and eighth week of the experiments were referred to as pre-test (PT), mid-test (MT), and post-test (ET), respectively. Three experiments were conducted each week, each lasting for 2 hours, while physical exercise was prohibited 72 hours before each experiment, vitamin supplements or alcohol should not be consumed within 12 hours, and stimulating drinks should not be consumed within 4 hours.

(1) Electroencephalogram signal collection

ES data were collected when participants were required to perform eye opening and closing operations while observing the changes in EEG and the specific EEG responses induced by scintillation stimuli during the process using Nemus2+ EEG-evoked potential meter (EB Neuro, Florence, Tuscany, Italy) [11-13]. Before the test, participants were reminded to relax as much as possible during the testing process to avoid tension or anxiety as these emotions might affect EEG results and remained still to avoid unnecessary muscle activity. The collected ES data were processed using EEGLAB (https://www.pnes.org) including checking for useless or bad conductive electrodes in the data, marking and removing these electrodes. The segments containing artifacts were also removed. The artifact components were separated through independent component analysis to obtain the required brainwave power values. Heart rate was monitored using Polar H10 heart rate band (Beijing Bohaotong Technology Development Co., Ltd., Beijing, China), which helped the experimental subjects maintaining a suitable intensity range for SAE.

(2) Different group intervention methods

For control group, the subjects did not engage in any physical activity intervention and only maintained a sedentary state but were required to remain awake throughout the entire process. For the experimental group, Lode Corival power bicycle (Lode B.V., Groningen, Netherlands) indoor spinning bikes were used for SAE testing with the workload between 7 – 1,000 W and extremely low noise, which had an eddy current electromagnetic braking mechanism to ensure the accurate and reliable test results [14]. The intensity was set to medium, corresponding to an average intensity value of 70% HRmax. During the intervention, the intensity was maintained within the range of ± 5 HRmax. The experimental subjects needed to warm up with SAE for 5 minutes. After the heart rate reached the target state, a 20-minute countdown was started immediately, and the rating of perceived exertion (RPE) (https://borgperception.se/) scale was used every 3 minutes for questioning. If the experimental subject experienced symptoms such as dizziness, nausea, difficulty breathing, chest pain, *etc*. and unable withstood the intensity of intervention while reaching the maximum estimated heart rate, the test might be stopped. When the RPE score exceeded 17, the test needed to be stopped immediately.

Indicator observation

The basic information of the subjects included height, weight, body mass index (BMI), gender, age, metabolic equivalent (ME), smoking and drinking habits, and participation in exercise. The scale used in the test included SDS that contained 20 items with each being graded into four levels (1 - 4 points) based on the frequency of symptom occurrence. Among them, 10 were reverse scoring. The scores of 20 questions were added together to obtain a rough score that was then multiplied by 1.25 and an integer was taken as the standard score. The scores of 50 - 59 was defined as mild depression, while 60-69 was moderate depression and > 70 was severe depression. SAS consisted of 20 items, each of which was graded into four levels based on the frequency of symptom occurrence. Among them, 5 items were scored in reverse, and the remaining scoring was calculated in accordance with SDS. PNES consisted of 20 items and was divided into two factors of positive emotions (PE) and negative emotions (NE). Each project was rated on a scale of 1 - 5 with the overall score being the sum of PE and NE scores. The physical activity rating scale-3 (PARS-3) (https://www.researchgate.net/) was used to assess an individual's level of physical exercise, primarily measured through 3 dimensions of intensity, time, and frequency of exercise. The calculation of exercise volume was as below.

Exercise volume = Intensity × Time × Frequency

According to the score, exercise intensity was divided into small exercise intensity, moderate exercise intensity, and large exercise intensity with scores corresponding to 0 - 19 points, 20 - 42 points, 43 points and above. RPE was used to measure exercise intensity, which helped experimental subjects and testers better monitor and adjust training intensity. This scale adopted a scoring standard of 6 - 20 points. 6 points represented "quiet and effortless feeling", corresponding to resting heart rate, while 7, 9, 15, 17, 19, 20 points represented "extremely easy", "very easy", "laborious", "very laborious", "extremely difficult", and "exhausted state", respectively. corresponding to the maximum heart rate. According to the international standard 10 - 20 system, the brain was divided into 10 regions based on 16 leads, which included the left frontal region (L1) of leads Fp1 and F3, the right frontal region (R1) of leads Fp2 and F4, the left central region (L2), right central region (R2), left parietal region (L3), right parietal region (R3), left occipital region (L4), and right occipital region (R4) of leads C3, C4, P3, P4, O1, and O2, respectively, left temporal region (L5) of leads F7, T3, and T5, right temporal region (R5) of leads F8, T4, and T6. The changes in ES data and the corresponding average power value (APV) of the region were recorded.

Data analysis

SPSS 26 (IBM, Armonk, NY, USA) was employed for statistical analysis of this research. Descriptive analysis was used for data processing. The data was expressed as mean ± standard deviation (SD). The emotional scores of each group before and after the experiment were tested using paired t-tests. Independent sample t-test was utilized for inter-group comparisons before and after the experiments. The ES data were analyzed using Shapiro-Wilk's test to determine if it followed a normal distribution. The relationship between PNES score and ES-APV was analyzed using Pearson correlation analysis, and the correlation between variables was evaluated using Pearson correlation coefficient (PCC). All statistical tests were performed utilizing a two-sided test. The *P* value less than

0.05 was defined as the statistically significant difference.

Results

Comparison of basic information

The basic information between the two groups demonstrated that there were no statistically significant differences in age, height, weight, SDS score, SAS score, PE score, NE score, and ME between the two groups. The average age of the CG was 48.71 ± 5.16 years old, while that of the EG was 48.16 ± 2.12 years old. The average height of the CG was 177.01 ± 6.26 cm, while that of the EG was 178.84 ± 6.98 cm. The average weight of the CG was 73.74 ± 11.57 kg, while that of the EG was 71.65 ± 8.29 kg. In terms of psychological assessment, the average SDS score of the CG was 59.06 ± 6.46, while that of the EG was 59.74 ± 6.34. The average SAS score of the CG was 59.87 ± 6.25, while that of the EG was 59.68 ± 6.17. The scores of the emotion scale showed that the PE score of the CG was 32.24 ± 8.31, and the NE score was 23.01 ± 10.58. The PE score of the EG was 30.52 ± 4.68, and the NE score was 26.59 ± 9.11. In addition, the ME of the two groups was also similar with a CG of 415.67 and an EG of 417.83. The balance of these baseline data provided a reliable basis for the comparison of subsequent experimental results.

Comparison of PNES scores before and after the experiment

The comparison of PNES scores between the two groups before and after the experiment showed that, before the experiment, there was no statistically significant difference between the PE and NE categories. In the ET stage, the scores of PE and NE categories were significantly reduced compared to the PE stage ($P < 0.05$). In the two categories of PE and NE, there was no significant difference in CG before and after the experiment, while, after the experiment, EG's PE score was significantly higher than that of CG, and the NE category score was significantly lower than that of CG ($P < 0.05$) (Figure 1).

Results of ES changes in two groups before and after the experiment

A comprehensive examination and comparison were conducted on the baseline EEG data of two groups, mainly recording the APV values of 10 brain regions (L1, R1, L2, R2, L3, R3, L4, R4, L5, and R5) at four rhythms (α, β, θ, and δ). In terms of left brain region (LBR), there was no statistically significant difference in APV values between the two groups for all rhythms. The APV values of alpha rhythm remained balanced in brain regions such as L1 with CG's 37.72 ± 14.06 *vs.* EG's 34.43 ± 12.34 and L5 with CG's 56.43 ± 20.92 *vs.* EG's 54.20 ± 17.73. There was no significant difference in beta rhythm between L1 region with CG's 38.52 ± 7.72 *vs*. EG's 38.53 ± 9.18 and L5 region with CG's 54.65 ± 12.90 *vs*. EG's 53.24 ± 13.37. The comparison of different brain regions with θ and δ rhythms also showed similar results. The data from the right brain region (RBR) also showed good intergroup balance with the α rhythm located in the R1 region (CG's 36.59 ± 15.66 *vs.* EG's 34.92 ± 12.48) and R5 region (CG's 22.37 ± 15.24 *vs*. EG's 48.24 ± 19.00). There was no statistically significant difference in the APV values of β rhythm in brain regions of R1 (CG's 21.91 ± 9.12 *vs*. EG's 19.93 ± 10.20) and R5 (CG's 27.80 ± 16.60 *vs*. EG's 25.31 ± 15.73). The comparison of theta rhythm and delta rhythm between groups in all RBRs did not reach a significant level. These detailed baseline data indicated that, prior to the experiment, the brain electrophysiological activity of the two groups of subjects was in a comparable state, providing a reliable prerequisite for comparing the effectiveness of subsequent interventions. The APVs of ES in different brain regions of the two groups before and after the experiment showed that the comparison of APV values in the alpha rhythm was significant in the L2, L3, L4, L5, R3, R4, and R5 regions ($P < 0.05$), while the comparison of APV values in different regions of the β rhythm was not obvious. There were significant differences in the APV values of the alpha rhythm among the four regions of L1, L3, R3, and R5 in the EG ($P < 0.05$), while the APV values of β rhythm in the L1, L2, L4, R1, R2, R3, and R5 regions also showed significant difference

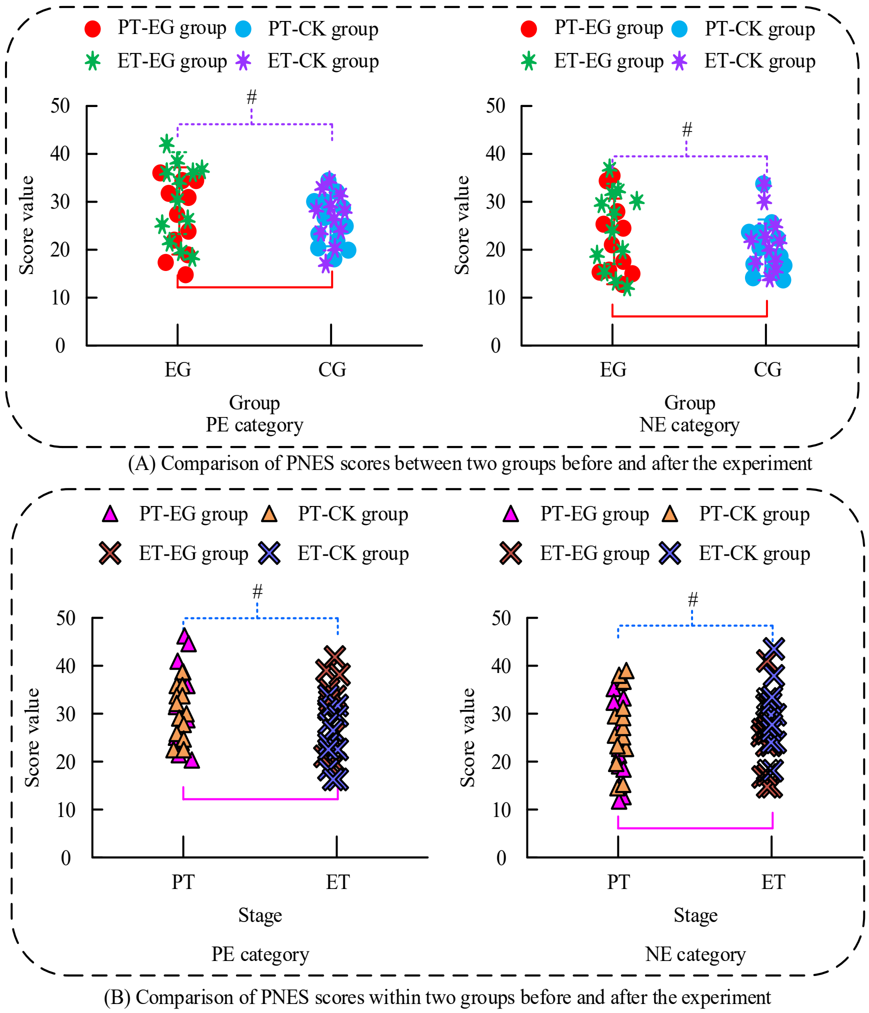
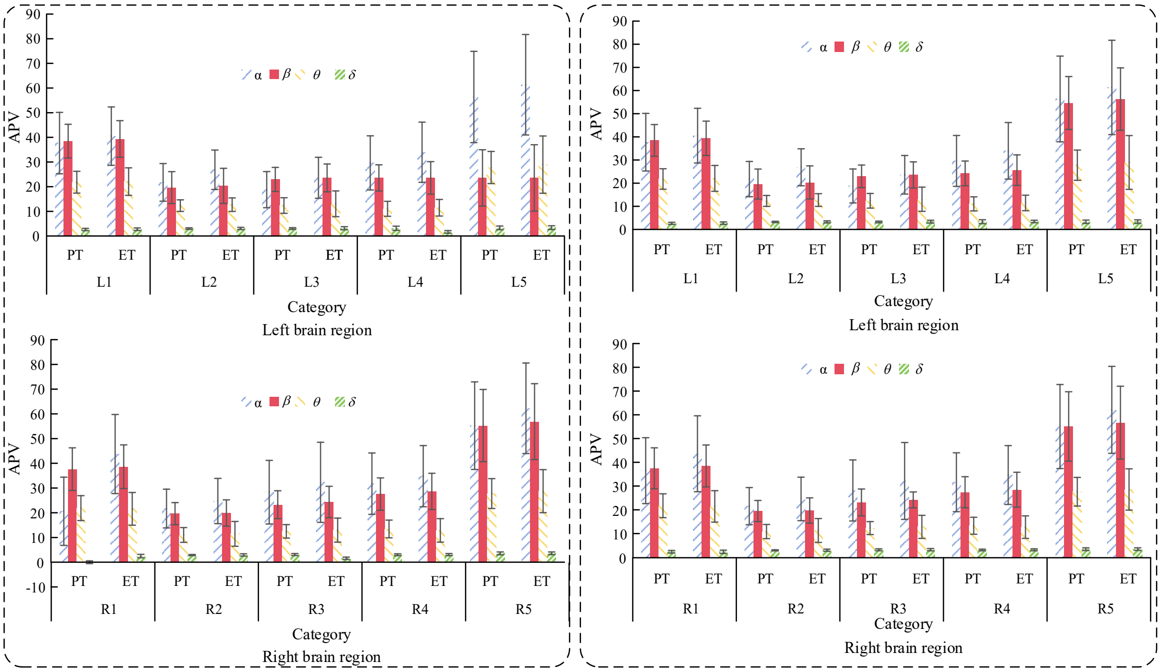


Figure 1. Comparison of PNES scores between two groups before and after the experiment.

($P < 0.05$). In the θ rhythm, there were significant differences in the areas of L1, L4, and L5 in the CG before and after the experiment ($P < 0.05$). The APV values of the δ rhythm in the comparison of L1, L4, and L5 regions demonstrated significant difference ($P < 0.05$), while there was no significant difference in comparing other electrode points (Figure 2). The APV results of ES data in the LBR between the two groups after the experiment demonstrated that there was no significant difference under alpha rhythm. However, there were significant differences in the APV values corresponding to the β rhythm between the L1, L2, and L5 regions ($P < 0.05$). The APV values in the θ rhythm showed that only the comparison between L1 and L2 regions showed significant difference ($P < 0.05$). In the δ rhythm, there was significant difference in APV values only in the comparison of the L1 region ($P < 0.05$) (Table 1). The APV results of ES data in the RBR between the two groups after the experiment showed that the alpha rhythm showed significant difference only in the R5 region ($P < 0.05$). The APV values under the β rhythm showed also demonstrated significant difference compared to the four regions of R1, R2, R3, and R5 ($P < 0.05$). The θ rhythm was observed in all regions of the right brain, and there was no significant difference in APV values. The APV values in the δ rhythm showed significant differences in the R1, R4, and R5 regions ($P < 0.05$) (Table 2).



(A) The average power values of ES in different brain regions of the CK group before and after the experiment

(B) The average power values of ES in different brain regions of the EG group before and after the experiment

Figure 2. The APVs of ES in different brain regions of two groups before and after the experiment.

Table 1. The APV of ES data in the LBR between the two groups after the experiment.

Brain region	Group	α		β		θ		δ	
		APV	*P*	APV	*P*	APV	*P*	APV	*P*
L1	CG	42.19 ± 14.97	0.76	32.44 ± 4.95	0.04	17.17 ± 7.16	0.01	3.01 ± 0.75	0.23
	EG	40.45 ± 2.06		39.24 ± 6.31		22.14 ± 8.38		2.76 ± 0.60	
L2	CG	26.25 ± 10.77	0.93	16.58 ± 3.30	0.04	10.61 ± 4.88	0.03	1.67 ± 0.66	0.36
	EG	26.93 ± 9.03		20.28 ± 3.11		12.69 ± 8.06		1.51 ± 0.52	
L3	CG	24.35 ± 9.38	0.87	20.28 ± 2.97	0.06	12.35 ± 5.25	0.66	1.67 ± 0.32	0.88
	EG	23.59 ± 9.64		23.64 ± 5.90		13.10 ± 6.37		1.58 ± 0.72	
L4	CG	35.25 ± 14.26	0.83	25.57 ± 4.71	0.49	12.89 ± 6.00	0.26	1.63 ± 0.46	0.07
	EG	34.03 ± 13.80		25.37 ± 3.80		11.50 ± 7.45		2.04 ± 0.62	
L5	CG	59.90 ± 20.07	0.91	45.28 ± 5.67	0.01	24.19 ± 15.41	0.12	4.41 ± 0.50	0.01
	EG	61.40 ± 23.02		56.28 ± 13.12		29.06 ± 15.21		3.41 ± 0.89	

Correlation analysis between PNES scores and ES changes in two groups before and after the experiment

The correlation between PNES scores and ES changes in two groups before and after the experiment showed that there was significant correlation between the APV value and NE in the R5 region under alpha rhythm (R = 0.473, P < 0.05). The L5 and R5 regions of APV values in the β rhythm showed a positive correlation with NE (P < 0.05). There was correlation between the APV value of L1 and NE changes under the θ rhythm (R = 0.443, P < 0.05). In the δ rhythm, the APV value of L1 showed a positive correlation with PE (R = 0.678, P < 0.05), while L5 and R5 showed active connection with NE (R = 0.706, P < 0.05 and R = 0.547, P < 0.05).

Discussion

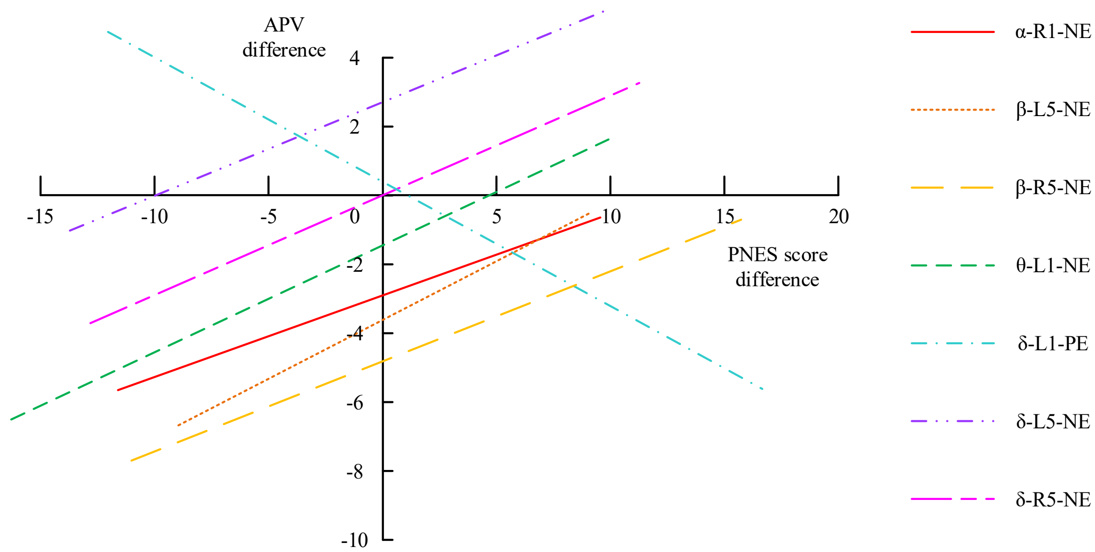


Figure 3. Correlation results between PNES scores and ES changes in two groups before and after the experiment.

Table 2. The APV of ES data in the RBR between the two groups after the experiment.

Brain region	Group	α		β		θ		δ	
		APV	*P*	APV	*P*	APV	*P*	APV	*P*
R1	CG	37.58 ± 13.36	0.18	31.58 ± 8.20	0.03	20.07 ± 10.29	0.64	2.97 ± 1.10	0.04
	EG	43.84 ± 18.0.7		38.56 ± 9.98		21.58 ± 7.48		2.52 ± 0.80	
R2	CG	22.90 ± 6.33	0.49	18.04 ± 5.40	0.03	11.84 ± 4.38	0.95	1.55 ± 0.43	0.28
	EG	24.80 ± 10.33		20.01 ± 6.01		11.53 ± 5.68		1.43 ± 0.52	
R3	CG	32.88 ± 12.68	0.92	20.37 ± 7.39	0.04	12.59 ± 4.98	0.90	1.73 ± 0.36	0.60
	EG	32.28 ± 18.30		24.40 ± 7.16		13.01 ± 5.48		1.61 ± 0.58	
R4	CG	38.11 ± 16.32	0.50	25.36 ± 7.59	0.29	12.45 ± 5.23	0.41	1.97 ± 0.73	0.03
	EG	34.78 ± 13.00		28.56 ± 8.28		12.93 ± 5.36		1.55 ± 0.47	
R5	CG	43.83 ± 15.91	0.01	49.04 ± 17.44	0.01	16.71 ± 5.70	0.11	4.77 ± 1.90	0.01
	EG	62.30 ± 20.14		56.94 ± 17.33		28.66 ± 9.82		3.59 ± 0.63	

Emotional disorders are a type of illness that affects an individual's emotional state and emotional regulation. It refers to an individual's inability to regulate their emotional responses in the face of pressure and challenges in daily life, resulting in abnormal emotional states such as fluctuating emotions, sustained lows or highs [15]. This state may significantly affect an individual's daily life, work, study, and social activities. Emotional disorders mainly include types such as depression and anxiety. Its formation is the result of a combination of multiple factors including biological factors such as genetics and neurotransmitter abnormalities, psychological and social factors such as family environment and childhood experiences, as well as environmental factors such as life stress and traumatic events. There are results indicating that SAE can significantly enhance PEs and reduce NEs, and its effect on improving emotions is closely related to the neural mechanisms of the brain [16]. However, the mechanism by which SAE affects ES in individuals with emotional disorders is currently unclear. In response to the above issues, this study conducted experiments in CG and EG using SAE and sedentary forms, respectively, to analyze the relationship between PNES scale categories and ES APV values. The results showed that, in the two comparative experiments before the experiment, there was no significant differences in the basic data, PNES scores, and APV values of the LBRs and RBRs between the groups, which indicated that the specific situations of different groups were balanced at the beginning of the experiment and could provide a foundation for the subsequent experiments. The results of this study indicated that aerobic exercise had a positive impact on the PE of patients with emotional disorders. Specifically, the EG showed significant improvement in PE and significant reduction in NE with significant differences compared to the CG, which indicated that SAE had a positive impact on improving emotions, significantly increasing the PE category and decreasing the NE category. Previous study showed that aerobic exercise could significantly alleviate chronic pain and improve NE including anxiety and depression. Numerous clinical trials also showed that molecules such as neurotrophic factors, inflammatory cytokines, neurotransmitters, and endogenous opioid peptides might be involved in alleviating the occurrence and development of chronic pain and emotional disorders under aerobic exercise conditions [17, 18], which were consistent with the findings of this study. The results of this study indicated that, during the sitting process, only a portion of the brain area with alpha rhythm showed significant changes in activity in the CG, and the overall changes in EEG activity were relatively small, which suggested that SAE had a broader impact on brain electrical activity, involving multiple brain regions and rhythms, thereby promoting the emotions of patients with emotional disorders. The alpha rhythm is mainly related to relaxation and concentration, while the beta rhythm is related to alertness and cognitive function. EG exhibited significant changes in multiple brain regions of alpha and beta rhythms, indicating that aerobic exercise might improve emotional states by regulating the activity of these brain regions. In addition, PEs were associated with the L1 region of the delta rhythm, while NEs were associated with multiple regions of the alpha, beta, and theta rhythms, which suggested that changes in emotional states might be reflected through electrical activity in specific brain regions. After moderate intensity aerobic exercise training, the dynamic amplitude of low-frequency fluctuations (dALFF) in brain regions such as parahippocampal gyrus, central posterior gyrus, and anterior cingulate cortex increased compared to before training. The dALFF in brain regions including middle frontal gyrus, right superior marginal gyrus, and angular gyrus decreased compared to before training [19, 20]. The results indicated that moderate intensity aerobic exercise training could cause functional plasticity changes in brain regions related to executive control networks and frontal parietal networks. This research deeply analyzed the brain area mechanisms related to SAE regulation of emotions and provided a safe, feasible, and low-cost solution for emotional disorders, providing scientific basis for clinical intervention. However, this study focused on short-term intervention effects and lacked tracking of long-term SAE interventions, making it difficult to effectively evaluate the long-term impact mechanism of this method. Therefore, the intervention time can be extended in future studies.

References

1. Nsugbe E. 2023. Toward a self-supervised architecture for semen quality prediction using environmental and lifestyle factors. AIA. 1(1):35-42.
2. Saminu S, Xu G, Zhang S, Kader IAE, Aliyu HA, Jabire AH, *et al*. 2023. Applications of artificial intelligence in automatic detection of epileptic seizures using EEG signals: A review. AIA. 1(1):11-25.
3. Zeng F, Lin Y, Siriaraya P, Choi D, Kuwahara N. 2020. Emotion detection using EEG and ECG signals from wearable textile devices for elderly people. JTE. 66(6):109-117.
4. Orowski P, Hobot J, Ruban A, Szczypinski J, Bola M. 2024. The relation between naturalistic use of psychedelics and perception of emotional stimuli: An event-related potential study comparing non-users and experienced users of classic psychedelics. J Psychopharmacol. 38(1):68-79.
5. Wang Y, Tian W, Xu J, Tian Y, Xu C, Ma B. 2023. Wearable wireless dual-channel EEG system for emotion recognition based on machine learning. IEEE Sens J. 23(18):21767-21775.
6. Aydin S. 2023. Investigation of global brain dynamics depending on emotion regulation strategies indicated by graph theoretical

brain network measures at system level. Cogn Neurodynamics. 17(2):331-344.

7. Asadzadeh S, Rezaii TY, Beheshti S, Meshgini S. 2022. Accurate emotion recognition utilizing extracted EEG sources as graph neural network nodes. Cogn Comput. 15(1):176-189.
8. Marinelli R, Parker AG, Levinger I, Bourke M, Patten R, Woessner MN. 2024. Resistance training and combined resistance and aerobic training as a treatment of depression and anxiety symptoms in young people: A systematic review and meta-analysis. Early Interv Psychia. 18(8):585-598.
9. Wasike BW, Uysal E, Un Yildirim N, Kilic RT. 2024. Effectiveness of aerobic exercise in geriatric individuals with depression. Phys Occup Ther Geri. 42(1/4):269-282.
10. Xing Z. 2024. Psychological study on the influence of physical exercise on college students' anxiety. JCER. 8(8):311-318.
11. Prasad R, Tarai S, Bit A. 2024. Emotional reactivity and its impact on neural circuitry for attention-emotion interaction through regression-based machine learning model. Cogn Neurodynamics. 18(5):2551-2573.
12. Zhu Y, Huang L, Chen J, Wang S, Wan F, Chen J. 2024. VG-DOCoT: A novel DO-Conv and transformer framework *via* VAE-GAN technique for EEG emotion recognition. Front Inform Tech El. 25(11):1497-1514.
13. Esmaeili M, Kiani K. 2024. Generating personalized facial emotions using emotional EEG signals and conditional generative adversarial networks. Multimed Tools Appl. 83(12):36016-36018.
14. Ulyanov SV, Mamaeva AA, Shevchenko AV. 2020. An intelligent diagnostic system for evaluating operator's emotions: EEG processing toolkit. J Biomed Eng. 54(6):145-148.
15. Zhang Y, Liu H, Zheng QQ. 2023. EEG-based emotion recognition with emotion localization *via* hierarchical self-attention. IEEE T Affect Comput. 14(3):2458-2469.
16. Ding Y, Robinson N, Guan ZC. 2023. TSception: Capturing temporal dynamics and spatial asymmetry from EEG for emotion recognition. IEEE T Affect Comput. 14(3):2238-2250.
17. Kamble K, Sengupta J. 2023. A comprehensive survey on emotion recognition based on electroencephalograph (EEG) signals. Multimed Tools Appl. 82(18):27269-27304.
18. Gunavathie MA, Susmi SJ. 2023. Pattern recognition and classification of EEG signals for identifying the human-specific behavior. JATIT. 101(8):3017-3026.
19. Dhara T, Singh PK, Mahmud M. 2024. A fuzzy ensemble-based deep learning model for EEG-based emotion recognition. Cogn Comput. 16(3):1364-1378.
20. Razumnikova OM, Tarasova IV, Trubnikova OA. 2024. Emotional intelligence and specificity of brain cortical activity in coronary heart disease. Hum Physiol. 50(1):15-24.