■ *Original Article*

Gender Difference in Electroencephalographic and Anxiety Status in Response to Single Bout of Physical Exercise

Nirmala Limbu[1], Ramanjan Sinha[2], Meenakshi Sinha[2], Bishnu Hari Paudel[1]
[1]Department of Physiology, BPKIHS, Dharan
[2]Department of Physiology, Sri Aurobindo Institute of Medical Sciences, Indore

Abstract

Background: Short-term or long-term physical exercise is associated with reductions in anxiety. Cerebral lateralization hypothesis predicts that anxiety reductions caused by exercise is due to decrease in right, relative to left, hemisphere activation. However, research reports on difference in anxiety reduction in response to short-term exercise are scanty. **Objective:** This study was aimed to compare the effect of acute bout of aerobic exercise on electroencephalographic (EEG) frontal alpha activity and anxiety between genders, and correlate between them. **Method:** A cross-sectional study was conducted on healthy 30 adult (male=15, female=15) subjects. They bicycled on automated ergometer, maintaining 50% HRmax for 20 min. EEG was recorded from frontal and occipital region (Fp, F1, F2, O1, and O2) and anxiety-scores were recorded before and after exercise. **Results:** Frontal EEG alpha activity power was significantly greater in females ($p<0.001$) than in males both in left (females=106.87±34.20 vs. males=53.68±7.90 μV^2) and right hemispheres (females=127.62±36.45 vs. males=48.33±8.18 μV^2) pre-exercise; and also in left (females=97.97±40.74 vs. males=54.12±10.73 μV^2) and right (females=116.01±54.70 vs. males =58.53±15.43 μV^2) hemispheres post-exercise. However, only males showed a statistically significant increase in right frontal activity (right=48.33±8.18 to 58.53±15.43 μV^2, $p<0.01$) post-exercise. Only males showed a significant negative correlation between pre-exercise state-anxiety and right frontal alpha activity (r value= -0.634, $p<0.05$). **Conclusions:** Our study suggests that females have positive affect at rest than males. In both genders, exercise reduced anxiety scores. However, only males supported cerebral lateralization hypothesis and negative association between resting frontal asymmetry and state-anxiety.

Keywords: acute aerobic exercise, anxiety, frontal alpha asymmetry, gender

Introduction

Physical exercise is advocated as a means to maintain and enhance good physical and mental health in healthy people and in clinical populations including patients with emotional disorder regardless of gender and age.[1, 2] Both single bout and regular exercise is associated with reductions in anxiety.[3] Exercise could provide a simple means to maintain brain function and promote brain plasticity.[4] Psychophysiological correlates of exercise could be assessed by asymmetrical patterns of electroencephalogram (EEG) activity. Differential hemispherical activation is associated with basic dimension of emotion where activation commonly refers to a reduction in alpha power over homologous sites of two hemispheres.[5] Resting left and right frontal alpha asymmetry indicates approach- and withdrawal- related

Address for correspondence:
Dr Nirmala Limbu
Associate Professor
Department of Physiology, BPKIHS
Email: nirulim@yahoo.com

behaviors, respectively. Thus, anterior asymmetry is an index of responses to positive and negative emotions, including fear and anxiety. [5] Asymmetrical EEG findings with affect have been contributed towards the formulation of cerebral lateralization hypothesis which predicts that anxiety reductions caused by exercise is due to decrease in anterior right, relative to left, hemisphere activation. [6] Most of these studies have been done in males and very few in females.

Objective

We aimed to compare the effect of single bout of aerobic exercise on frontal alpha activity and anxiety between genders, and correlate between them.

Method

A cross-sectional study was conducted on healthy adult volunteers of either sex (n=30; male=15; female=15), with age group ranging from 19 to 29 years in the temperature controlled Electroencephalography (EEG) laboratory. To make uniformity among the female subjects, the study was conducted in the midluteal phase of their menstrual cycle.[7, 8] The study was approved by the Ethical Committee of the institute and informed written consent was taken from all the subjects prior to conduction of the study.

Exclusion criteria were applied to those subjects having history or presence of any medical illness, or physical disability associated with increased anxiety that might affect the performance or results of exercise stress test. Subjects suffering from seizure disorders, psychoactive substance users or any drugs or habits that might affect EEG were also excluded from the study.

Subjects were advised to come after two hours of breakfast with a washed scalp and hair and proper sleep in previous night. To assess pre-exercise anxiety scores, the subjects were asked to answer set of questionnaires of standard self-rating Spielberger's State-Trait Inventory Scale (STAI) forms. Then, according to 10-20 system, EEG electrodes were attached. The probe of the pulse oxymeter was placed in the index finger to monitor pulse rate and arterial oxygen saturation.

The subjects were asked to lie down in supine position in relaxed and stress free condition with eyes closed. Resting EEG and heart rate was recorded till alpha waves were observed for more than 50% of the recording time at least for 10 min.

With the EEG electrodes remaining fixed on the scalp and oxymeter probe fixed on the index finger, the subjects sat on the automated bicycle ergometer. Initially, subjects experienced a zero resistance on the pedal. Then subjects started to pedal at the rate of 50 revolution/min for males and 40 revolution/min for females. The ergometric exercise load was increased by 10 watts at every 2 min of exercise, and when a load was reached at 30 and 20 watts for male and female respectively, it was maintained at same watts constantly throughout bicycling period for 20 min which was equivalent to 50% of HRmax. After exercise, again EEG and heart rate were recorded till the heart rate returned close to baseline value as observed in pre-exercise. The STAI questionnaire was again given to the subjects to assess their post-exercise anxiety scores.

The EEG records were visually inspected on the computer monitor to check for eye blinks, detectable eye movements and body movement artifacts, during the pre- and post-exercise sessions. Then, five-artifacts-free-6-sec epochs were randomly selected from each of the pre- and post-exercise sections of the record and were subjected to computerized Fourier (frequency) analysis for dissecting EEG into its different constituent rhythms (spectra). The obtained spectral power for alpha band was then exported to Microsoft Excel Worksheet, and averaged (M±SD) for both pre and post-exercise separately.

The similar anxiety scores of each question obtained from the subjects answering the STAI questionnaires during pre- and post-exercise sessions were added for each subject in terms of state (how they felt at that moment) and trait (how they generally feel) anxiety and, then averaged (M±SD) for males and females separately.

These values were then exported to SPSS (version 10) for statistical analysis. Pre-and post-exercise bilateral frontal alpha activity and anxiety score were compared between male and female by Mann Whitney test and, the correlation between bilateral frontal alpha activity and anxiety score was done by Spearman's correlation. P value less than 0.05 was considered as statistically significant.

Results

The age of males was similar to that of females. However, males had significantly higher height and weight as compared to females (Table 1).

Table1: Subject Characteristics

variables	Males	Females	P- value
Age(years)	22.87±2.75	21.93±4.09	NS
Height (cm)	166.27±5.50	152.87±5.94	<0.001
Weight (Kg)	58.53±8.37	48.67±3.5	<0.001

Comparison of pre- and post-exercise alpha activity in frontal hemispheres between males and females

There was significant difference in the frontal alpha activity between males and females, before and after exercise in both hemispheres. Before exercise, frontal alpha activity was significantly greater in female ($p<0.001$) in both hemispheres as compared to male. After acute aerobic exercise, right frontal alpha activity was significantly increase as compared to pre-exercise values (right 48.33± 8.18 to 58.53± 15.43, $p<0.01$) in males (Table 2). Whereas in females, a trend towards decrease in both hemispheres (left 106.87±34.20 to 97.97±40.74; right 127.62±36.45 to 116.01±54.10) was observed. In addition, when exercise induced change in alpha activity in both the frontal lobes were compared between genders, a significantly greater ($p< 0.001$) frontal alpha activity was observed in female (left 97.97± 40.74; right 116.01± 54.10) when compared to male (left 54.12 ±10.73, right 58.53 ±15.43) (Table3).

Table 2. Effect of acute aerobic exercise on left and right frontal alpha activity in males and females

Experimental	Left frontal region			Right frontal region		
Status	Males	Females	P- value	Males	Females	P- value
Pre-exercise	53.68±7.91	106.87±34.20	<0.001	48.33±8.18	127.62±36.45	<0.001
Post-exercise	54.13 ± 10.73	97.98±40.74	<0.001	58.53±15.43	116.01±54.10	<0.001

Table 3.Comparison of pre- and post-exercise frontal alpha activity of left and right hemispheres between males and females

Gender	Left frontal region			Right frontal region		
	Pre-exercise	Post-exercise	p-value	Pre-exercise	Post-exercise	p-value
males	53.68 ±7.91	54.13 ±10.73	NS	48.33± 8.18	58.53 ±15.43	<0.01
females	106.87±34.20	97.98± 40.74	NS	127.63±36.45	116.01±54.10	NS

*NS: Not Significance

Comparison of pre- and post-exercise anxiety scores between males and females

The difference in anxiety scores between males and females were not found to be statistically significant both before and after exercise (Table 4).

Table 4. Comparison of pre- and post-exercise anxiety scores between males and females

Anxiety	Pre-exercise			Post-exercise		
	Males	Females	p-value	Males	Females	p-value
State	40.40 ± 7.23	39.73 ± 11.26	NS	31.87 ± 6.88	33±6.72	NS
Trait	43.87± 5.91	43.67±11.14	NS	36.13±7.37	37.7±7.24	NS

*NS: Not Significance

Correlation of pre- and post-exercise anxiety scores with frontal hemispheric alpha activity in males and females

Before exercise, males showed a trend of negative correlation and, females showed a trend of positive correlation between anxiety scores and bilateral frontal alpha activity. Only the males showed statistically significant negative correlation ($r= -0.634$, $p<0.05$) of state anxiety with right frontal alpha activity (Table 5). However, after acute aerobic exercise, no significant correlation was observed in any gender (Table 6).

Table 5. Correlation of pre-exercise anxiety scores with frontal alpha activity of left and right hemispheres in males and females

Anxiety	Males				Females			
	Left frontal (r value)	P- value	Right frontal (r value)	P- value	Left frontal (r value)	P- value	Right frontal (r value)	P- value
State	-0.182	0.515	-0.634	0.011	0.217	0.438	0.313	0.255
Trait	-0.186	0.507	-0.251	0.366	0.162	0.564	0.202	0.407

Table 6: Correlation of post-exercise anxiety scores with frontal alpha activity of left and right hemispheres in males and females

Anxiety	Males	Females						
	Left frontal (r value)	P- value	Right frontal (r value)	P- value	Left frontal (r value)	P- value	Right frontal (r value)	P- value
State	-0.421	0.119	-0.294	0.288	-0.094	0.740	-0.033	0.906
Trait	-0.141	0.617	0.032	0.909	0.424	0.115	0.378	0.164

Discussion

This study was done to investigate the gender difference on EEG and anxiety status in response to acute bout of exercise. EEG and anxiety (state and trait) status were recorded before and after a standardized exercise.

As reported in the previous studies [6,9,10], we also found resting EEG frontal asymmetry, but according to gender, asymmetry pattern was different. Males had a relatively greater left-sided and female had a relatively greater right-sided EEG frontal activity power at rest (Table 2). Alpha asymmetry in anterior brain region is said to be predominant feature of the neural circuitry of human affective experience. Activity in alpha bandwidth is thought to reflect activation of the underlying cortex, such that greater alpha activity is related to less activation whereas, less alpha activity is associated with greater activation. [10]

Studies have found relations between individual differences in resting anterior brain activity asymmetry and characteristic levels of affect. Individuals having relatively greater left sided anterior activity have higher levels of dispositional positive affect while at rest, and those with relatively greater right-sided anterior activity have higher level of dispositional negative affect at rest.[11] Our study indicates a higher level of positive affect at rest in females as compared to males. Males have a relatively higher right sided anterior activity indicating a preponderance of negative affect at rest. However, it would be pertinent to mention here that other research reports have not always matched this pattern of relations between resting anterior cortical activity and affective style or disorders. Individuals with anxiety disorder exhibited relatively higher levels of right posterior cortical activity,[12] individuals with relatively higher levels of negative affect exhibited relatively higher levels of resting left temporal cortical activity.[13] Such results highlight the potential complexity of relations between resting brain activity and affective style or disorders.[14]

Studies on the effects of acute aerobic exercise on affective experience have focused on interhemispheric asymmetry in frontal alpha activity. [15] Handers and landers proposed a cerebral lateralization hypothesis , which predict that increased alpha activity (i.e., less activation) in the anterior right hemisphere, relative to anterior left hemisphere, occurs as a result of exercise, and this change should be related to enhanced affect (e.g., reduced anxiety). [6] Our study showed a significant increase in right frontal alpha power, post-exercise as compared to pre-exercise in males i.e. anterior activation was more on the left side, thereby supporting the cerebral lateralization hypothesis. On the contrary, after the intervention of acute aerobic exercise in females, showed a decreasing trend in alpha activity in right frontal region as compared to left. Thus, our results may indicate a relatively better post-exercise reduction of anxiety in males as compared to females. It has been found that topographical distribution of alpha activity is not inversely related to the activities of higher brain centers that elicit affective responses and the electrocortical frequencies in these areas. For example, emotional processing has been

associated with increased beta activity, while alpha activity does not change in right temporal and parietal regions.[16] It also has been reported that self-ratings of positive affective experience during meditation were correlated with increased theta activity, but not alpha activity, in the anterior frontal region. [17] Hence, it is unlikely that alpha activity alone provides a sufficient indicator of the activity of cortical networks linked with subcortical regions that may moderate pleasant and unpleasant emotions. [15]

In consistent with the previous studies, our result also showed that after acute bout of aerobic exercise both state and trait anxiety was significantly reduced in both males and females. The result was after cycling at the rate of 50% of HRmax for 20 min, in contrast to other reports [6, 9, 10], where the anxiety was reduced only at 70% VO2max exercise condition, not at 55% of VO2max. This may be due to difference in height and weight between theirs and ours participants (Table 1).[6] However, these findings might be specific to active, fairly fit college-aged subjects as ours and might not be exactly extrapolated to inactive, unfit, older or younger populations. [9]

A reduction in anxiety after exercise was accompanied by decreased left frontal alpha activity after exercise [6] but another study found that frontal alpha asymmetry measured at rest or in response to moderately intense exercise was unrelated to emotional response after exercise, despite a reduction in anxiety.[19] In our male subjects a significant reduction in anxiety was observed that corroborated with a decreased left frontal alpha activity after exercise. However, after the exercises, the alpha activity changes in females did not follow a similar pattern, though their psychological assessment revealed a similar degree of reduction in anxiety.

On correlating anxiety scores with frontal asymmetry in males, our results showed a negative correlation between state anxiety and right frontal alpha activity at rest which suggest that increase left frontal activation, relative to right, was associated with lower state anxiety in them. This finding seems similar to the study of Petruzzello and Landers [6] but their negative correlation was with trait anxiety. Whether lower anxiety leads to greater relative left frontal activation or vice versa is unknown. Therefore, it is reasonable to speculate that individuals with relatively greater left than right anterior activation would seek out challenging activities like exercise.[6] However, females showed a trend towards positive correlation.

Limitations of the study: Anyone can raise a question about the sample size (15 in each). However, there are studies with well controlled recording/testing environment. [20,21]We also did in well controlled environment. However, we limit generalizing the findings of our study. Another factor that could be questioned is age range of our subjects. It is because we wanted to see the effect of single bout of physical exercise on EEG and anxiety status in males and females. Thus we took the subjects with full reproductive maturity. We excluded older/younger ages where sex differences are relative less or more depending on variables.

The exercise load was put different for men and women because of their likely difference in performance, on the basis of known facts including difference in height and weight. We launched anxiety questionnaires before and after exercise (about 1/2 hour apart); this could have some recall bias. We tried to minimize this effect by not providing hint/ information that questionnaires launched after the exercise are same as that of pre-exercise. We believe that recall could not affect to that extent causing significant difference.

Strength of the study: Our study showed effect of single bout of aerobic exercise on anxiety reduction in both sexes which is validated by record of spontaneous neural activity of brain through EEG and their correlation.

Conclusion

A difference in patterns of EEG frontal alpha activity and anxiety exists between sexes. Our study indicates a positive affect at rest in females as compared to males. In both the genders, the anxiety was reduced after acute aerobic exercise. However, only male supported the prediction of cerebral lateralization hypothesis that anxiety reductions caused by exercise is due to decrease in right, relative to left, hemisphere activation. The correlation between anxiety and frontal alpha activity showed opposite trends in males and females. Only in male, we found that increase left frontal activation, relative to right, was associated with lower state anxiety in male at rest.

Further studies supplementing changes especially in beta activity in similar brain regions and the effect

of female hormone on them would help to throw more light related to gender differences in EEG patterns and its anxiety correlates after exercise.

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