



A Study on Effect of Acute Exercise in Alpha and Beta Electroencephalo Graphic Activity

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ABSTRACT

Electroencephalograph activity, particularly alpha and beta waves, reflect key aspects of brain function. Alpha waves are associated with relaxation and a calm, wakeful state, while beta waves indicate mental engagement, active thinking and arousal. These waves provide valuable insights into the dynamic balance between relaxation and cognitive effort. Physical activity has been recognized for its role in improving brain health, enhancing neuroplasticity and cognitive performance. Exercise has been shown to modulate alpha and beta electroencephalograph (EEG) rhythms, which are associated with cognitive and emotional states. This study seeks to explore the immediate impact of physical exercise on these brainwave patterns, contributing to a deeper understanding of the brain's responses to exercise. To analyze the effect of acute exercise on alpha and beta electroencephalograph activity, exploring the neurophysiological alterations induced by physical activity. This study included 50 physically active, healthy subjects of 21-30 years of age. Anthropometric parameters were recorded. Pre-exercise EEG was recorded after 10 minutes of rest. Then the subjects were instructed to do cycling in cycle ergometer until voluntary exhaustion. Immediately after exercise, Post-exercise EEG was recorded. SPSS Software-23 version was used. Paired t test was used for analysis. p value < 0.05 was considered to be significant. Initially at rest, the subjects had increased beta wave amplitude i.e. in pre-exercise EEG. This indicates the heightened mental alertness and cognitive engagement. Later on, after completing the cycle ergometer exercise, their post-exercise EEG showed a significant increase in alpha wave amplitude and a decrease in beta wave amplitude mainly in occipital and parietal leads, indicating reduced mental alertness and increased relaxation. This study found that acute exercise increased alpha and decreased beta activity, suggesting a relaxed yet alert mental state. These findings highlight the potential of exercise to positively influence the brain function and mental health.

INTRODUCTION

In past decade, sedentary lifestyle has become more prevalent, particularly with the rise of desk-based professions and increased screen time, there is increased risk of developing many health-related issues. Physical activity is recommended as it helps to sustain and improve both physical and mental well-being (Biswalter^[1], Guskowska^[2]). Thus, physical activity has gained significant attention in recent days. Exercise has a positive impact on mental well-being by improving mood and cognition (Colcombe^[3] Tomporowski^[4]). Physical activity helps to reduce stress, lower anxiety and alleviate symptoms of depression (Salmon^[5]). Consequently, exercise is being recommended as an essential intervention not only to combat physical ailments such as cardiovascular diseases, obesity and diabetes, but also recent research indicates that physical exercise can improve cognitive abilities, brain function and mental well-being (V. Brummer^[6] L. Verburgh^[7] Y.K. Chang^[8]). Earlier studies have indicated a connection between exercise and changes in brain activity (Helena^[9]). The positive impact of physical activity on the brain has sparked an interest in understanding how exercise influences neural activity, particularly through the use of electroencephalography (EEG). Electroencephalography is a non-invasive technique that records the electrical activity of the brain using electrodes placed on the scalp. It provides real-time data on brain function with high temporal resolution and is widely used in both clinical and research settings. An increasing number of studies have utilized neurophysiological techniques, such as electroencephalography (EEG), to directly measure brain activity and gain deeper insights into the neural processes improved by exercise (Y.K. Chang^[10] Hillman^[11]). Electroencephalography (EEG) serves as one of the valuable tools for assessing alterations in brain activity. (Limbu^[12]). Different frequencies of brain waves are associated with various cognitive and behavioural states. Alpha waves are typically associated with a state of relaxation and calm, while beta waves are linked to alertness, active thinking and concentration. Increased alpha activity signifies reduced cortical activation, often associated with relaxation, fatigue or lower levels of anxiety while decreased alpha activity indicates heightened cortical activation. (Petruzzello^[13] Boutcher^[14]). Investigating how exercise affects these EEG patterns can provide valuable insights into the neural mechanisms underlying the cognitive and emotional benefits of physical activity. Due to its high temporal sensitivity, EEG has become a commonly used tool for evaluating brain function and human behaviour (Babiloni^[15] Bevilacqua^[16]). Several studies have demonstrated that

exercise induces significant changes in EEG activity. Both short-term and long-term physical exercise can enhance brain functions, leading to improvements in cognitive performance (Hillman^[17]). Acute exercise, in particular, has been found to modulate both alpha and beta rhythms. These alterations in brain wave patterns point to the potential of exercise as a tool to regulate brain function, enhance mood and improve cognitive performance. The present study aims to explore the effect of acute exercise on alpha and beta electroencephalograph activity. By employing EEG, we can objectively measure the immediate impact of exercise on brain function, providing a neurophysiological perspective on the role of physical activity in enhancing mental well-being. Understanding these changes can offer valuable insights into the application of exercise as a therapeutic intervention for stress, anxiety and cognitive dysfunctions. This research could also pave the way for future studies focused on the long-term impact of regular physical activity on brain health.

MATERIALS AND METHODS

This study was a Cross-sectional study, conducted in the Research Laboratory, Department of Physiology, Tirunelveli Medical College, Tirunelveli, Tamilnadu. This study included total of 50 healthy and physically active subjects (25 males and 25 females) of 21-30 years of age. Subjects with Physical disabilities, cardiorespiratory diseases, known case of seizure disorder on treatment, any neurological disorders or mental illness, past history of head injury, Diabetes Mellitus, Hypertension, Hypothyroidism, Alcoholics, Smokers, Drugs which affect EEG like amphetamines, benzodiazepines, barbiturates, antidepressants, anti psychotics, opioids were excluded from the study. After getting Institutional Ethics Committee approval, the study was commenced. The subjects were informed to come to the Research Laboratory by 10 am. Informed written consent was obtained from the subjects. Subjects were instructed to sleep well the night before the experiment. They were instructed to avoid caffeine or other stimulants for 12 hours prior. Hair should be clean and free of oils or sprays to ensure proper electrode contact. If the subject was taking any medication, it should be continued. They were instructed to avoid fasting to prevent hypoglycemia. Demographic details including name, age, sex, occupational details, personal history, family history, medical history, treatment history if any was collected through face-to-face interview. Anthropometric measurements like Height, Weight were measured and Body Mass Index (BMI) was calculated using Quetelet's formula. Subjects were given self-constructed questionnaire which included

information like hours of sleep and quality of sleep, any history of regular physical activity, if yes, type of the exercise, frequency and intensity of exercise. The subjects were asked to relax for 10 minutes. They were made to sit in a comfortable chair. Resting BP and Heart rate was recorded. Twenty EEG electrodes were placed on the scalp using adhesive gel, with reference to International 10/20 system. The subjects were instructed to relax as much as possible to avoid artefacts. EEG was recorded using RMS EEG Acquisition and Analysis Software. Two EEG recordings were taken. One before the exercise (pre-exercise) and another after the exercise (post-exercise). Pre-exercise EEG was recorded for about 10 minutes in a quiet, sound proof room with comfortable temperature and with minimal electrical interference, with eyes closed. The subject was instructed to do a warm-up followed by cycling on a cycle ergometer until reaching the point of voluntary exhaustion. Voluntary exhaustion is the point during physical activity, at which a subject willingly stops exercise due to an inability to continue due to fatigue, discomfort or reaching their perceived physical activity. Immediately Post-exercise EEG was recorded for 10 minutes by making the subject to sit in a comfortable seat in a sound proof room with minimal visual interference with eyes closed. Alpha and beta wave amplitude were taken for analysis in both Pre-exercise and Post-exercise EEG. These data were recorded in Microsoft Excel. SPSS software version 23 was used for analysis. Paired t test was used for analysis to compare the mean differences of two groups before and after exercise. p value <0.05 was considered to be significant.

RESULTS AND DISCUSSIONS

The participants in the study were compared based on the age, height, weight and BMI. No significant differences were observed in these parameters across the study population, ensuring homogeneity of the sample. Initially at rest, the subjects had increased beta wave activity and decreased alpha wave activity in pre-exercise EEG. This indicates the heightened mental alertness and cognitive engagement. Later on, after completing the cycling on cycle ergometer, their post-exercise EEG showed a significant increase in alpha wave activity and a decrease in beta wave activity mainly in occipital and parietal leads i.e., O1, O2, P3, P4, Pz leads. These changes suggest a shift towards more relaxed and less cognitively active state. Paired t-test confirmed that the p value for alpha wave power before and after the exercise was found to be significant (0.023) which was <0.05. p value for beta wave power before and after exercise was found to be significant (<0.0001) which was <0.05.

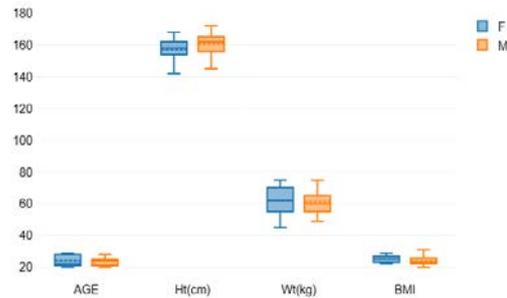


Fig 1: Comparison of Age and Anthropometric Parameters Among Study Participants

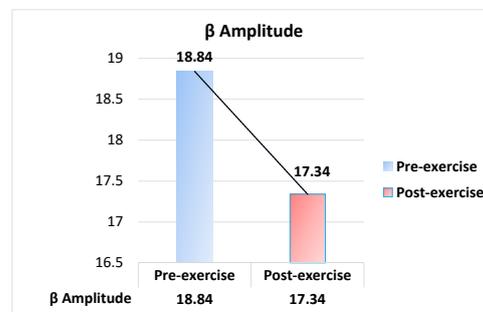


Fig 2: Comparison of Pre-Exercise and Post-Exercise Alpha Wave Amplitude Among the Study Participants

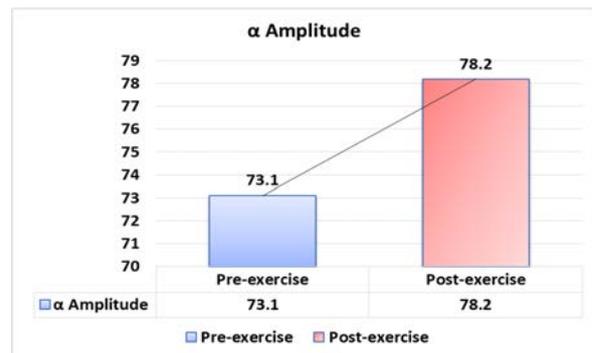


Fig 3: Comparison of Pre-Exercise and Post-Exercise Beta Wave Amplitude Among the Study Participants

This study revealed that the subjects had decreased alpha activity and increased beta activity pre-exercise. Also, the present study showed a significant increase in alpha activity particularly in occipital and parietal leads and a decrease in beta activity post-exercise. These findings suggest that acute exercise promotes a state

Table 1: Comparison of Age and Anthropometric Parameters Among Study Participants

	Gender	Frequency	Mean	Std. Deviation	p value
AGE	F	25	24	3.25	0.9636
	M	25	23.96	2.91	
Ht(cm)	F	25	157.08	7.19	0.0638
	M	25	160.72	6.35	
Wt(kg)	F	25	61.96	8.27	0.8004
	M	25	61.4	7.27	
BMI	F	25	25.04	2.28	0.1058
	M	25	23.88	2.68	

Table 2: Comparison of Pre-Exercise and Post-Exercise Alpha Wave Amplitude Among the Study Participants

	Mean (SD)	Median	Mean difference	p value
α Amplitude pre-exercise	73.1 (10.05)	74.2	5.04	0.023*
α Amplitude post-exercise	78.2 (12.69)	79.4		

*Statistically significant-p value <0.05

Table 3: Comparison of Pre-Exercise and Post-Exercise Beta Wave Amplitude Among the Study Participants

	Mean (SD)	Median	Mean difference	p value
β Amplitude pre-exercise	18.84 (1.24)	19.2	1.50	<0.0001*
β Amplitude post-exercise	17.34 (1.09)	17.6		

*Statistically significant-p value <0.05

of relaxation and reduced mental tension, consistent with the calming and restorative effects of physical activity. Studies have demonstrated that acute exercise increases alpha activity, indicating a relaxed mental state, while simultaneously modulating beta activity, leading to reduced cognitive arousal (Woo^[18] and Gutmann^[19]). Many studies have highlighted a rise in alpha activity during and after an acute exercise session. (Petruzzello^[20] Youngstedt^[21]). This increase in alpha activity after exercise indicates improved neural efficiency and a transition towards a calm and focused mental state following exercise. The elevated beta activity observed at rest prior to exercise indicates increased mental activation or stress, potentially due to anticipation or psychological demands of preparing for the task. Conversely, the decline in beta wave activity is commonly associated with active cognitive engagement and stress, suggests that exercise helps in reducing mental arousal and cognitive load. Post-exercise changes in alpha and beta wave activity, particularly in the occipital and parietal regions suggest enhanced cortical efficiency and relaxation. These findings are consistent with similar studies which highlights the role of exercise in facilitating a calmer and more efficient neural state in these brain areas (Schneider^[22]). Studies have shown that moderate-to-vigorous exercise enhances alpha activity, particularly in occipital and parietal regions, suggesting a shift toward a more relaxed yet alert mental state following exercise. Demographic factors, including age, height, weight and BMI, were comparable across subjects, ensuring that the observed changes in EEG activity were primarily due to the intervention. This homogeneity strengthens the validity of the findings,

highlighting that the exercise-induced effects were not influenced by these variables. Previous research has demonstrated that acute exercise enhances Cerebral blood flow (K. Herholz^[23]) and also suggests that exercise stimulates arousal mechanisms in the brain, thereby improving implicit information processing. (M. Audiffren^[24]). Recent research indicates that even short-term aerobic exercise training, with minimal fitness improvements, can promote neuroplasticity in sedentary adults, enhancing brain health and cognitive function. (S. B. Chapman^[25]). EEG activities originate from cortical generators and are influenced by neurotransmitters (Olejniczak^[26]). Glutamate and GABA play key roles during states of alertness, while cholinergic, adrenergic and serotonergic modulations occur during transitional states of alertness or recovery following exercise (Serman^[27] Olejniczak^[26]). Some studies have demonstrated that there is a potential mechanism that underlies these responses, are the release of neurotransmitters such as endocannabinoids and opioids triggered by exercise (Boecker^[28] Sarbadikari and Saha^[29] Dietrich and McDaniel^[30]). Research has concluded that chronic (Netz and Wu^[31]) and acute exercise (Reed and Ones^[32]) can lead to significant improvements in mood and anxiety. These findings highlight the significant impact of acute exercise on brain activity which can be studied with the help of Electroencephalography (EEG).

CONCLUSION

This study demonstrates that acute exercise, performed using cycle ergometer until voluntary exhaustion, significantly affects the brain activity, which is evident by an increase in alpha wave and

decrease in beta wave amplitude. These changes are observed particularly in occipital and parietal regions. These changes suggest a transition from anxious state to relaxed yet alert mental state after exercise. This supports the role of physical activity as a non-pharmacological strategy for reducing stress and improving cognition.

Limitations: This study is only short-term, focusses on studying only the immediate effects of exercise on EEG activity. Future research is needed to explore the effects of various types of exercise, intensities and durations of exercise on brainwave pattern. Expanding the understanding of exercise-induced neural changes, could inform targeted interventions for stress management and cognitive enhancement across diverse population. In this study, the potential difference in EEG responses due to gender is not explored. Future research should focus on examining the impact of gender on EEG changes following acute exercise.

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Authors Contribution: All authors in our study contributed to the data collection of the patients

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