New York Science Journal

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MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

# Electroencephalographic and electromyographic activity changes after a single bout of aerobic exercise in children with attention deficit hyperactivity disorder

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**Abstract: Background**: Exercises are extensively studied as a non pharmacological treatment of attention deficit hyperactive disorder to alleviate inattention, hyperactivity and impulsivity. **Objective**: The current study assessed the effects of a single bout exercise on brain waves related executive function (attention control ) and hyper activity in ADHD patients. **Design**: within subject design. **Methods**: 25 child were diagnosed as ADHD tested by single channel EEG / EMG biofeedback unit pre and post a single bout of moderate aerobic exercise for 10 minutes, THETA / BETA ratio as indicator of executive function and EMG as indicator of hyper activity were collected and statistical analysis was done to investigate the effect of exercise on EEG and EMG activities. **Results**: Acute exercise decrease the amplitude of theta band frequency and increase the amplitude of beta band frequency resulting in decrease of theta/beta amplitude ratio and decrease the EMG activity. **Conclusion**: These findings suggest that a single bout of aerobic exercise improves attention control and decreases hyperactivity in ADHD. **Recommendations:** To conduct therapeutic exercise sessions for children with ADHD as part of their treatment plan before school and even during school hours as a method of temporarily increasing students' concentration and reducing hyperactivity.

[Essam Abdelazem Gad, Manal Salah Abdelwahab. **Electroencephalographic and electromyographic activity changes after a single bout of aerobic exercise in children with attention deficit hyperactivity disorder**. *N Y Sci J* 2021;14(8):34-40]. ISSN 1554-0200 (print); ISSN 2375-723X (online). http://www.sciencepub.net/newyork. 6. doi:10.7537/marsnys140821.06.

**Keywords:** Electromyography; Electroencephalography; Exercise; Theta/beta ratio; ADHD.

## 1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a debilitating neurodevelopmental disorder characterised by developmentally abnormal signs of inattention , impulsivity and hyperactivity.

Attention Deficit/ Hyperactivity Disorder (ADHD) is a prevalent, highly and over activity. It typically emerges early in childhood and commonly persists through adolescence and into adulthood **(American Psychiatric Association, 2013)** High rates of social relations / academic/occupational failure, criminality, and drug abuse describe the outcomes of ADHD.

Family functioning is also highly affected by the child's ADHD. Recognition and management of ADHD in children is important so that their long-term outcomes can be improved **(Colvin and Stern, 2015).**

Physical exercises is defined as organized skeletal muscle movement associated with an increase in energy expenditure with the intention to develop or maintain physical fitness and/or health. Physical Exercise has a significant impact on brain functions and structures, and is one way to influence neural and cognitive growth in the short and long term. **(Dishman et al., 2006).**

Physical exercises affecting cognition include , but is not limited to, unstructured physical exercise, standardized physical education programs, and sport competition. The key variables of importance manipulated in laboratory studies are exercise type, intensity, and time. Intensity is usually expressed as a percentage of a person's maximum work load as determined by oxygen uptake or heart rate. Duration of interventions are categorized as either short-term (single exercise session) or long-term (multiple exercise sessions) **(Audiffren, 2009).**

Brain activity has been proposed to be important in examining affective and perceptual responses to acute bouts of exercise, furthermore , activity in the frontal regions of the brain has been related to affective responses to acute bouts of exercise **(Nybo and Nielsen, 2001), (Petruzzello et al., 2006).**

The metabolic changes associated with central fatigue during prolonged exercise can cause changes in brain activity. **(Dalsgaard and Secher, 2007).**

EEG band frequencies have a great impact on cognition and can be trained to improve several aspects of cognitive performance in neurofeedback; assessment of EEG data can be a good indicator for attention and other executive function, Low frequency to high frequency amplitude ratio (as theta beta ratio) is used to assess attention **(Barry et al. 2003).**

In healthy people, theta/beta ratio may be a biomarker for attention control abilities. and may predicts resilience to the effects of physical activity, such as stress, on self-reported state attentional control.

Theta/beta ratio appears to be a useful biomarker in the investigation of physical exercise and other anxiety–cognition interactions. **(Putman et al., 2014).**

Behavioral disinhibition and cognitive deficits are associated with a relative lack of alpha and a prevalence of slow oscillations during normal development, In typical development, the relative contribution of low frequencies (i.e. delta and theta) to the EEG power spectrum decreases with age, while the contribution of higher frequencies (mostly alpha and beta) increases, which is generally regarded as a sign of maturation. **(Clarke et al., 2007)**

It is shown that slow-wave and alpha oscillations are reciprocally related to each other. This reciprocal relationship may reflect an inhibitory control over motivational and emotional drives which is implemented by the prefrontal cortex. **(Knyazev, 2007)**.

## 2. Material and Methods

**Subjects:**

25 patients referred by pediatric psychiatrist to National Institute of Neuromotor System and DELTA Physical therapy clinic with diagnosis of ADHD participated in this study , Age range from 8 to 12 years, Selected from both genders , Inattentive or mixed type ADHD on Coners Parent Rating Scale – Revised: Short form **(Gianarris et al., 2007)** Children with history of chronic cardiac , chest disease , Physical disability , Mental retardation and Autism were excluded.

**EEG/EMG biofeedback system used for assessment Model:**

NEXUS 10 (Netherland): Is considered a reliable research tool for assessment and modification of brain and muscular activities by biofeedback applications, Medical CE certified (IIa), FDA registered (II) **(Kober et al. 2019).**

10-20 international system is used for electrode placement which is based on the relation between the location of electrode and the underlying area in the cerebral cortex with active electrode on CZ (sensory motor cortex ),reference electrode on right earlobeA2 and ground electrode on left ear lobe A1.

Mean theta amplitude, Mean beta amplitude, Theta / beta ratio and EMG amplitude are recorded.

Ergometer stationary bicycle for exercise program, max model , made in china and Treadmill , model ( grand fit) made in china

Calculating the maximum heart rate for patient age by subtracting the age from 205, warming up running in place for 3 min running in place followed by 5 min stationary bicycle on grade 3 resistance and 5 min fast walking on Treadmill on speed 4 km / hour and 0 inclination**,** Monitoring the heart rate during exercise no to exceed 75 % of max heart rate.

Reassessment immediately after exercise with the same procedures of assessment and start recording for 5 minutes and extract post exercise data.

**Design of study**:

Within subject design

All participants were tested by NEXUS 10 EEG/EMG biofeedback instrument and data were recorded as pre exercise and post exercise and data was compared and statistical data were collected.

## 3. Results

**Statistical analysis**

The results are expressed as mean ± standard deviation. A paired t test was used to compare data collected before and after exercise. Statistical Package for Social Sciences (SPSS) computer program (version 19 windows) was used for data analysis. P value $\leq 0.05$ was considered significant.

This study was conducted on 25 ADHD children admitted to the outpatient clinic of National Institute of Neuromotor System and DELTA Physical therapy center, They were tested before exercise by nexus 10 EEG/EMG biofeedback system for 5 minutes to detect the pre exercise value of theta, beta ,EMG mean amplitude followed by 10 min exercise on ergometer bicycle and Treadmill with target heart rate 75% of maximum heart rate. Reassessment after exercise by nexus 10 for 5 minutes to detect the post exercise theta, beta , EMG mean amplitudes.

**I- General characteristics of the studied children**

The age of the studied children was ranged from 8.0 to 12.0 years with mean (± SD) equal to 9.84 ± 1.62 years , As regards gender distribution, 3 (12.0%) out of the 25 children were girls and the other 22 (88.0%) were boys (Table 1).

**Table 1:** General characteristics of the studied children.

| | Number | Percent |
|---|---|---|
| **Age** (yrs.)<br>Mean ± SD<br>**Gender**<br>**Girls**<br>**boys** | <br>9.84 ± 1.62<br><br>3<br>22 | <br><br><br>12.0<br>88.0 |

**EEG parameters**

**I- Theta**

The mean value (± SD) of theta amplitude measured at pre-exercise and post-exercise was 26.07 ± 6.58 UV and 24.18 ± 5.56 UV, respectively. There was a statistical significant decrease in its values measured at post-exercise when compared to its corresponding value measured at pre-exercise (t= 5.518, p= 0.001). The percent decrease in its mean value was 7.25% (Table 2; Fig.1 ).

**Table 2:** Mean values of theta amplitude measured at pre-exercise and post-exercise in the studied group.

| | Pre-exercise (n= 25) | Post-exercise (n= 25) |
|---|---|---|
| Mean ± SD | 26.07 ± 6.58 | 24.18 ± 5.56 |
| Mean Difference<br>% change<br>t value<br>p value | 1.89<br>7.25% ↓↓<br>5.518<br>0.001 (S) | |

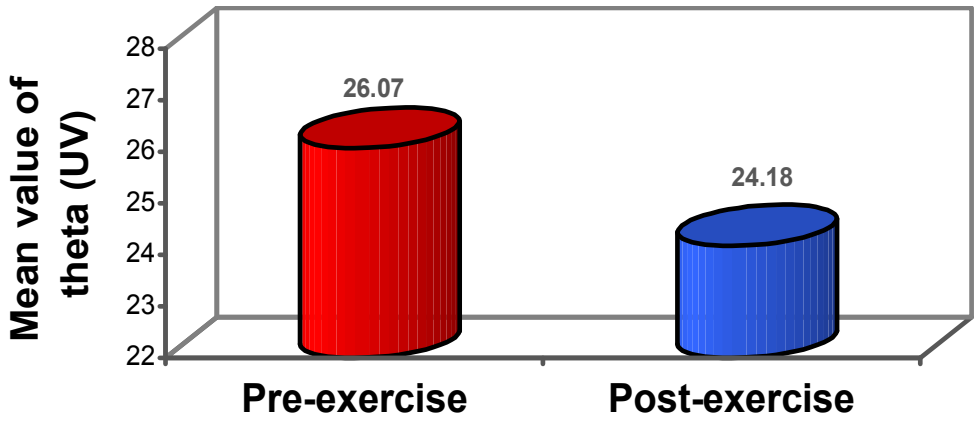


**Fig.1:** Mean values of theta measured at pre-exercise and post-exercise in the studied group.

**II- Beta**

The mean value (± SD) of beta measured at pre-exercise was 10.05 ± 1.82 UV while it was 10.28 ± 1.83 UV at post-exercise. Its mean value was significantly increased at post-exercise when compared to its corresponding value measured at pre-exercise (t= -2.839, p= 0.009). The percent increase in its mean value was 2.29% (Table3; Fig. 2).

Table 3: Mean values of beta measured at pre-exercise and post-exercise in the studied group.

| | Pre-exercise (n= 25) | Post-exercise (n= 25) |
|---|---|---|
| Mean ± SD | 10.05 ± 1.82 | 10.28 ± 1.83 |
| Mean Difference<br>% change<br>t value<br>p value | 0.23<br>2.29% ↑↑<br>-2.839<br>0.009 (S) | |

**III- Theta/Beta ratio**

The mean value (± SD) of theta/beta ratio measured at pre-exercise was 2.61 ± 0.61% while it was 2.38 ± 0.55% at post-exercise. Its mean value was significantly decreased at post-exercise when compared to its corresponding value measured at pre-exercise (t= 6.897, p= 0.001). The percent decrease in its mean value was 8.81% (Table4; Fig.3 ).

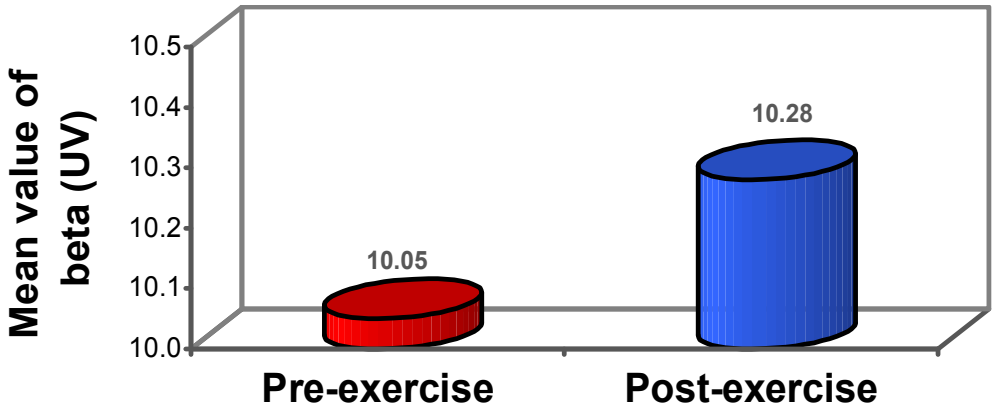


**Fig.2: Mean values of beta measured at pre-exercise and post-exercise in the studied group.**

Table 4: Mean values of theta/beta ratio measured at pre-exercise and post-exercise in the studied group.

| | Pre-exercise (n= 25) | Post-exercise (n= 25) |
|---|---|---|
| Mean ± SD | 2.61 ± 0.61 | 2.38 ± 0.55 |
| Mean Difference<br>% change<br>t value<br>p value | 0.23<br>8.81% ↓↓<br>6.897<br>0.001 (S) | |

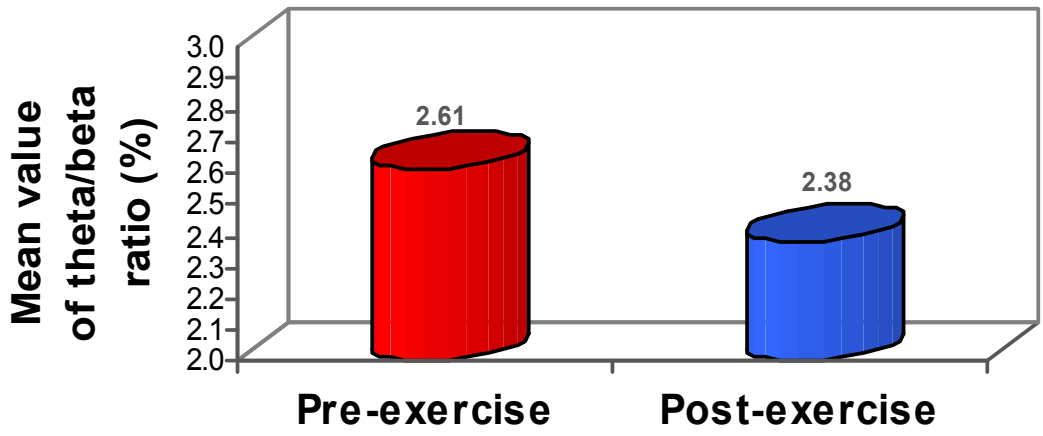


Fig.3: Mean values of theta/beta ratio measured at pre-exercise and post-exercise in the studied group.

**EMG**

The mean value (± SD) of EMG measured at pre-exercise was 3.50 ± 1.06 MV while it was 2.99 ± 0.77 MV at post-exercise. Its mean value was significantly decreased at post-exercise when compared to its corresponding value measured at pre-exercise (t= 2.939, p= 0.007). The percent decrease in its mean value was 14.57% (Table5; Fig.4).

Table 5: Mean values of EMG measured at pre-exercise and post-exercise in the studied group.

| | Pre-exercise (n= 25) | Post-exercise (n= 25) |
|---|---|---|
| Mean ± SD | 3.50 ± 1.06 | 2.99 ± 0.77 |
| Mean Difference<br>% change<br>t value<br>p value | 0.51<br>14.57% ↓↓<br>2.939<br>0.007 (S) | |

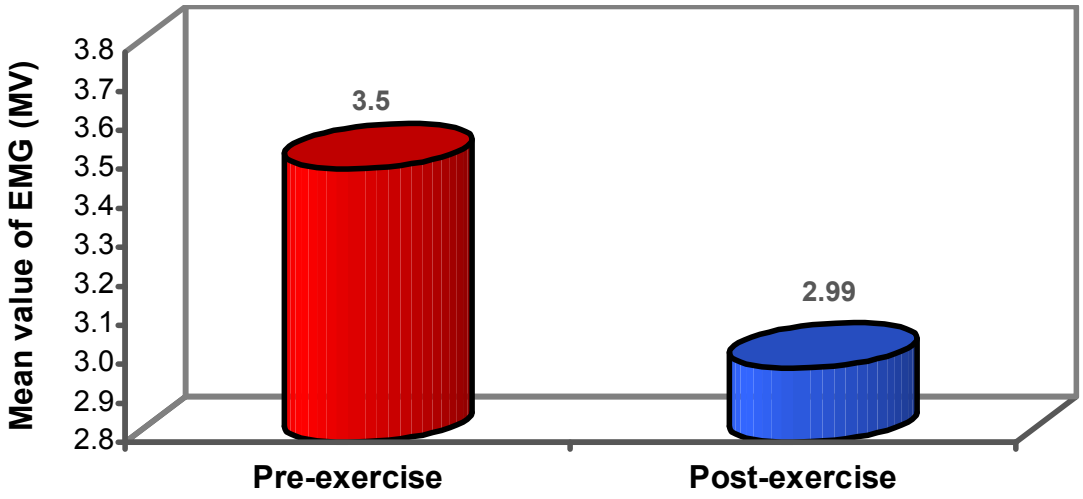


Fig.4: Mean values of EMG (MV) measured at pre-exercise and post-exercise in the studied group.

**4. Discussions**

The aim of this research was to see how a single dose of aerobic exercise affected certain EEG band frequencies amplitudes related to attention and EMG activity related to hyper activity in children with ADHD.

The findings showed that after a 10-minute session of aerobic exercise, children with ADHD revealed significant smaller theta amplitudes , Theta is considered the slow awake brain activity ranging from 4-8 Hz , theta rhythms in the frontal midline are often linked to theta rhythms in the hippocampal region. Theta oscillations are thought to be involved in memory encoding and retrieval and associated with creativity and spontaneity, but also with distractibility and inattention, daydreaming, depression, minor traumatic brain injury and anxiety. Theta that is excessive or laterally asymmetrical may reflect depression (LH), anxiety (RH), and other emotional disorders. Children have higher theta amplitudes than adults so the lower the theta the higher the attention and the lower the distractibility and vice versa.

Significant higher beta amplitudes post exercises noted on results as fast wave activity, or "any rhythmic activity (13-26) Hz" , It has been associated with being focused, analytical, externally oriented, or in a state of relaxed thinking. Dominant beta frequencies are higher in adults than children, Maximal Beta amplitude is usually in the fronto-central regions, but it may be widespread, during drowsiness, Beta may seem to decrease in amplitude.

Significant decrease in theta/beta ratio over the central cortical sites was observed after the exercise condition. which is consistent with our hypothesis that Higher resting theta/alpha and theta/beta ratios have been associated with impaired inhibitory ability and cortical hypo-arousal and the lower the ratio the higher the attention and lower distractibility.

Our findings provide a prove that a single bout of exercise could affect frontocentral cortical sites which may exhibit abnormal EEG patterns and regulate the inattention commonly observed in children with ADHD.

Other studies have found that physical activity helps build the mechanism that increases the amount of neurotransmitters in the brain and their postsynaptic receptors , dopamine, serotonin and norepinephrine, as well as other molecules are released and may regulate the inconsistency. Exercise boosts mood, well-being, anxiety, and depression, as well as stress management. **(Ratey, 2008).** and support the use of EEG data as a good indicator for attention and other executive

function, Low frequency to high frequency amplitude ratio (as theta beta ratio) is used to assess attention **(Barry et al. 2003)**, thus Affective and perceptual reactions to acute bouts of exercise are partly assessed by brain activity.

These abnormality of resting EEG recordings in ADHD need more researches towards clinical co-relations as it can detect developmental problems and test the effects and side effects of medicines and other interventions on ADHD child.

In addition to correction of abnormal patterns of resting EEG, the present study observed significantly decrease EMG mean amplitude as an indicator of hyperactivity in the ADHD post exercise compared to the pre exercise supporting the presence of motor impairments with ADHD symptomology and the ability of exercise to improve the inhibitory control.

A number of studies have shown that acute exercise improves inhibitory performance in children with ADHD, as a single bout of aerobic exercise improved their performance in the Color–Word condition of the Stroop Test **(Chang et al. 2012)** another study compared to those who sat and read during the treatment period, children with ADHD demonstrated higher response accuracy and improved stimulus-related processing after a single bout of moderate-intensity aerobic exercise. **(Pontifex et al.,2013)** and acute exercise can improve the performance and a shorter reaction time developing appropriate response preparation in Go/No Go task **(Chuang et al., 2015)**

Recent findings indicate that single bouts of vigorous exercise can normalize impulsivity and attentional vigilance as measured by reaction time (RT)-based measures and a cognitive task requiring sustained attention. in ADHD **(Medina et al., 2010).** Despite the fact that While all participants were advised to be drug-free for at least 48 hours prior to participating in this study, residual medication effects may have stayed beyond this time frame and may contribute by certain degree on the positive effect noted on results.

Since we only used resting EEG as a measure of cognition after the exercise condition, we can only conclude that acute exercise in children with ADHD would have been reflected in a smaller resting theta, higher beta and smaller theta/beta ratio can improve cortical control and inhibit subcortical impulses.

Our study looked at the immediate effect of exercise on EEG and EMG, which revealed a significant improvement, but it didn't look at the aftereffect of exercise or how long the positive effect would last. Study did not utilize a sample of normally developing children as a control group, we searched the appropriate control for physical activity should be, Participants in studies on the effects of physical activity are aware of the physiological tasks to which they are subjected. As such, a control group would allow researchers to determine the extent to which these EEG changes caused by acute exercise are unique to children with ADHD.

Accordingly, In such cases, it is critical to consider how often expectancy and motivation may have contributed to the observed results.

**Recommendations**

Our findings suggest that encouraging children with ADHD to engage in physical activity may improve aspects of neurocognitive function and inhibitory control.

As part of a comprehensive school-based physical activity programme, we recommend incorporating small doses of exercise during the school day.

Larger samples need to be recruited in future researches, also increase the number of female subjects to investigate potential gender differences.

The effects of physical exercise performed in a laboratory setting using cycle ergometry/treadmill do not reflect typical sporting traits of children; therefore, the practical utility of these protocols must be investigated, as results obtained in a non-habitual setting may be biassed due to feelings of discomfort.

**Funding:**
Not funded.

**Conflict of Interest:**
Authors declare no potential conflicts of interest.

**Acknowledgments**
Authors would like to thank all children who participated in the current study.

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7/22/2021