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Neural Dynamics of Theta Wave in Children with Attention Deficit Hyper activity Disorder

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Abstract
Attention deficit hyperactivity disorder having variable cluster of hyperactivity, impulsivity and inattention symptoms affecting the normal cognitive and behavioral function of an individual ADHD is characterized by decreased attention span and impulsivity. EEG power were investigated in patients with attention deficit hyperactivity disorder (ADHD) diagnosed as per DSMV criteria. EEG were conducted for 30 ADHD children and 30 healthy controls of comparable age (8-9 yr) and sex. The EEG power tests include absolute power of theta, ADHD patients showed significantly higher theta absolute power, (p<0.005). This study supplants the tenet of maturational arrest of higher cognitive function of alertness and attention in ADHD.
Keywords: *Attention deficit hyperactivity disorder (ADHD), Diagnostic and Statistical Manual (DSM V), Power spectrum density (PSD).*

Introduction

Attention-deficit hyperactivity disorder (ADHD) is a Neuro developmental disorder characterized by developmentally age inappropriate levels of hyperactivity, impulsivity and inattention[1]. ADHD is one of the most common disorders of children, the prevalence of which has been estimated to be approximately 5-10% in children and 4-6% in adult[2]. Boys are affected 2 – 4 times more than girls[3].

ADHD is primarily manifested clinically by – inattention and early distractibility, impulsivity, motor restlessness and hyperactivity, difficulty with planning and organizing task, and emotional liability.

The American Psychiatric Association's (APA) Diagnostic and Statistical Manual (DSM-5) states that patients must have experienced a minimum of six symptoms of inattention (e.g. failing to sustain attention in tasks or play activities, not listening when being spoken to directly), or six symptoms of hyperactivity/impulsivity (e.g. talking excessively, fidgeting with hands or feet). The manual distinguishes between three subtypes of the disorder: predominantly hyperactive/ impulsive type, predominantly inattentive type and combined type.

ADHD shows abnormal activation pattern and neural dynamics in structure associated with these function. The neurophysiological correlates of cingulo – frontal parietal cognitive / attention network (CFP) that include the frontostratial and frontoparietal pathways (interactions). The main nodes of the CFP network include the dorsal anterior midcingulate cortex (daMCC), dorsolateral prefrontal cortex (DLPFC), ventrolateral prefrontal cortex (VLPFC) and parietal cortex all of which feature significant connectivity with affective subcortical structure mainly in the striatum[4].

The daMCC play a putative major role in motivational processing and novelty detection. Da MCC modulates response selection, response inhibition, and error detection (Bush, 2011). DLPFC and VLPFC are thought to mediate vigilance, selective attention, attention shifting, planning, and working memory function[4].

In ADHD subjects hypo activation of the DLPFC has been seen in task that require motor inhibition, interference inhibition, memory inhibition, sensoriomotor timing and working memory. Recent advancement in functional and structural neuroimaging techniques have led to a broad system approach to ADHD they noted that dysfunction in localized region just be a result of anomalous connectivity within and variety of neuronal network.

A whole spectrum of attention deficit problem may result from abnormal synchronization of the functional neurons and their antecedent neural dynamics in the human brain and the resultant neurophysiological human mind[5].

Scalp EEG

Multichannel electroencephalography, or EEG, records the electrical activity of the brain via electrodes placed on the scalp. The bioelectric activity as results of the firing of neurons within the brain is recorded along the scalp as brain waves in the form of Electroencephalograph (EEG). EEG activity reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation

In scalp EEG non – invasive recordings, theta is most prominently seen over the frontal midline location[6,7,8,9] and has been found to be modulated by *Multiple Cognitive Demands/Tasks* such as *working memory*[10] and *error monitoring and matching*[11]. This "frontal – midline" theta is consistent with generators in the anterior cingulate [10]

ADHD exhibits excess slow wave activity and epileptiform spike and wave activity especially as a maturation delay marked by under-arousal[12]. EEG wave forms are a mixture of several different frequency bands which are transformed and quantified for further analysis.

Computerized power spectral analysis permits the topographic representation and statistical analysis of EEG with the use of digital EEG as been recommended by the American Academy of Neurology[13].

The present study was designed to access the theta wave pattern in ADHD.

Material and Method

The present study was carried out in the Department of Physiology in collaboration with the Departments of psychiatry and Pediatrics, SMS Medical College, Jaipur. 30 children in the age group of 7 to 14 years suffering from ADHD disorder, diagnosed as per DSM V criteria, were included in the study. A control group of 30 children matched for age and sex were recruited for comparative evaluation. Each group having 95% confidence interval and 80% power to verify the expected minimum difference of 6.84 {± 9.94} in the frequency of alpha wave and difference of 19.30 ±{ 14.8} in frequency of theta wave among the ADHD and control group.

The inclusion criteria for the study adopted were children having IQ > 70, no chronic medical illness and no previous psychiatric and neurological disorder. DSM V diagnosed children were recruited in study Children with anxiety or depression. with hearing or vision disorder, lead poisoning were excluded from the study . The family background of children also considered children from broken families inclusive of any abuse also excluded from study.

Procedure

The EEG recordings were run for 5 minutes for each of the maneuvers with the subjects at rest, with eyes closed, eye open. Informed written consent was obtained from all the control and ADHD children's parents or the gurdian who were enrolled in the present study.

The subjects and patients so included in the study were asked to wash their hair the night before the EEG test run and not apply anything (hair cream, oils or spray) after the shampoo. The EEG was recorded on the central lead (Fz, Cz, Pz, Oz,). Impedance was kept below 5 Ω and electrical activities, amplified with a band-pass filter of 0.5 - 30.0 Hz, were digitized at sampling rate 256 Hz. Recording of EEG was taken in a sound attenuated, dimly lit room. qEEG was done for all the participant using BESS (brain electro scan software) of the Axxonet System (India). Artifacts free epochs of 3 seconds each were chosen because after every of 2-3 seconds the changes both inclusive and exclusive in the amplitude were taking place more than 10% and their spectral content evaluated by means of Fast Fourier Transform analysis[14].

Result & Observation

Table 1 Theta power in eye close session

Channels	ADHD			Control			P Value
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	
Fz	30	7.38	2.76	30	3.55	2.23	<0.001S
Cz	30	9.16	3.06	30	3.92	2.46	<0.001S
Pz	30	9.30	3.28	30	4.20	2.11	<0.001S
Oz	30	10.50	3.36	30	4.23	2.11	<0.001S

N= number of subject and control, S= significant

The above table showed theta power in eye close session which was found significantly higher in children with ADHD (p value <0.001)

Table: 2 Theta power in eye open session

channel	ADHD			Control			P Value
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	
Fz	30	6.88	2.85	30	4.21	2.35	<0.001S
Cz	30	7.79	2.72	30	4.48	2.57	<0.001S
Pz	30	7.36	2.18	30	4.86	2.35	<0.001S
Oz	30	7.83	2.76	30	4.29	2.06	<0.001S

N= number of subject and control, S= significant

Above table showed the Theta power in eye open which was significantly higher in children with ADHD as compare to control.(p value<0.001)

Discussion

In scalp EEG non – invasive recordings, theta is most prominently seen over the frontal midline location (Maurer and Dierks, 1991; Mitchell et al, 2008; Nunez et al, 2001; Srinivasan et al, 2006) and has been found to be modulated by *Multiple Cognitive Demands/Tasks* such as *working memory* (Onton et al, 2005) and *error monitoring and matching* (Debener et al, 2005).

The Power Spectral Density (PSD) of theta waves so observed in ADHD children in the present study was high and not commensurate with the documented PSD of theta waves in normal control healthy children. In the present study, significant increase in absolute power of theta wave – form could be appreciated during the eye closed, eye open ($p < 0.001$) in children with ADHD when compared to that observed in normal healthy controls in the central EEG electrode pairs of Fz, Cz , Pz, Oz. The said central EEG electrode pairs reflect the underlying cognitive neural mechanisms sub serving attention and alertness.

The anomalous profiling of *theta wave form* in ADHD children in real – time seems to be due to dysfunctional theta generator primarily in anterior cingulate gyrus. The data so observed in ADHD children support the premise that maturational delay implicates dysfunctional attentional neural network that forms the mainstay of such children afflicted with blemish in attentional neuronal mechanisms and is subsequently translated in the form of an enhanced absolute power (representative of synchronized neuronal pools that do not transform, transcribe and transliterate into desynchronized activity form contingent and interlocked to the antecedent stimulus) of theta wave – form (statistically significant with predictive value of less than 0.001, $p < 0.001$) so observed in the central EEG electrode pairs of Fz, Cz, Pz, Oz.

Conclusion

The present study supplants the tenet of maturational arrest of higher cognitive function of alertness and attention in ADHD children as exemplified by significant ($p<0.001$) raised theta power in central EEG electrode pair.

From the present study it can be concluded that of EEG holds a promising role in elaborating the neurophysiological mechanisms of disorders related to attention (ADHD) & higher mentation, further study on a large scale need to be undertaken in order to validate the diagnostic & prognostic relevance of EEG in ADHD.

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