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Brain Waves and Connectivity of Autism Spectrum Disorders

Norsiah Fauzan^a, Nur Hurunain Amran^b^a*Faculty of Cognitive Science and Human Development, 94300, University of Malaysia Sarawak.*^b*Faculty of Cognitive Science and Human Development, 94300, University of Malaysia Sarawak.*

Abstract

This research reports the brain wave pattern of individuals with ASD and to pinpoint the anomalies of ASD and its difference with the normal group. The findings revealed a general disruption in the overall connectivity of the different lobes known as hyper or hypo connectivity with excessive presence of slow wave (delta) at the frontal lobe and deficiency of beta in most of the brain regions. Other anomalies includes low alpha at the sensory motor regions, excess alpha in the left hemisphere and excess theta in the right frontal region. These anomalies explain the associated problem in attention, anxiety and social behaviors of ASD.

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1. Introduction

The Quantitative Electroencephalogram (QEEG) is a leading tool in the evaluation of autistic spectrum disorders (ASD) [1] It is noninvasive and the most helpful in identifying the areas of unique variability in the brains of children or individuals with ASD. The EEG is a collection of electrical activity produces at the cortex of the human brain that can then be recorded and measured. The brain maps or qEEG Maps are collected using 19 electrodes based on the International 10/20 system [2](Jasper, 1958). QEEG maps are quantitative analyses of EEG characteristics of frequency, amplitude and coherence during various conditions or tasks. For example, by looking at the quantitative electroencephalogram (qEEG) *alone*, Robert Coben and his colleagues [3] (2008) have been able to distinguish autistic children from neurotypical children with a success rate of 88%. It is an assessment instrument to measure (quantify) the electrical activity summation in a given region of the brain to localize the area of dysfunction. Such regions and aspects of dysfunctional neurophysiology may then be targeted specifically to decide on the individualized specific training protocols applied in EEG biofeedback or known as Neurofeedback (NFT) training. A psychologist or neurofeedback practitioner could easily reach wrong conclusions by obtaining a description of symptoms and decide by the application of an initial interview and series of clinical questions if the brain is in the specific state of performance and therefore train the specific frequencies to acquire peak performance. There should be an increasing dialogue between the professionals from various disciplines in cognitive science, more neurologists may be interested in psychological processes and more psychologists searching for an “organic”

* Corresponding author. Tel.+0-6082-581515; fax: .+0-6082-581567.

E-mail address: nursiahfauzan@gmail.com

basis for the different disorders. The EEG biofeedback practitioners should build an individualized training protocol based on the assessment derived from the EEG findings in relation to the individual's medical history and psychological diagnosis or neuropsychological tests. The current research reports the preliminary findings obtained from QEEG report for a sample of ten individuals diagnosed with ASD and 10 normal individuals. The brain mapping were conducted to pinpoint the anomalies and to decide on the individualized NFT training protocol. The data obtained from the normal group were used as a comparison to identify the unique difference or the common markers for this particular group. This is not a controlled experimental study and the main purpose was to analyze the QEEG recurring patterns in individuals and children with ASD and compared with normal individuals.

2. Background

Previous research and collections of data points out that various brainwaves should be distributed throughout the brain in normal consistent patterns with some small degree of variability. Analysis of brain wave patterns in the qEEG are helpful for identifying the area that are often likely the underlying reason for the presenting symptoms [4]. Recent research highlights the association of autistic symptoms with information integration deficits resulting from under or over-connectivity within and between specialized areas of the brain.

Rondeau [5] observed few qEEG recurring patterns in children with ASD. The first pattern observed in ASD is the presence of excess slow wave activity (delta, theta) and excess fast waves (alpha, beta) relating to hyper- or hypofunctioning of the localized area. Children with learning disabilities affected with hypofunction in the area of the brain related particular functions such as reading and problem solving might struggles in the reading comprehension or the learning of mathematics. On the other hand, children with anxiety problems are often identified in qEEG with hyperfunctioning at the localized area such as right frontal region of the brain. The second recurring pattern in the qEEGs of autistic children discussed in the literature by [3,5] is the presence of particular rhythm called "mu", a characteristic waveform found in the 8-13 hz (alpha) range over the sensorimotor cortex. [5]. The third recurring pattern is a general disruption in the overall connectivity of the different lobes to themselves and to each other known as hyper or hypoconnectivity. The differences in qEEG results between various studies related to ASD must have been due in greater part to the different characteristics of the casuistry studies.

In another research by Dr. Linden [6] of Attention Learning Centers identified six QEEG patterns of Autism and two of Aspergers based on 19 channel EEG recordings and analysis of raw EEG, absolute power, relative power and multivariate connectivity. The six Autism QEEG subtype patterns are: 1) High Beta activity which corresponds to obsessing, overfocusing and anxiety, 2) High Delta/Theta activity which corresponds to cortical slowing and inattention, impulsivity and hyperactivity, 3) Abnormal EEG/Seizure activity, and 4) Metabolic/Toxic pattern of lower overall EEG activity (voltage), 5) Mu activity which corresponds to social skills, and 6) Coherence Abnormalities. The High Beta and coherence subtypes were the most common subtypes, occurring in approximately 50-60 percent of the students with ASD. The Delta/Theta subtype occurred in 30-40 percent, the Abnormal EEG subtype in 33 percent and the Metabolic/Toxic subtype in 10 percent. The QEEG patterns with students with Asperger's primarily occurred in the right temporal and parietal regions, sites involved in social and emotional recognition mechanisms.

Each of the children differed in terms of severity (behaviorally and biochemically). Individuals with severe intellectual disabilities may have more delta activity in frontal-temporal regions and those with less intense disabilities had more theta activity. There's also a tendency that the alterations were accentuated due to the mental deficiency of the disability or otherwise the decrease in abnormalities might be due to maturity factors.

3. Objective

Autism Spectrum disorder (ASD) is a neurodevelopmental disorder associated with deficits in executive function, language, emotions and social communication [3]. Their social behavior corresponds with QEEG subtypes patterns as previously discussed in the literature of ASD. The current investigation is not a controlled experimental study and the main objectives were to:

- i. Analyze the QEEG sub types patterns in individuals and children with ASD and compared with normal individuals.
- ii. Pinpoint the anomalies from the data obtained from ASD and compare with the normal group to identify the unique difference or the common markers for the particular group.

4. Methods

The data were obtained from QEEG finding from a sample of ten individuals diagnosed with ASD and 10 normal individual. The data obtained from the normal group were used as a comparison to identify the unique difference or the common markers for this particular group

Participants

The ASD group composed of 10 participants diagnosed with ASD, ranging in age from 5-18 years were recruited from Kuching Autism Association Sarawak. The normal group consisted of 6 male participants and 4 female aged 7-21 years were volunteers. Inform consent were obtained from the parents and normal young adults above 18 years of age. The normal individual had no history of neurological disorders or mental illness as assessed through the personal interview, self-report and mental fitness screening profile.

Refer to Table 1 for the demographics characteristics of the participants involved in the study.

Table 1:

Participant’s demographics characteristic

Demographic Background	Component	ASD	Normal	Frequency	Percentage (%)
Gender	Male	10	6	16	80
	Female	0	4	4	20
Age	Below 6	1	0	1	5
	7 to 12	5	7	12	60
	13 to 15	0	0	0	0
	Above 16	4	3	7	35
Ethnic	Native	1	7	8	40
	Non-Natives	9	3	12	60

5. Procedures

The procedure begins when the EEG data were recorded by means of the Mitsar amplifier from 19 electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2 sites in the International 10-20 system) with 250 Hz sampling rate in 0.3 – 70 Hz frequency range in the resting eyes opened (EO) conditions. During the recording, participants sat comfortably on a reclining leather sofa. The duration of the recording session was approximately from 10-30 minutes.

The EEG is then stored on a computer. The subsequent steps are to visually inspect the data and remove the artifacts (movement, interference, noise, etc) and compute the fast fourier transform (FFT) providing spectral analysis output to examine for peculiar patterns. The output is then displayed as topographical “map” to identify for differences in cerebral functioning using estimates of absolute and total power.

The spectral analysis for the four EEG bands were imported into Microsoft excels for computation of z scores for each of the measurements used in QEEG such as absolute power (uV^2), frequency (Hz) and symmetry. The z scores were computed from the mean of absolute power (uV^2), and to be compared across the different normally distributed sets of data from the international 10/20 system (Fp1, Fp2, Fp3, Fz, Fp4, F7, F8, C3, Cz, C4, P3, P4, T3, T4, T5, T6, O1, O2). The z score is the difference between the mean score of a population and the patient’s individual score divided by the standard deviation of the population. The Z value indicates how “deviant” an individual’s score is from the mean. In the case of qEEG data, the Z-score indicates whether there is deficient or

excessive activity in a given frequency for a given electrode (or group of electrodes). The z score graphs were plotted to indicate a collective impression of the location, degree of deviation and difference of individual's qEEG abnormalities from the normal.

6. Results and discussion

Findings revealed the presence of excessive slow wave activity (delta and theta) at the prefrontal lobe and Frontal lobe or roughly regions Fp1, Fp2, F7 and F8, and O2 or right posterior regions. The z score graphs for the four EEG bands were plotted to allow visual inspection of QEEG patterns in individuals and children with ASD and compared with normal individuals. (Look at Figure 1(a), (2a), (3a) and (4a) and Figure 1(b), (2b), (3b) and (4b) below)

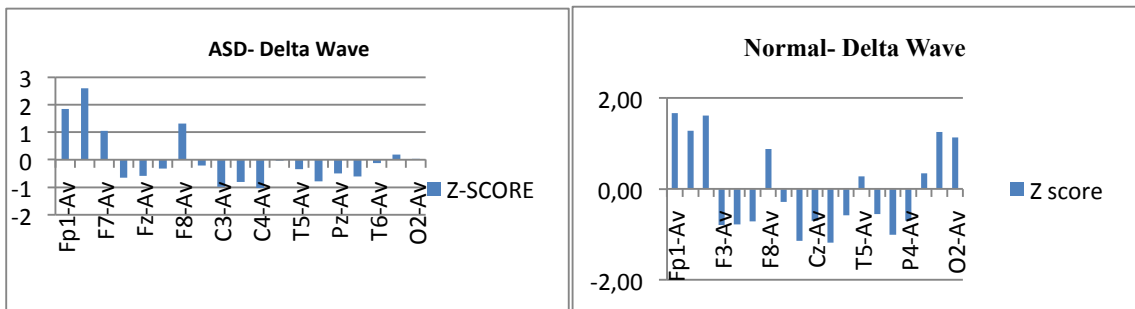


Figure 1 (a)

Figure 1 (b)

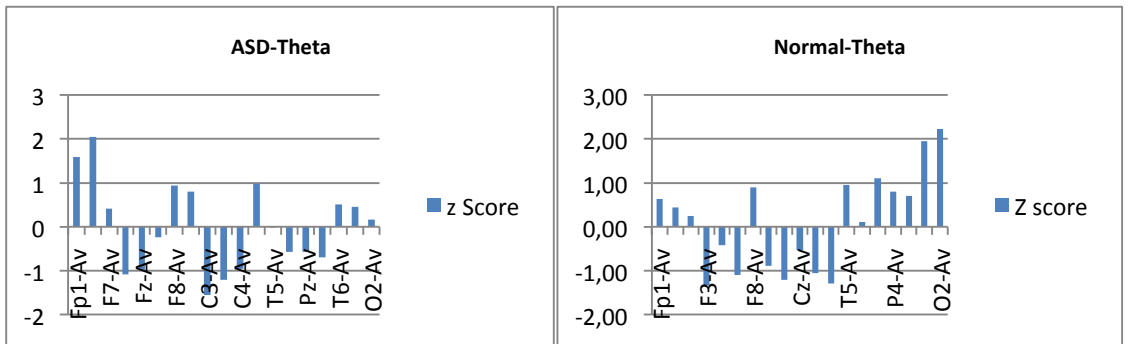


Figure 2 (a)

Figure 2 (b)

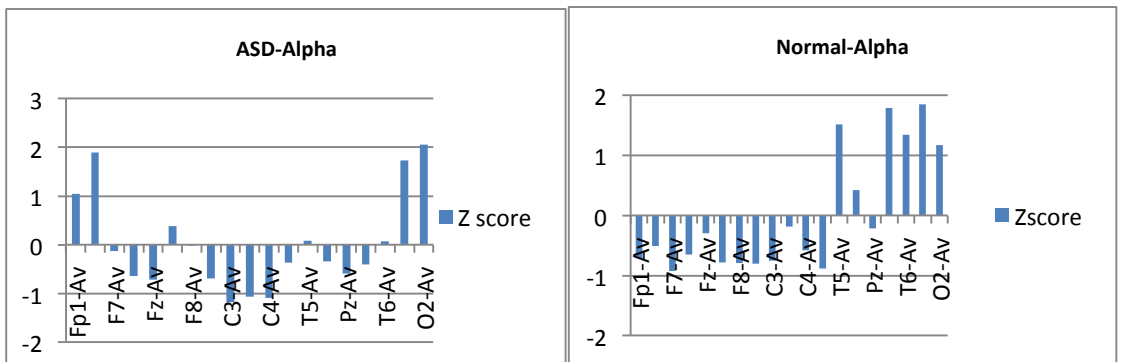


Figure 3(a)

Figure 3 (b)

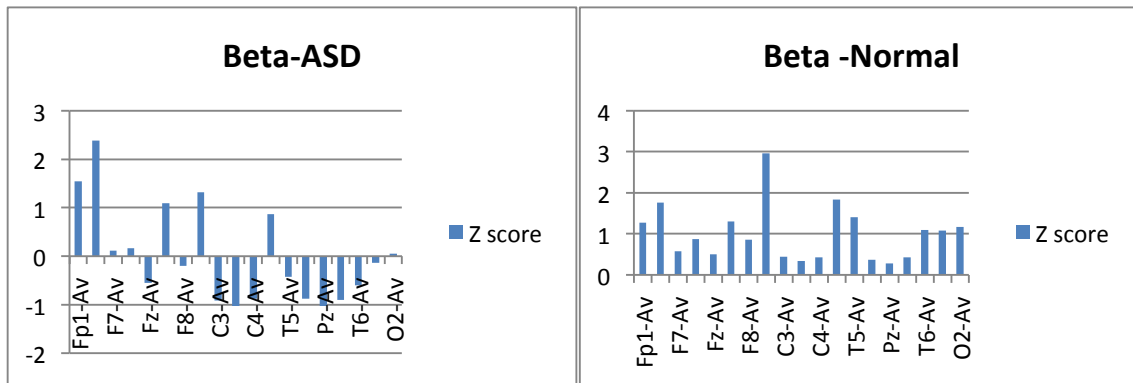


Figure 4 (a)

Figure 4 (b)

Figure 1(a), (2a), (3a) and (4a) showed the z scores of ASD children brain waves pattern from each of the points in the international 10/20 system in comparison with the brain waves from Figure 1(b), (2b), (3b) and (4b) from the normal group. Several electrodes are grouped together to designate a region of interest. The regions include electrodes such as ; Left Lateral – F7, T3, T5, Right Lateral – F8, T4, T6, Left Medial – FP1, F3, C3, P3, O1, Right Medial – FP2, F4, C4, P4, O2, Left Anterior (Frontal) – FP1, F7, F3, Right Anterior(Frontal) – FP2, F8, F4 ;Left Central – T3, C3; Right Central – T4, C4 , Left Posterior – T5, P3, O1, Right Posterior – T6, P4, O2, Mid (Midline) – FZ, CZ, PZ.

6.1 EEG bands and z scores distribution

Delta wave (1.5 -3.5 Hz) and Theta (3.5-7.5 Hz)

Individuals with ASD demonstrated excessive presence of slow wave activity (delta) at the frontal area (Fp1,Fp2 and F8) with a z score of more than +2.05 from the mean at Fp2.(Figure 1 (a)). The distribution of theta waves demonstrate more frontal involvement as shown in Figure 2 (a). They appear to demonstrate higher level activity as evced by excess fast waves (beta) at Fp2 (Figure 4.a.) with a standard deviation of +2.38. This might relate to hyper or hypo functioning of the localized area especially at the frontal lobe suggesting faulty neural integration between frontal and the posterior regions.

Alpha (7.5-12.5 Hz)

Visual inspection of the z scores in Figure 2(a) ASD- Alpha hythm (8-13 Hz) seems to show an attenuation of Alpha rhythm (8-13 Hz) over the sensory motor regions. The z scores at C3,Cz and C4 were -1.18, -1.07 and 1.06 respectively. The presence of Alpha indicate the presence of mirror neuron activity, the variant that might explain the ASD childrens’ behavioral imitation impairment and inability to mimic an instructed tasks (Oberman et al, 2005) The Negative z scores at the sensory motor area (C3, C4) as demonstrated in Figure 2 (a) and within Temporal-parietal area which corresponds with T3,T5, Pz,P3,P4 indicates abnormalities. The distribution of Alpha amplitude should build positively towards the posterior regions, as displayed by the amplitude of the normal group in Figure 2 (b) where the pattern of deviations was different from the ASD. However, the significantly low absolute amplitude value at frontal-temporal areas indicated by the negative z scores might suggest artifact contamination. Inspection of the graphical presentation of the z scores demonstrated that the normal group did not exhibit the same activity as the ASD group. Specifically, the normal group demonstrated alpha predominantly in the posterior regions.

Beta (12.5 -25 HZ)

There is insufficient presence of beta in most of the brain regions compared to the normal group. Regions at Fp1, Fp2 recorded a high presence of beta than the posterior regions at T5, T6, P3, P4, O1 and O2 which recorded deficiency of beta wave with negative z scores that indicates abnormalities. This might explain disconnectivity issues between frontal and posterior regions and their subsequent behavior or disabilities. Deficiency in beta brainwave were often associated with problem in attention, learning disabilities and brain injuries [7].

6.2 Anomalies at the Frontal and Posterior Regions

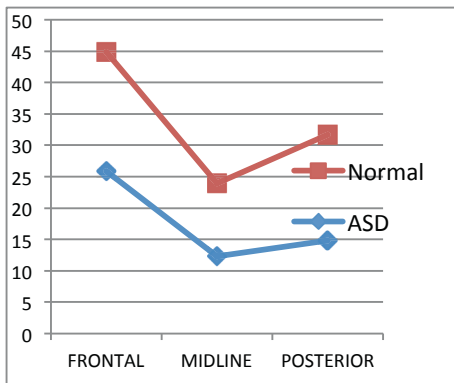


Figure 5 Absolute Delta

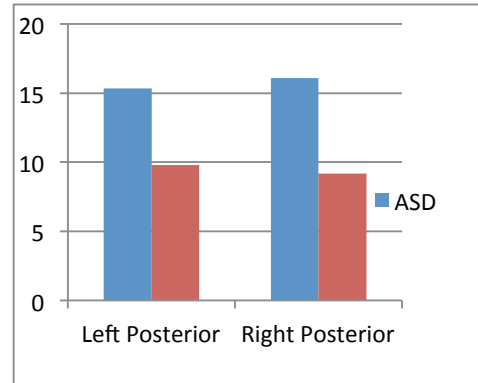


Figure 6 Left –Right Posterior ASD

Figure 5 revealed the excessive presence of delta wave at the prefrontal and Frontal lobe. The higher presence of slow activity in the right hemisphere at the posterior region of the brain indicated in Figure 6 might explain the associated social impairments among the ASD children. Hypofunction at the temporal occipital area in the right hemisphere corresponding with T4 and T6, resulted in lack of social interactions among ASD children. Fusiform gyrus, located at this area is highly involved in the processing of facial recognition and emotions.

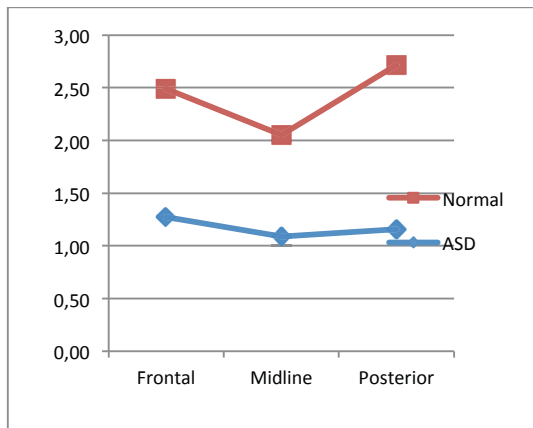


Figure 7 Absolute Theta

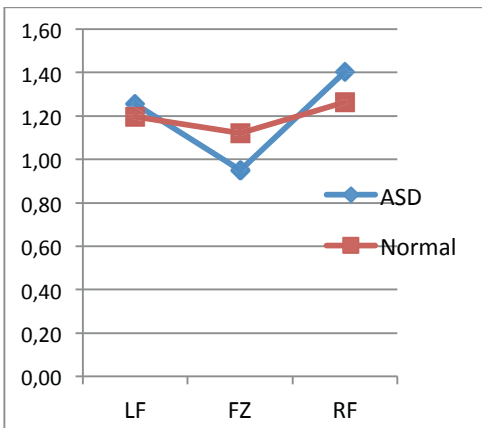


Figure 8 Left-Right Frontal

Theta brainwave was observed to be higher among the normal group, but more diminished in left hemisphere with recorded lower intensity of theta value at the left hemisphere compare to right hemisphere. The lowest intensity of theta brainwave was 0.83 (uV²) at C3 area (Left Hemisphere) among the ASD. Figure 7 shows the distribution of theta waves among the ASD and the normal group with more intensity and synchronization of

theta between the frontal and posterior region among the normal group. However, there are increase in the absolute power of theta in the right frontal hemisphere among the ASD children as demonstrated in Figure 8 Normal theta is important as it mediates and/or promotes adaptive activities such as learning and memory. Learning and memory reflected activity carried by the limbic system and hippocampus region located at the posterior temporal area. Insufficient theta will disrupt the internal focus and cause difficulties in activities such as learning and memory [8].

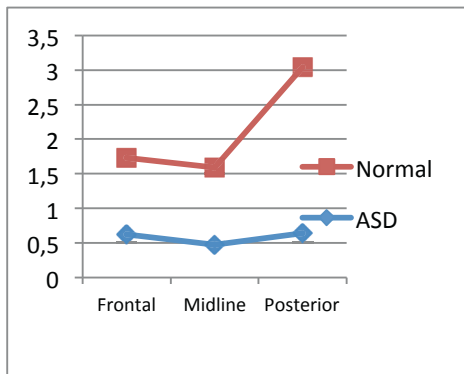


Figure 9 Absolute Alpha

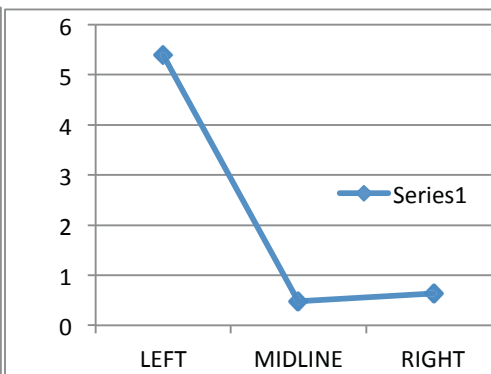


Figure 10 Left-Right Hemisphere of ASD

The brain wave pattern of ASD group is characterized by lower Alpha frequency compared to the normal group as demonstrated by Figure 9. Alpha amplitude of the normal children is building towards the posterior regions (Q-Metric-Inc, 2013), sufficient alpha is needed for sensory processing and integration and insufficient of alpha brainwave is associated with anxiety state. However, excess of alpha brainwave is associated with attention problem, depression and memory deficiency [7]. There are excessively high frequency of alpha wave in the left hemisphere of ASD children which indicated hyperfunctioning. Excess of alpha brainwave at the temporal area (T3) is linked to impairment in verbal memory [9] leading to language and communication impairments among ASD children. Figure 10 shows the excessive presence of Alpha in the left hemisphere of the ASD children.

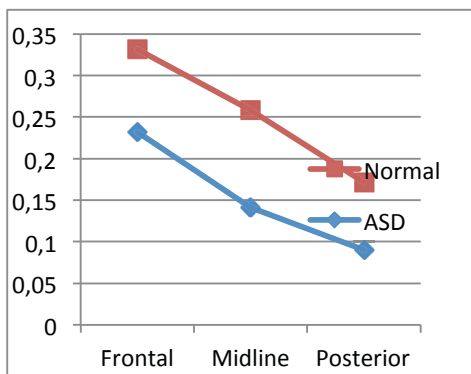


Figure 11 Absolute Beta -Frontal and Posterior

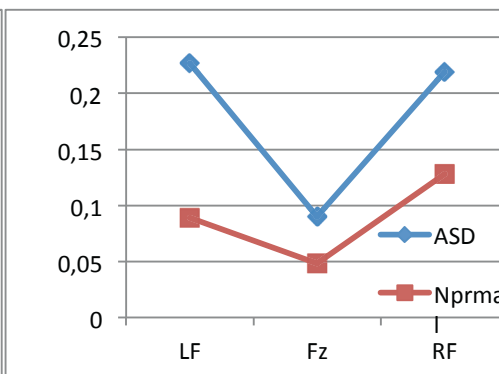


Figure 12 Beta at Left Frontal (LF) and Right Frontal

There is insufficient presence of beta in most of the brain regions compared to the normal group. Regions at Fp1, Fp2 recorded a high presence of beta than the posterior regions at T5, T6, P3,P4, O1 and O2 which recorded deficiency of beta wave. Thus, indicated no connections of frontal and posterior regions. Deficiency in beta brainwave were often associated with problem in attention, learning disabilities and brain injuries [7]. High beta at

FP1 and FP2 at the right frontal lobe area is associated with anxiety, irritability and also poor integration which might explain language impairment and anxiety of children with ASD.

7.0 Conclusions

The findings revealed consistencies in the QEEG subtypes pattern as discussed in the previous studies by [3,4] . There is a general disruption in the overall connectivity of the different lobes to themselves and to each other known as hyper or hypoconnectivity. Excessive presence of slow wave (delta) at the frontal lobe and excessive presence of beta waves might relate to hypo functioning and hyper functioning at the localized area. Insufficient presence of Alpha wave (8-12 Hz) at the sensory motor regions explains the ASD children's behavioral impairment and inability to mimic the instructed tasks. The presence of Alpha indicate the presence of mirror neuron activity or particular rhythm called "mu", a characteristic waveform found in the 8-13 hz (alpha) [10] . However, there were excess of alpha brainwave at the temporal area (T3) which is linked to impairment of language and communication among ASD children as compared to the normal individual where the alpha is building towards the posterior regions. Insufficient presence of beta in most of the regions such as T3,T4,O1and O2 which indicated no connections of frontal and posterior regions. More significantly, there was a pattern of under connectivity in autistics compared to normal participants. These results suggest faulty neural integration of frontal and posterior brain regions in autistics along with a pattern of neural under connectivity. This is consistent with other research in EEG, MRI and fMRI research suggesting that neural connectivity anomalies are a major deficit leading to autistic symptomatology.

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