POWER SPECTRAL ANALYSIS OF EEG AS A POTENTIAL MARKER IN THE DIAGNOSIS OF SPASTIC CEREBRAL PALSY CASES

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ABSTRACT

The detection and diagnosis of various neurological disorders are performed using different medical devices among which electroencephalogram (EEG) is one of the most cost effective technique. Though significant progress had been made in the analysis of EEG for diagnosis of different neurological disorders, yet detection of cerebral palsy (CP) is not quite clear. This study was performed to analyze the EEG power spectrum density (PSD) of spastic CP and normal children to find if any significant EEG patterns could be used for early detection of CP. Twenty children participated in this study out of which ten were spastic CP and other ten were normal healthy children. EEG of all the participants was recorded from C3 C4 and F3 F4 regions following montage 10-20 system. The artifact-free EEG signals of 15 minutes duration was extracted for spectral analysis using Fast Fourier Transformation (FFT) algorithm in MATLAB and power density spectrum (PSD) was plotted. The PSD revealed high intensity power peak at frequency of 50Hz and smaller at 100 Hz, which was consistent for all healthy subjects. In case of spastic CP children, high intensity peak at 100Hz were prominent and smaller peak was observed at 50Hz. The high intensity 100Hz peak observed in the PSD of spastic CP patients demonstrated that this tool can be used for early detection of spastic CP.

KEYWORDS:

Cerebral palsy, electroencephalogram (EEG), Fast Fourier Transformation (FFT), power spectrum density (PSD)

1. INTRODUCTION

Brain's electrical activity had been continuously studied to understand its function or to diagnose neurological disorders. Various medical imaging devices are employed for the diagnosis of neurological disorders; but none of these are as cost effective and practical as using an electroencephalogram (EEG). EEG recordings are obtained by placing the electrodes on the surface of the scalp to acquire signals that have a frequency range which spans from 0 to 100Hz where different frequency bands represent different activity levels [1]. EEG provides real time

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pictorial information of the cerebral activity that help in the identification and classification of a number of neurological disorders in both pediatric and adult population [2]. Recently, EEG is widely used to detect brain's neurological dysfunction such as epilepsy, Parkinson's disease, Alzheimer's disease, etc. [3,4,5]; and in the study of mental stress [6], effect of anesthesia [7], dyslexia[8], and so on; but the role of EEG in detection of cerebral palsy (CP) has not been well established [9,10].

Cerebral palsy also known as static encephalopathy causes abnormality of movement and posture; it occurs due to lesion of a developing brain in children below the age of two years. CP results in different movement patterns including spastic, dyskinetic, hypotonic, ataxic, and mixed forms; among which the most common is spastic affecting almost 70 to 80% of the patients [11]. The motor disorder in CP is often accompanied by disturbances of sensation, perception, cognition, communication, behavior, epilepsy and secondary musculoskeletal problems [12]. These problems arise due to abnormal brain activity in these children which was noted by Perlstein*et al* (1955), who studied 1217 CP patients and found that 90% of them had abnormal electroencephalogram (EEG) recordings [13]. Similar conclusions were given by Lindsley and Jones (1956); Melin (1962) and Al-Sulaiman (2001) after performing EEG studies on CP patients [14,15,16].Thus this study was aimed at analyzing the EEG power spectrum density (PSD) of spastic CP and normal children to find if any significant EEG patterns were presentwhich could be used for early detection of CP.

Power spectral analysis is one of the widely used methods for quantification of EEG signal. The PSD provides 'frequency content' of the signal or the distribution of power over frequency. PSD analysis is a mathematical method for frequency analysis of complex waveforms, which provides a sensitive means for detecting periodicity within the waveforms and determining the relative energy content of the periodicities. This method has been useful in computerized analysis of EEG using Fourier transformations [17].

2. MATERIALS AND METHODS

2.1 Participants

Twenty children were recruited in this study after informed consent from their parents or guardians and approval by the Institutional Ethics Committee on Human Samples or Participants. Ten participants were spastic CP children (7 male and 3 female, mean age: 8.1 $\pm$SD 4.20) and other ten were normal healthy children (6 male and 4 female, mean age: 8.6 $\pm$SD 3.31) not suffering from any neurological disorders. The spastic CP children were screened on the basis of their reports from registered medical practitioner and physiotherapists. The recruited children (both CP and normal) were from the out-patient department of UDAAN-for the differently abled, a non-profit organization in Delhi that has pioneered in rehabilitation based treatment using physical, occupational, speech therapy since 1992 and it also runs anoutreach learning program for the normal children of nearby areas from the low income group families.

2.3 EEG recording

The EEG recording on the participants was performed using Nexus Mark II, neurofeedback system (Mind Media B.V., Netherlands). Prior to recording, the participants underwent a preparatory procedure, where the participants were asked to sit on the chair and relax. The target recording areas on their scalp was cleaned using alcohol swabs and the metal electrodes were fixed into those areas using a conductive gel. The selected recording areas were F3, F4 and C3, C4; the reference electrode was placed at right mastoid (figure 1).The electrodes were placed according to the internationally recognized Montage 10-20 system [18]. After the electrode placement was completed, the recording was started which continued for 20 minutes at an output rate of 256 samples per second using a 2 channel bipolar electrodes. The entire recording of EEG signal was performed without using any anesthetics and hence the participants were awake during the process. After completion of the recording, electrodes were removed and the conductive gel on the scalp of the patients was washed with water.

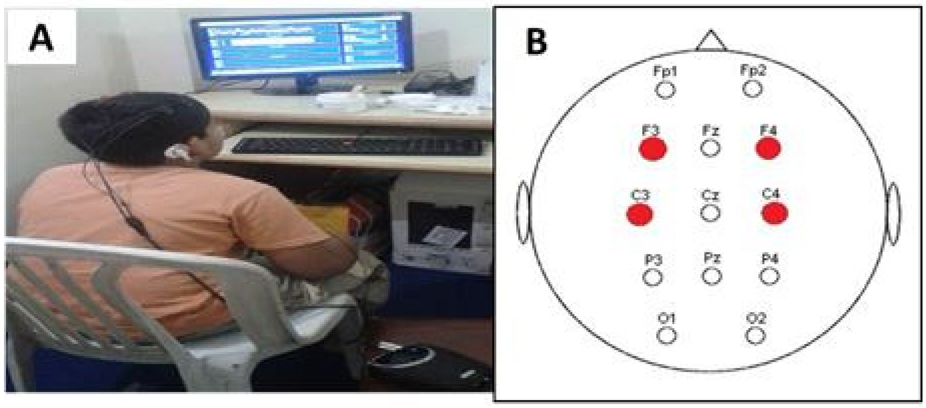


Figure1: A) EEG recording of a normal child: B) 10-20 showing recording areas

2.4. Data Analysis

The recorded EEG signal was imported in an ANSI text file format from the Biotrace+ software that runs the Nexus Mark II, neuro feedback system. Pre-processing of EEG signals such as removal of artifact and noise was performed using the software prior to converting the signals into ANSI text file.The ANSI text file was used for data analysis in MATLAB. The EEG data of 15 minutes was used for analysis with Fast Fourier transformation using Welch method to obtain the PSD which were plotted power versus frequency. Welch is a non-parametric method achieved by dividing the signal sequence into segments, multiplying the segment with an appropriate window and calculation of the periodogram by computing the squared magnitude on the result of its discrete Fourier transform. Individual periodogram obtained are then averaged, resulting in the measurement of power in relation to frequency [19]. Welch method offers to reduce noise if compared to the standard periodogram with fewer computations.

In this method the data sequences $x_i(n)$ can be represented as

$$x_i(n) = x(n + iD) \qquad \text{here } n = 0, 1, 2, \ldots, M - 1 \text{ and } I = 0, 1, 2, \ldots, L - 1$$

whereiD is the beginning of ith sequence. This will lead to formation of L data segments each of length $2M$. The modified periodogram is given as:

$$\tilde{P}_{xx}^{(i)}(f) = \left| \frac{1}{MU} \sum_{n=0}^{M-1} x(n)\omega(n)\, e^{-j2\pi fn} \right|^2$$

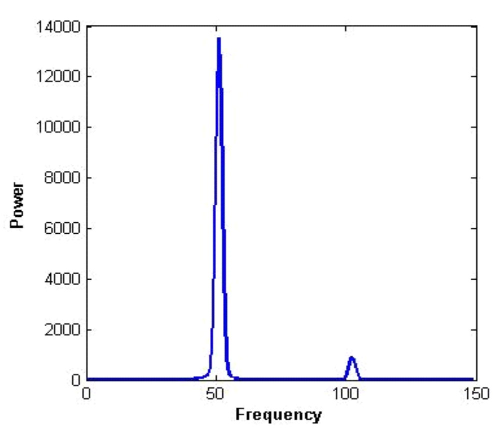
where$U$ is the normalization factor for the power in the window function given as: $U = \frac{1}{M}\sum_{n=0}^{M-1} \omega^2(n)$and $\omega(n)$ is the window function. Finally the Welch power spectrum which is the average of these periodogram is given as:

$$P_{xx}^{W}(f) = \frac{1}{L}\sum_{i=0}^{L-1} \tilde{P}_{xx}^{(i)}(f)$$

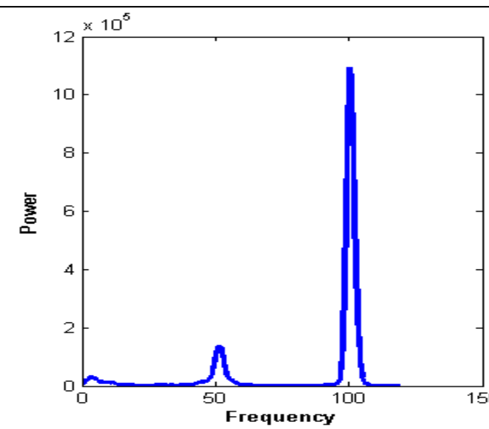
3. RESULTS

From the PSD of EEG signal, it was observed that there were two power peaks at frequency 50Hz and 100Hz. These power peaks were common, both in spastic CP and normal children; though slight variation such as power intensity and slight frequency shift (between 100Hz and 103Hz) was observed in different participants. The results from different areas of the brain and from different participant type are discussed below:

Table 1**:** PSD of central brain area ofnormal and spastic CP children(C3 C4).



PSD of normal participant



PSD of spastic CP participant

Case 1:

Table 1 represents two PSD plots of normal and spastic CP participants from the central area of the brain (C3and C4). The power peak of high intensity was consistently observed in all the normal childrenat frequency 50Hz and a small peak at 100Hz. In case of, spastic CP children, the power peak of higher intensity was observed at frequency 100Hz in 9 of the participants and comparatively low intensity peak at 50Hz were present

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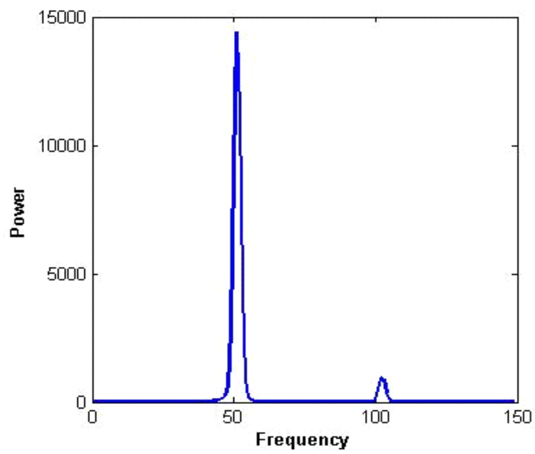
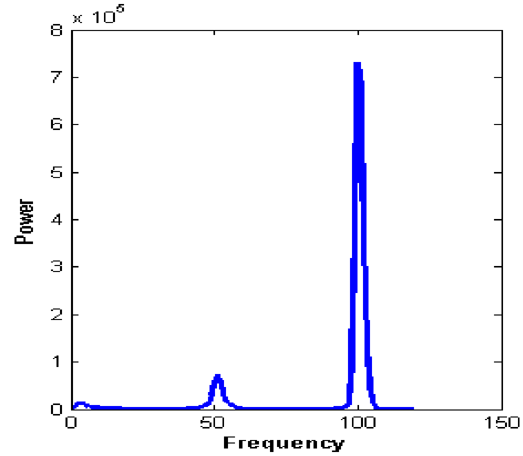
Table 2: PSD of frontal brain area of normal and spastic CP children (F3 F4).



PSD of normal participant



PSD of spastic CP participant

Case 2:

Similar to the PSD plots of central region, PSD of frontal area of normal and spastic CP participants also showed two peaks at 50Hz and 100Hz. Two sample PSD plots of normal and spastic CP participants from the frontal area of the brain (F3 andF4)are shown in table 2. The power peak of high intensity was consistently found in all the normal children at frequency 50Hz, along with a small peak at 100Hz. In spastic CP children, the power peak of higher intensity was observed at frequency 100Hz in eight of the participants along with a low intensity peak at 50Hz.

The high intensity peaks at frequency 100Hz observed in spastic CP patients could be due to the abnormal electrophysiological brain activity that affects their movement and posture, since the EEG recording areas used in this study are known for movement and motor planning.

4. DISCUSSION

Though significant progress had been made in the analysis of EEG signals using various algorithms yet the diagnosis of CP are still based on clinical assessment and neuroimaging findings such as Magnetic Resonance Imaging, Computer Tomography, Cranial Ultrasound and so on [20]. However, in the presence of associated seizures, it was essential for the electrical characterization of the seizure discharge, which is performed using EEG. As reported by previous researchers [15-18], EEG of CP patients demonstrate abnormal activity, thus we decided to find some pattern in the acquired signal using a FFT based algorithm such that EEG of these patients can be used for diagnostic purpose. If proven and established, this technique could be beneficial in examining large number of cases at comparatively lower costs. In our study, we used FFT based program in MATLAB to perform power spectral analysis of spastic CP and normal children. It was observed that PSD of spastic CP children from both central and frontal areas of the brain showed high intensity peaks at 100Hz which could be due to high neuronal activity in the motor areas that is responsible for their uncoordinated movement and posture. The 100Hz peak was observed in nine (9) out of the 10 children in the central region and eight (8) out of 10 in the frontal region of spastic CP children. PSD of 1 child in central and 2 children in frontal region showed a number of peaks at 3Hz, 20 Hz, 51Hz and 103Hz which could be due to errors during signal acquisition. Nevertheless, these findings are significant steps towards development of diagnostic tool for the detections of CP using cost effective EEG signals.

However, our study had some limitations - first, the study had a small sample size since we were considering only spastic CP patients due to their availability in the rehabilitation center. Second, the EEG signals were taken from C3C4 and F3F4 position only and not from any other parts of the brain. Third, PSD was obtained using only FFT- Welch method and no other feature extraction algorithm were employed.

5. CONCLUSION AND FUTURE WORKS

Previous researches had shown that CP patients have abnormal EEG but still the diagnosis of this disorder was not performed using EEG even thoughrecording of this signal is comparatively simple and cost effective. In this study we used the EEG signals of both normal and spastic CP participants to extract some meaningful feature using FFT-Welch method. The result of our study demonstrate that FFT based algorithm can be used to convert raw EEG signals into meaningful information that can be used for diagnosis purpose. The high intensity 100Hz peak in the PSD of spastic CP patient was consistent in the central and frontal areas of the brain; demonstrating that this can be used as potential markers in the early diagnosis of CP.Furthermore, in our future work we will consider more parameters which can demonstrate early diagnosis of different types of cerebral palsy.

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