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Brain wave power in Epilepsy: A power spectral EEG analysis

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Abstract

Background: Epilepsy is a neurological disorder associated with anxiety, depression, lethargy. The condition itself and antiepileptic medication may cause alterations in brain waves demonstrated by quantitative electroencephalogram(QEEG) study in epileptic patients. **Objective**: To evaluate brain waves using power spectrum analysis of QEEG in female epileptic patients. **Methods:** This observational study was conducted on 40 female epileptic patients (aged 20–40 years) and 40 healthy female volunteers of similar age were control. EEG of all participants were recorded by 22 scalp electrodes for five minutes in eye-close state using an EEG data acquisition device, EEG Traveler Brain Tech 32+ CMEEG-01 to assess cortical electrical activity. EEG data was subjected to power spectral analysis using BT40 analysis software. Independent-Samples T Test was used for statistical analysis. **Results:** When compared to controls, epileptic patients displayed considerably lower absolute power of alpha and beta brain waves and stronger delta and theta waves in almost all electrodes across all cortical regions. **Conclusion:** This study concluded increased slow frequency and decreased high frequency brain waves indicating high cortical excitability along with lack of relaxing power, were associated with epilepsy patients.

Keywords: EEG, Epilepsy, QEEG, brain waves, Power spectral analysis.

Introduction

Epilepsy is a neurological disorder that affects the electrical activity of brain, leading to seizures. The International League Against Epilepsy (ILAE) defined a seizure as "a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain." According to the World Health Organization (WHO), 50 million people suffer globally and in Asia 23 million have epilepsy.[1] Prevalence rate of epilepsy in Bangladesh is estimated to be 8.4 per 1000 people and more than half of epileptic patients did not receive any medical attention[2]. It is non-communicable with mostly unknown etiology but may be caused by a genetic abnormality, brain injuries,infection, tumor or abnormal brain development.[3]

This chronic illness has been reported with neurocognitive impairments, moderate to severe anxiety, depression, lethargy, fatigue and decreased working efficacy and the anti-epileptic drugs showing several side effects among them cognitive impairment, unsteadiness, sleepiness, tremor, depression and fatigue are common.[4-5]

The epileptic seizures in both ictal and interictal states can be diagnosed by qualitative study of EEG.[6] EEG is believed to reflect a variety of processes of the brain, especially the neocortex, in which our cognitive function and sensorimotor information are processed.[7] EEG activity patterns correlate with changes in cognitive arousal, attention, intention and evaluation.[8]

QEEG is a popular method for analyzing EEG data by distributing individual brain signal into discrete frequency ranges. Through the use of numerous scalp electrodes recording raw signals, individual frequency features can be extracted using the QEEG approach. It does this by using mathematical methods to transform analog signals into digital values. The goal of QEEG is to extract information from EEG data that is concealed and may not be immediately visible upon eye inspection.[9-10] power spectral density (PSD) of EEG signal provides the distribution of power over frequency. This method is useful in computerized analysis of EEG using Fast Fourier Transformation (FFT). Recently power spectral analysis of EEG signals is widely used in neurological research which can detect the change in the power of different frequency band waves in different given condition including different neurological disorders.[11] It has been used as a potential marker in the diagnosis of some neurological diseases.[12] Studies in neuroscience explore the effects of various interventions on brain activities by analyzing changes in powers of the basic brain waves (delta, theta, alpha and beta) specially in research of various relaxation techniques.[13] QEEG analysis in patients with epilepsy showed changes in brain waves, which is induced either by the disease itself or treatment with antiepileptic drugs A recent study reported association of increased slow frequency waves and decreased high frequency waves with epilepsy. Therefore, the study's objective was to assess the EEG absolute power of all brain waves in patients with epilepsy.

Methods

Study design and setting

This observational study was conducted at the Bangabandhu Sheikh Mujib Medical University (BSMMU) physiology department in Shahbag, Dhaka, between March 2023 and February 2024.

Study participants

Forty (40) 20–40 years old women diagnosed with epilepsy were chosen from the Neurology Out-Patients Department (OPD) at BSMMU in Shahbagh, Dhaka. Forty volunteers who matched in age, sex, and BMI and appeared healthy were chosen. No central nervous system-affecting medications were taken by any of the subjects. They were all right-handed. [14,15]

Sampling

Both the patients and the control participants were chosen using purposive sampling.

Exclusion criteria

Patients with a history of smoking, alcoholism, pregnancy, lactation, or menstruation were not included. Every participant had normal blood pressure, no diabetes, and no thyroid condition.[16]

Data collection

Each participant's complete medical history was recorded, and their informed written consent was obtained. Following that, each of them had a handedness test using the Edinburgh Handedness Inventory (EHI) scale[17]. They were then instructed to appear at the Noorzahan Begum Neurophysiology Laboratory at the Department of Physiology, BSMMU, between 8 and 8:30 AM on the day designated for EEG recording, after which they were given a detailed explanation of the process and preparation for the sessions and EEG recording. In order to avoid feeling exhausted or sleepy during the EEG recording process, the subject must have slept well the night before. Additionally, they were instructed to wash their hair well the day before the experiment to eliminate oil from the scalp using a gentle, non-fragrant shampoo and to avoid using any perfumes, deodorants, or sprays twelve hours before the test.[18] They were instructed to avoid caffeine-containing beverages such tea, coffee, or cola for three hours before to the experiment and to eat a light meal in the morning. Additionally, they were told to wear clean clothes and avoid from applying any fragrances, sprays, or cosmetics to their bodies.[19] When the subjects arrived, they were given a sterile, odorless gown that was especially designed for the experiment. Prior to the actual EEG recording, participants were then permitted to relax in a cozy armchair in the lab's cool, serene setting for ten to fifteen minutes. The individual was instructed to avoid from speaking, eating, or drinking during this time, as well as from performing in any mental or physical activity, including sleeping.

Laboratory setting

To provide the highest possible level of error-free quality data, the laboratory environment was strictly regulated to reduce environmental effects on the digital data recording device. In order to limit sunlight and outside noise, the laboratory's temperature was kept between 23°C and 25°C, and the lights were kept low.[18] During the test, the lab door was closed and nobody was permitted to enter or exit the space.

EEG data recording

The international 10-20 system was followed in placing a set of 22 electrodes, including the ground electrode, on the scalp surface of each patient using conductive and adhesive EEG paste. Both groups performed a 5-minute EEG recording session with their eyes closed.

The recording of EEG measures was done by EEG (traveler) BrainTech32+ CMEEG-01(India) and analysis was done the software Brain Tech 40+ Standard version 4.47a. A high pass filter was set at 1 Hz to reduce lower frequencies and a low pass filter was set at 35 Hz to ensure the signal is limited to the highest frequency of beta band .[20] The gain was set at 7.5 μv/mm. By default Analog to digital (A/D) conversion was 24 bits, the notch filter was at 50 Hz, sampling rate was 1024 Hz (Clarity, India). In this device it was by default at 20K ohms indicating that the values of impedance should be less than or equal to this. Recorded EEG signals was displayed as brainwaves (analogue) in specific electrode on the window. Using Fast Fourier Transformation (FFT), this analogue signal was digitalized by default A/D converter. The default software of this device then generated a frequency table with the power spectral parameter (Absolute power) for each specific EEG frequency bands (delta, theta, alpha, and beta) which were recorded.

Statistical analysis

The Shapiro-Wilk test was used to assess the distribution of all the data. The mean ± SD was

used to express the data. For statistical analysis, SPSS for Windows, version 25, was used. After determining that the data were normally distributed, the Independent-Samples T Test was performed.

Results

In this study, female epileptic patients and healthy controls shared similar general features (Table I). Everyone who took part was right-handed.[21] For both patients and control participants, the absolute power (uV2) of each EEG frequency band (delta, theta, alpha, and beta) was measured. The information was displayed in Tables II, III, IV, and V. The topographical mapping of every frequency band was displayed in Figure I. Our findings revealed that, across all cortical areas, patients with epilepsy had significantly (P value ≤0.05) lower alpha and beta absolute power and significantly (P value ≤ 0.05) higher delta and theta absolute power than healthy controls.

Table I: General characteristics of the subjects (N= 40)

Parameters	Epilepsy (n=40)	Control (n=40)	p value
Age (years)	30.10±4.7	31.30 ±4.01	0.390
BMI (Kg/m2)	22.55±1.4	23.00±1.7	0.384
Resting pulse (beats/min)	80.80 ±7.2	80.35 ±6.6	0.839
Resting SBP (mmHg)	113.25 ±10.6	112.75±7.8	0.867
Resting DBP (mmHg)	71 ±5.9	72.75 ±5.9	0.360
Respiratory rate (breaths/min)	13.85 ±1.2	14.10 ±1.4	0.553
Temperature (°F)	98.15±0.7	98.37 ±0.4	0.245
Oxygen saturation (SpO2)	98.90 ±0.9	98.60 ±0.8	0.297
Handedness (Score)	72.75 ±8.0	71.25 ±9.30	0.588

Data were expressed as Mean ± SD. Statistical analysis was done by Independent Samples "T" test. Here, N-Total number of subjects; n-number of subjects in each group; BMI- Body Mass Index; SBP- Systolic Blood Pressure; DBP- Diastolic Blood Pressure; SpO2-Peripheral oxygen saturation

Table II: Absolute power (μV2) of Delta wave distribution in brain cortical regions in two group at baseline (N=40)

Cortical regions	A1(n=20)	B1(n=20)	P value
Prefrontal	10.93 ±3.8	3.19±1.3	0.000
Frontal	6.56 ±3.2	1.71±0.5	0.000
Parietal	5.35 ±2.7	1.52±0.9	0.000
Temporal	5.64±3.2	1.72±1.4	0.000
Occipital	9.73±5.2	2.31±1.1	0.000

Data were expressed as mean ±SD. Comparison of data was done by Independent-Samples T Test, Here N= Total number of subjects, n=total number in each group, A1= Patients with epilepsy at baseline, B1= Control group at baseline.

Table III : Absolute power (μV2) of Theta wave distribution in brain cortical regions in two group at baseline (N=40)

Cortical regions	A1(n=20)	B1(n=20)	P value
Prefrontal	7.70±3.5	1.38±0.6	0.000
Frontal	6.27±3.4	1.20±1.0	0.000
Parietal	3.79±3.4	0.96±0.4	0.000
Temporal	5.21±3.0	1.10±0.6	0.000
Occipital	8.38±3.53	1.79±0.9	0.000

Data were expressed as mean ±SD. Comparison of data was done by Independent-Samples T Test, Here N= Total number of subjects, n=total number in each group, A1= Patients with epilepsy at baseline, B1= Control group at baseline.

Table IV : Absolute power (μV2) of Alpha wave distribution in brain cortical regions in two group at baseline (N=40)

Cortical regions	A1(n=20)	B1(n=20)	P value
Prefrontal	2.43±0.7	3.98±1.5	0.000
Frontal	1.93±0.5	2.90±1.4	0.000
Parietal	2.12±0.7	3.69±2.3	0.000
Temporal	2.06±0.8	3.83±2.9	0.000
Occipital	3.17±1.4	6.75±4.1	0.000

Data were expressed as mean ±SD. Comparison of data was done by Independent-Samples T Test, Here N= Total number of subjects, n=total number in each group, A1= Patients with epilepsy at baseline, B1= Control group at baseline.

Table V: Absolute power (μV2) of Beta wave distribution in brain cortical regions in two group at baseline (N=40)

Cortical regions	A1(n=20)	B1(n=20)	P value
Prefrontal	1.48±0.4	1.78±0.8	0.008
Frontal	1.36±0.4	1.66±0.4	0.000
Parietal	1.12±0.3	1.29±0.3	0.000
Temporal	1.05±0.3	1.39±0.6	0.000
Occipital	1.16±0.4	1.40±0.6	0.000

Data were expressed as mean ±SD. Comparison of data was done by Independent-Samples T Test, Here N= Total number of subjects, n=total number in each group, A1= Patients with epilepsy at baseline, B1= Control group at baseline.

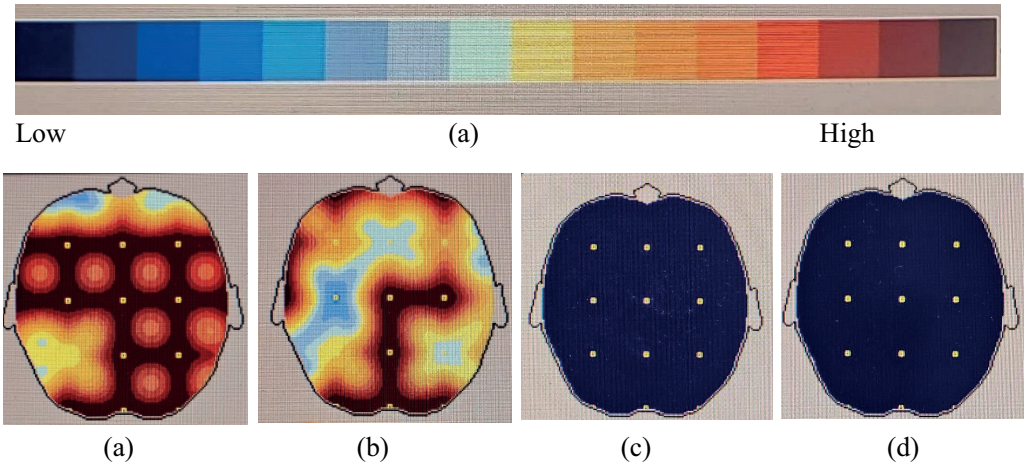

Figure 1: Brain topographic map showing distribution of brain waves in patients with epilepsy at baseline (a) a color-coded scale representing lower to higher power values; (b) distribution of delta wave (b) distribution of theta wave; (c) distribution of alpha wave; (d) distribution of beta wave.

Discussion

The EEG results showing higher absolute power of delta and theta in all cortical regions of their brains in both hemispheres in epilepsy than healthy volunteer, agrees to previous studies though some difference were there in distribution of the scalp area and treatment discrimination.[22,23,24,25]

Higher spectral power in the delta and theta bands, primarily in the left hemisphere and central region in Idiopathic generalized epilepsy and also in other sub categories such as grand mal seizure on awakening, juvenile myoclonic epilepsy and juvenile absence epilepsy during their interictal period has been published similar to our observation.[25,26] Epilepsy caused alterations in the spectral power EEG, which were unrelated to AED use.[27] According to published research, 50% of people with epilepsy also were affected with mental health issues. AEDs and surgery were also recognized as potential risk factors for these patient's development of psychiatric disorders.[26]

Although the patients in our study were not undergone mental health evaluation, but the higher power of slow-frequency waves in these patients suggested their depressed mental health. Researchers found higher delta and theta power in major depressive disorder patients compared to normal psychology subjects.[27,28] The literature explains the significance of absolute power suggesting its use to evaluate the overall image of neural synchronization. On the other hand, relative power quantifies the specific frequency band's contribution to the synchronization of neurons. It has also been stated that increased or decreased synchronization, reflected by the changes of these power values hints the underlying neurophysiological disturbance in epilepsy.[24]

In this study, lower absolute of alpha and beta in all cortical regions in epilepsy patients compared to healthy control were similar to the observation of other researches in similar studies. Alpha waves are normally predominant in awake but in a state of quiet, resting cerebration reflecting moderate cortical activity and commonly located in occipital cortex and thalamus. They are prominent in adults and occur when an individual is temporarily idle but still alert.[29,30]

Alpha brain waves are related with enhanced state of relaxation and calmness and beta waves

is found when an awake person's attention is directed to some specific type of mental activity or vigilance.[31,32,33]

Lower alpha and reduced beta power suggest decrease state of relaxation and decrease cognitive and motor activity[34] associated with hyperactive cortex but increased sleepiness.[11,30] These features are also found in our study epilepsy patients. So lower alpha and beta may confirm this altered psychological state in epilepsy. These altered brain wave activity expressed in absolute power change may act as an index of epilepsy induced less relaxing capability and compromised attention and other higher cognitive task in epileptic patients. Therefore, power spectral analysis of EEG can be recommended as a tool for assessment of mental health in epileptic patients.

Conclusion

From the results of this study, it may be concluded that increased slow frequency and decreased high frequency brain waves demonstrating high cortical excitability along with lack of relaxing power, were associated with epilepsy patients.

Conflict of interest

There is no conflict of interests pertaining to this study.

Ethical clearance

The departmental ethical and academic committee first authorized the study protocol, which complied with the Helsinki (1964) ethical guidelines. The Institutional Review Board (IRB) of BSMMU then gave it additional review and approval.

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