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# Brain electrical activity in female Major Depressive Disorder patients

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## Abstract

**Background:** Quantitative EEG provides insight to the brain activity associated with depressive illness. Frontal asymmetry and changes of slow wave frequencies brain activity have been found as the characteristic features of Major Depressive Disorder (MDD). **Objective:** To assess the brain activity by power spectral analysis of EEG in female patients with MDD. **Methods:** This observational study was carried on 20 female MDD patients (age 20-40 years) enrolled from the Department of Psychiatry, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka. Twenty (20) healthy volunteers of the same age were considered the control group. For the study, EEG was recorded for 3 minutes in eye closed position by EEG data acquisition device, EEG Traveler BrainTech 32+ CMEEG-01, India. Power spectral analysis of EEG data was done by BT40 analysis software. For statistical analysis, the Mann-Whitney U test was done. **Results:** Significantly higher Absolute power of delta and theta brain wave, and lower alpha and beta brain wave activity was observed in female MDD patients compared to control in all most all electrodes in all cortical regions. **Conclusion:** MDD patients showed low excitable brain state and characteristic feature of high slow frequency wave and low fast frequency wave in MDD which can be diagnosed by quantitative EEG analysis.

**Keywords:** EEG, MDD, brain waves, QEEG, Depression, Power spectral analysis.

## Introduction

Major Depressive Disorder (MDD) is a subclass of depressive disorder which is characterized by depressed mood, and loss of interest in activities, for most of the day, nearly every day, for at least two weeks.[1] According to the latest updates, global prevalence of depression is about 3.8% and it is higher in female population.[1,2] In Bangladesh, almost 7 million people suffer from anxiety and depression.[3]

In addition to traditional symptom based diagnosis various objective based neuro imaging techniques are employed for better diagnostic evidence in various psychiatric illness.[4,5] EEG is believed to reflect a variety of oscillation of brain activity, especially the neocortex. Quantitative analysis of EEG data is usually employed for diagnosis of various neurological and psychiatric conditions including MDD.[4,5] Power spectral analysis was widely used for quantification of various frequency bands of waves.[6,7]

Previous studies report of high alpha activity in female depressed patients showed discrepancy in frontal inter-hemispheric alpha asymmetry in MDD patients which is considered as a risk marker for vulnerability of psychomotor retardation in depression.[8,9,10] Moreover the spectral power of EEG especially alpha asymmetry has been advocated as machine based important diagnostic tool for MDD.[11]

In addition, increased theta power was also observed in patients in the early stages of depression.[12] Many prognostic studies reported about the presence of excess theta activity in the anti-depressant resistant MDD patients which provides evidence for anti-depressant treatment failure.[13,14] One gender-based article reported depressed males showed lower delta power compared to females.[15]

Results of several studies were contradictory and varying regarding various EEG waves in MDD patients. Increased beta activity which contrast the MDD features and decreased alpha activity are also published.[12]

To validate the application of quantitative EEG as diagnostic and prognostic tool for MDD patients, it is important to explore the characteristics of brain wave pattern in MDD. Therefore, this present study has been designed to investigate brain waves pattern by power spectral analysis of EEG in female MDD patients.

## Methods

*Design and setting*

This prospective observational study was done in the Department of Physiology from September 2022 to August 2023.

*Study participants*

Twenty (20) newly diagnosed female MDD patients from OPD of Psychiatry were enrolled. Age, sex, BMI and socio-economic status matched 20 apparently healthy subjects were also participated as control.

*Sampling*

Purposive sampling was adopted to select the patients as well as the control subjects.

*Inclusion criteria*

Newly diagnosed female MDD patients following DSM-V criteria diagnosed by a psychiatrist, aged between 20-40 years. All the participants were free from medication that affects the central nervous system. All of them were right-handed.

*Exclusion criteria*

Smokers, alcoholic, menstruating, pregnant, and lactating.

*Data collection*

After taking history and informed written consent their baseline characteristics were recorded. Thereafter, all of them were tested for handedness by the Edinburgh Handedness Inventory (EHI) scale.[16,17] Then the detail procedure and preparation for EEG recording and the sessions were explained to all subjects. For EEG recording, the subject was asked to finish their dinner by

9:00 pm and had a sound sleep in the previous night, so that they would not be fatigued or drowsy during the procedure. From previous night up to the time of test, they were requested to avoid consciously any physical or mental stress and also avoid taking any sedatives or any other drugs that may affect central nervous system.[18] They were advised to wash their hair properly in the day before experiment to remove oiliness from the scalp with a mild non-fragrant shampoo and not to apply any sprays, antiperspirants or perfumes to their hair and body twelve hours prior to testing.[19] They were advised to have light breakfast in the morning without any caffeinated beverage such as tea, coffee or cola three hours before the experiment.[20] Upon their arrival, subjects were provided with clean odorless gown to wear specially made for this experiment. Then they were allowed to sit in a cool and calm environment of lab for rest in a comfortable armchair for 10-15 minutes before actual EEG recording.

EEG were recorded in laboratory environment with noise free, dim light and temperature between 23°C-25°C. [19]

EEG electrodes were placed on the scalp by international 10-20 system. A set of 22 electrodes including the ground electrode were placed onto her scalp surface using conductive and adhesive EEG paste. EEG recording was obtained for total 3minutes duration in eye closed position for both groups.[21]

The recording of EEG measures was done by EEG (Traveler) Brain Tech 32+ CMEEG-01(India) and analysis was done by 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.[5] 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). Impedance was set at 5K Ohms.[22] Recorded EEG was displayed as brainwaves (analogue) in specific electrode on the window. This analogue signal was digitalized by default analogue to digital (A/D) converter using Fast Fourier Transformation (FFT). By power spectrum analysis the frequency table showed the values of absolute power of delta, theta, alpha and beta wave which were recorded.

*Statistical analysis*

All data were checked for normal distribution by the Shapiro-Wilk test. Data were expressed as median (IQR). Data were found non-normally distributed, and then a non-parametric test Mann-Whitney-U test was done by using software SPSS 25.

## Results

In this study, the baseline characteristics were similar in MDD patients and healthy controls (Table I). All the participants were right-handed (table I). The absolute power (μV2) was calculated for each frequency band (delta, theta, alpha, beta) for both MDD and control group. Our results revealed there was significantly (p-value <0.05) higher delta and theta absolute power in MDD patients compared to control in all electrodes of all cortical regions. However, alpha power was significantly lower in all cortical regions except the overall prefrontal region though it was significant in electrodes. The difference in alpha power was also non-significant at F8 electrode of the frontal, and T3 and T4 electrodes in the temporal region. Beta power was significantly lower in all cortical regions except F8, CZ electrodes of the frontal region, and P3, P4 electrodes of the parietal region (Table II, III, IV and V). Topographical features of absolute power of all brain waves of MDD patients are shown in figure 1.

**Table-I :** The baseline characteristics of the participants (N=40)

| | MDD (n=20) | Control(n=20) | P value |
|---|---|---|---|
| Age (years) | 27.5 (13.25) | 30.5 (4) | 0.086 |
| BMI ($Kg/m^2$) | 22.39 (8.75) | 23.8 (9.25) | 0.128 |
| SBP (mmHg) | 116 (16.25) | 120.5 (9.75) | 0.399 |
| DBP (mmHg) | 78.5 (5.5) | 74.5 (11.5) | 0.059 |
| Pulse (beats/min) | 78 (11.5) | 76.5 (10) | 0.651 |
| $SpO_2$(%) | 97 (2) | 97 (1) | 0.302 |
| Handedness test (score) | 79 (6.5) | 80 (8.75) | 0.327 |

Data were expressed as median (IQR). Comparison of data between patient and control were done by Mann-Whitney U test. Here, N- Total number of subjects; n- Number of subjects in each group; MDD- Major Depressive Disorder

**Table II :** Absolute power ($\mu V^2$) of Delta wave in MDD patients and control (N=40)

| Cortical region | Electrode | MDD (n=20) | Control (n=20) | p value |
|---|---|---|---|---|
| Prefrontal | FP1 | 16.37 (15.12) | 2.17 (0.53) | 0.000 |
| | FP2 | 18.12 (20.93) | 2.15 (0.49) | 0.000 |
| | All above | 7.44 (14.24) | 1.56 (0.83) | 0.000 |
| Frontal | F7 | 6.47 (10.23) | 1.71 (0.91) | 0.000 |
| | F3 | 8.19 (8.79) | 0.91 (0.24) | 0.000 |
| | FZ | 6.31 (10.02) | 0.83 (0.32) | 0.000 |
| | F4 | 9.45 (12.49) | 0.95 (0.62) | 0.000 |
| | F8 | 6.32 (15.27) | 1.30 (1.44) | 0.000 |
| | CZ | 4.72 (5.58) | 0.77 (0.54) | 0.000 |
| | All above | 6.66 (10.56) | 0.99 (0.60) | 0.000 |
| Parietal | C3 | 7.02 (5.73) | 0.59 (0.47) | 0.000 |
| | C4 | 6.72 (5.58) | 0.67 (0.34) | 0.000 |
| | P3 | 4.95 (5.05) | 0.93 (0.59) | 0.000 |
| | PZ | 6.66 (6.28) | 0.72 (0.23) | 0.000 |
| | P4 | 5.49 (3.59) | 0.81 (0.44) | 0.000 |
| | All above | 5.5 (5.20) | 0.75 (0.42) | 0.000 |
| Temporal | T3 | 4.97 (12.58) | 1.10 (0.52) | 0.000 |
| | T4 | 15.58 (12.02) | 1.22 (0.98) | 0.000 |
| | T5 | 7.35 (10.54) | 1.20 (1.10) | 0.000 |
| | T6 | 7.25 (14.95) | 1.06 (0.51) | 0.000 |
| | All above | 7.62 (12.23) | 1.12 (0.78) | 0.000 |
| Occipital | O1 | 6.7 (5.23) | 1.26 (0.61) | 0.000 |
| | O2 | 8.69 (4.03) | 1.28 (0.59) | 0.000 |
| | All above | 8.21 (4.88) | 1.26 (0.80) | 0.000 |

Data were expressed as median (IQR). Comparison of data between patient and control were done by Mann-Whitney U test. Here, N- Total number of subjects; n- Number of subjects in each group; MDD- Major Depressive Disorder

**Table III :** Absolute power ($\mu V^2$) of Theta wave MDD patients and control (N=40)

| Cortical region | Electrode | MDD (n=20) | Control (n=20) | p value |
|---|---|---|---|---|
| Prefrontal | FP1 | 2.51 (1.93) | 1.12 (0.42) | 0.000 |
| | FP2 | 2.67 (2.33) | 1.06 (0.59) | 0.000 |
| | All above | 2.65 (2.21) | 1.11 (0.44) | 0.003 |
| Frontal | F7 | 1.58 (1.53) | 0.97 (0.40) | 0.165 |
| | F3 | 3.03 (1.97) | 0.85 (1.05) | 0.000 |
| | FZ | 2.71 (11.84) | 0.99 (0.57) | 0.000 |
| | F4 | 2.56 (1.22) | 0.85 (0.70) | 0.000 |
| | F8 | 1.75 (1.09) | 0.97 (0.51) | 0.000 |
| | CZ | 1.98 (1.07) | 0.92 (1.04) | 0.000 |
| | All above | 1.86 (1.60) | 0.96 (0.62) | 0.000 |
| Parietal | C3 | 1.63 (1.63) | 0.83 (0.43) | 0.000 |
| | C4 | 1.59 (0.84) | 0.73 (0.47) | 0.000 |
| | P3 | 2.81(2.62) | 0.93 (0.45) | 0.009 |
| | PZ | 1.00 (2.59) | 0.73 (0.42) | 0.002 |
| | P4 | 1.66 (1.44) | 0.72 (0.50) | 0.005 |
| | All above | 1.63 (2.18) | 0.79 (0.47) | 0.000 |
| Temporal | T3 | 1.83 (1.02) | 0.92 (0.71) | 0.000 |
| | T4 | 1.92 (1.57) | 0.89 (0.29) | 0.000 |
| | T5 | 2.29 (1.85) | 0.92 (0.91) | 0.002 |
| | T6 | 2.73 (4.02) | 0.94 (0.38) | 0.000 |
| | All above | 2.00 (1.61) | 0.92 (0.30) | 0.000 |
| Occipital | 01 | 2.58 (1.86) | 1.51 (1.16) | 0.001 |
| | 02 | 2.58 (1.56) | 1.47 (1.13) | 0.001 |
| | All above | 2.58 (1.61) | 1.51 (1.11) | 0.000 |

Data were expressed as median (IQR). Comparison of data between patient and control were done by Mann-Whitney U test. Here, N- Total number of subjects; n- Number of subjects in each group; MDD- Major Depressive Disorder

**Table IV :** Absolute power ($\mu V^2$) of Alpha wave MDD patients and control (N=40)

| Cortical region | Electrode | MDD (n=20) | Control (n=20) | p value |
|---|---|---|---|---|
| Prefrontal | FP1 | 2.26 (1.05) | 5.13 (2.19) | 0.002 |
| | FP2 | 2.46 (3.65) | 7.45 (2.16) | 0.001 |
| | All above | 2.32 (2.90) | 6.22 (2.09) | 0.085 |
| Frontal | F7 | 2.05 (2.34) | 5.33 (1.22) | 0.000 |
| | F3 | 2.64 (2.89) | 4.15 (3.40) | 0.021 |
| | FZ | 1.88 (4.66) | 4.46 (2.92) | 0.004 |
| | F4 | 2.06 (3.68) | 4.12 (2.58) | 0.018 |
| | F8 | 1.97 (2.52) | 2.66 (2.56) | 0.096 |
| | CZ | 1.52 (3.06) | 3.95 (3.07) | 0.004 |
| | All above | 1.92 (3.58) | 3.20 (3.03) | 0.000 |
| Parietal | C3 | 1.86 (1.68) | 3.40 (3.22) | 0.001 |
| | C4 | 1.73 (1.46) | 3.08 (2.58) | 0.000 |
| | P3 | 2.42 (3.25) | 4.13 (1.66) | 0.001 |
| | PZ | 1.60 (1.42) | 4.66 (8.72) | 0.000 |
| | P4 | 2.33 (2.54) | 7.92 (9.98) | 0.000 |
| | All above | 1.97 (1.67) | 3.92 (5.87) | 0.000 |
| Temporal | T3 | 1.61 (2.13) | 2.22 (1.07) | 0.231 |
| | T4 | 1.91 (1.43) | 2.44 (1.66) | 0.086 |
| | T5 | 2.22 (1.93) | 5.57 (2.58) | 0.002 |
| | T6 | 1.91 (6.87) | 5.67 (10.23) | 0.009 |
| | All above | 1.91 (1.85) | 2.81 (4.79) | 0.000 |
| Occipital | O1 | 2.79 (4.48) | 11.04 (13.86) | 0.000 |
| | O2 | 2.59 (6.09) | 7.71 (15.63) | 0.000 |
| | All above | 2.79 (4.74) | 10.0 (14.78) | 0.000 |

Data were expressed as median (IQR). Comparison of data between patient and control were done by Mann-Whitney U test. Here, N- Total number of subjects; n- Number of subjects in each group; MDD-Major Depressive Disorder

**Table V :** Absolute power ($\mu V^2$) of Beta wave MDD patients and control (N=40)

| Cortical region | Electrode | MDD (n=20) | Control (n=20) | p value |
|---|---|---|---|---|
| Prefrontal | FP1 | 0.67 (0.50) | 1.01 (0.45) | 0.000 |
| | FP2 | 0.65 (0.64) | 1.00 (1.01) | 0.017 |
| | All above | 0.67 (0.49) | 1.01 (0.74) | 0.000 |
| Frontal | F7 | 0.72 (0.46) | 1.43 (1.01) | 0.002 |
| | F3 | 0.67 (0.36) | 0.93 (0.25) | 0.003 |
| | FZ | 0.62 (0.33) | 0.78 (0.38) | 0.043 |
| | F4 | 0.76 (0.29) | 0.95 (0.69) | 0.005 |
| | F8 | 0.74 (0.32) | 0.84 (0.37) | 0.429 |
| | CZ | 0.58 (0.26) | 0.76 (0.52) | 0.102 |
| | All above | 0.70 (0.34) | 0.88 (0.43) | 0.000 |
| Parietal | C3 | 0.64 (0.43) | 1.25 (1.02) | 0.000 |
| | C4 | 0.62 (0.29) | 1.01 (0.94) | 0.000 |
| | P3 | 1.11 (0.60) | 1.36 (0.51) | 0.076 |
| | PZ | 0.57 (0.41) | 0.99 (0.39) | 0.000 |
| | P4 | 1.08 (0.91) | 1.33 (0.71) | 0.192 |
| | All above | 0.73 (0.54) | 1.21 (0.57) | 0.000 |
| Temporal | T3 | 1.13 (0.39) | 1.64 (1.16) | 0.046 |
| | T4 | 0.82 (0.40) | 1.21 (0.83) | 0.006 |
| | T5 | 0.88 (0.42) | 1.62 (1.16) | 0.000 |
| | T6 | 0.95 (0.60) | 1.24 (0.83) | 0.013 |
| | All above | 0.92 (0.64) | 1.55 (0.77) | 0.000 |
| Occipital | O1 | 1.28 (0.42) | 1.89 (1.06) | 0.006 |
| | O2 | 1.32 (0.49) | 1.88 (0.69) | 0.006 |
| | All above | 1.28 (0.46) | 1.88 (0.89) | 0.000 |

Data were expressed as median (IQR). Comparison of data between patient and control were done by Mann-Whitney U test. Here, N- Total number of subjects; n- Number of subjects in each group; MDD- Major Depressive Disorder

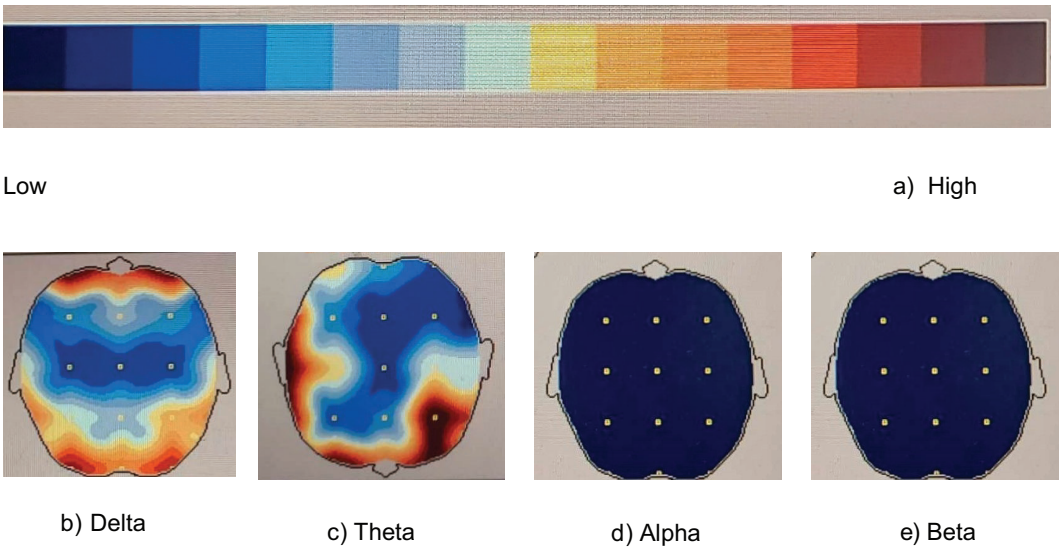


**Figure 1:** Topographical presentation of Absolute power ($\mu V^2$) in MDD group. a) a colour coded scale representing lower to higher absolute power value; b) delta; c) theta; d) alpha and e) beta wave

## Discussion

In our study quantitative EEG parameters, notably elevated absolute power of delta and theta waves were in all cortical regions of the current series of drug free MDD patients align with the prior studies indicating, less excitability state was associated with psychological status of depression.[10,25] Some authors found right hemispheric predominance of delta power in drug free depressed individuals but this feature was noted unchanged after clinical improvement of depression, suggesting lack of treatment effect on characteristic reduced excitability state on MDD patients.[10] In the present study we could not observe this feature after treatment as our patients were newly diagnosed. Similar pattern of delta and theta findings were observed in elderly depressed subjects with cognitive impairment.[25]

While these slow waves are associated with relaxation in healthy subjects during varying psychological oscillation such as emotional stress, day dreaming, drowsiness, deep meditation; but their excessive increase has been linked to dementia.[21,25]

Furthermore, this study uncovered significantly lower absolute power of alpha and beta waves in all cortical regions of MDD patients compared to healthy controls. Reduced alpha power, particularly in parietal, temporal and occipital regions, was consistent with previous researches in depressed states.[24] Interestingly, some studies suggested alpha asymmetry with hyperactivity in the right hemisphere and relative hypo activity in the left hemisphere in MDD patients. In contrast, higher alpha power was noted in parietal and occipital regions in other studies.[13]

Research evidence has been suggested involvement of prefrontal cortex in depression. As it is the center of emotional expression, in depression lower alpha activity in this region demonstrated more negative emotion. As the case is true for the lower alpha activity in the frontal region of the patients as well as the rest of the regions are also witnessed lower alpha activity. These findings are evident in our newly diagnosed, drug free patients in eye closed position associated with their very poor attention or any task performance.[24]

In our study, lower beta activity in MDD patients, suggests decreased attention and increased sleepiness, were in line with some prior research.[25] However, conflicting results were also observed, with some studies reporting higher beta power in MDD patients, associated with early-stage anxiety.[7,12]

## Conclusion

The results of the study concluded that MDD patients had characteristic feature of brain wave with high delta, theta and low alpha, beta in almost all cortical regions is related to features of the clinical diagnosis of MDD. Quantitative EEG can be used as index of depression in MDD patients. It can also suggest that the extension of regions involvement can determine the severity of depression.

## Conflict of interest

There are no conflict of interests pertaining to this study.

## Ethical clearance

The ethical aspects of this study protocol involving human subjects followed the Helsinki (1964) ethical guidance and was first approved by the departmental ethical and academic committee. It was then further reviewed and approved by Institutional Review Board (IRB) of BSMMU.

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