Original Article

Resting State Quantitative Electroencephalogram Power Spectra in Patients with Depressive Disorder as Compared to Normal Controls: An Observational Study

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ABSTRACT

Introduction: A significant number of quantitative electroencephalogram (qEEG) studies indicate that increased spectral activities distinguish patients with depressive disorder from control subjects. But they did not yield consistent findings in the delta, theta, alpha, or beta bands. **Methods:** A total of 30 drug-naïve or drug-free subjects with a depressive episode or recurrent depressive disorder were compared with 30 age, sex, education, and handedness-matched healthy controls using qEEG power spectra in six frequency bands (delta, theta, alpha, beta, slow beta, and fast beta) and total activities separately. Spectral analysis was performed on a section of 180 s of qEEG digitized at the rate of 512 samples/s/channel, and absolute powers were log-transformed before statistical analysis. **Results:** Statistically significant differences between the patients and normal controls were found in the delta and the total bands, while Structured Interview Guide for the Hamilton Depression Rating Scale (SIGH-D) score predicted the fast beta spectral power at the left temporal region. In the entire region of the brain, in the theta band, lesser absolute spectral power was found in patients than normal controls, whereas in the fast beta band, it was greater. In other bands, greater powers of spectral activities were found in patients than normal controls consistently in the parietal and occipital regions. **Conclusion:** Various findings of qEEG absolute power spectra could demonstrate a difference between the patients with depressive disorder and the normal controls independently and efficiently. However, all the differences collectively showed stronger evidence. The findings may steer future studies to differentiate the patients with depressive disorder from controls.

Key words: *Depression, qEEG, power spectra, healthy controls, resting state*
Key messages: *qEEG absolute power spectra differed between patients with depressive disorder and the normal controls.*

Earlier studies with electroencephalogram (EEG) described various changes in depression in the form of background frequencies and sleep-related abnormalities.[1,2] But later studies based on computerized quantitative EEG (qEEG) provided objective as well as reliable data, and the possible

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psychiatric diagnostic utility of these methods of assessment has already been evaluated.[3,4] But various qEEG studies in depressive disorder exhibited a wide range of findings. Depressed patients presented with increased beta activity: more precisely, increased fast beta activity was found in frontal areas in patients of major depression with melancholia.[5,6] For the alpha frequencies, unipolar patients with depressive disorder had symmetrical or increased power on the left side compared to the right.[7] Although patients with depressive disorder exhibited greater alpha blocking, euthymic recovered depressed subjects showed greater alpha amplitudes, whereas unmedicated currently depressed patients exhibited elevated EEG alpha and beta.[8-10] In delta and theta bands, increased absolute powers of the right hemisphere were found in drug-free depressed patients compared to controls, and no change was noted after clinical improvement.[11] But patients with depression had also shown decreased alpha activity and increased delta, theta, and beta activity but no interhemispheric asymmetry.[12] A significant increase in spectral power in theta (4–7.5 Hz), alpha (7.5–14 Hz), and beta (14–20 Hz) frequency bands was found in depressed patients at parietal and occipital sites, both in eyes closed and eyes open conditions. An increase in slow (theta and alpha) activity in the EEG pattern reflected a decreased cortical activation in these brain regions, and enhancement of beta power correlated with anxiety symptoms which were suggested as playing an important role in the onset of depressive disorder.[13]

However, a few recent studies point toward the involvement of anterior cingulate and prefrontal cortices in depression. Subjects of major depressive disorder (MDD) showed significantly elevated current density in the delta, theta, alpha, beta1 (13–18 Hz), and beta2 (19–21 Hz) frequency bands relative to controls in anterior cingulate and prefrontal cortices when qEEG data were analyzed using low-resolution electromagnetic tomography method.[14] The importance of the intrinsic functional connectivity of the left dorsolateral prefrontal cortex (DLPFC) with the subgenual cingulate area in depression has already been established.[15] The MDD group, and particularly the depressed males, displayed increased overall frontal and parietal alpha power and left mid-frontal hypoactivity associated with increased theta2 (6–8 Hz) activity in the anterior cingulate cortex (ACC), whereas females with MDD had increased right parietal activity, suggesting increased emotive arousal. It was proposed that altered theta in the ACC might reflect emotion regulation abnormalities in MDD.[16] Concurrent measurements of brain electrical activity by EEG and glucose metabolism by positron emission tomography showed that the rostral ACC was the largest cluster with positive correlations followed by right frontotemporal regions in theta band only. The results pointed toward a link between theta and cerebral metabolism in the ACC as well as disruption of functional connectivity within frontocingulate pathways in depression.[17] ACC plays a key role in treatment outcome in depression as dorsolateral prefrontal and dorsal cingulate regions are implicated in cognitive control.[18]

A magnetic resonance imaging (MRI) study confirmed structural changes in the brain of depressed subjects, demonstrating significantly lower gray matter volume in the left and right DLPFC.[19] However, evidence related to peripheral growth factors, proinflammatory cytokines, endocrine factors, and metabolic markers are still growing to contribute to the understanding about the pathophysiology and to provide a biological signature of depressive disorder.[20] But in electrophysiology, though a significant number of qEEG studies indicated that increased spectral activities distinguished depressed from control subjects, they did not yield consistent findings in the delta, theta, alpha, and beta bands.[21] This study was an attempt to assess the profile of the absolute spectral activities in patients with depressive disorder as a group compared to normal healthy controls.

METHODS

This study was conducted at the Central Institute of Psychiatry (C.I.P.), Ranchi, India. It is a postgraduate teaching hospital having bed strength of 673 and imparts training in psychiatry, clinical psychology, psychiatric social work, and psychiatric nursing. The study was approved by the Institute Ethics Committee and written informed consent was taken from all the participants (and their legally qualified representatives in case of patients) before enrolling them for the study. The subjects were recruited by purposive sampling technique over a period of 10 months from November 1, 1996 to August 31, 1997.

Data collection and participants

The subjects who constituted the sample were outpatients and inpatients with a diagnosis of a depressive episode or recurrent depressive disorder according to the Diagnostic Criteria for Research of International Classification of Diseases 10th edition.[22] Both male and female patients aged between 18 and 60 years formed the patient group. Only those patients who were drug-naive completely or psychotropic-drug-free for at least 4 weeks were included. Patients with a diagnosis of schizoaffective disorder, mixed affective state or depression as a part of bipolar affective disorder, or organic mood disorder (depressed type) and the patients who received electroconvulsive therapy within 6 months before the EEG study were excluded. Female patients

who were in menstrual period were also excluded to avoid the changes in electrical activities of the brain due to altered hormone levels. The control group consisted of age, sex, education, and handedness-matched healthy subjects. In the control group, subjects with a history of any psychiatric illness, any major physical illness, neurological illness, significant head injury, or family history of psychiatric illness in first-degree relatives were also excluded.

Clinical assessment

Relevant sociodemographic and clinical data of all the participants were collected in a specially designed sociodemographic and clinical data sheet. The patients were assessed on various psychiatric rating scales on the day of qEEG recording procedure: Structured Interview Guide for the Hamilton Depression (SIGH-D) rating scale,[23] Hamilton Anxiety (HAM-A) rating scale,[24] the Brief Psychiatric Rating Scale (BPRS),[25] to assess the severity of depression, the anxiety associated with depression, and the general psychopathology, respectively. Hindi version of Sidedness Bias Schedule was used to assess the hand preference in both the patient and the control groups.[26] Healthy controls were screened with the General Health Questionnaire (GHQ-5).[27]

EEG recording

The patients, as well as the normal controls, were informed regarding the qEEG recording procedure in detail to remove any apprehensions so that the artifacts were reduced to a minimum. If electromyogram (EMG) related artifacts were present in the qEEG recording, the recording was discontinued, and the patients underwent Jacobson's Progressive Muscular Relaxation (JPMR) training. If the EMG-related artifacts still persisted, the particular qEEG and the patient both were excluded from the study. Among the included patients, six underwent JPMR training, but none of the control group required JPMR training. The participants were advised to avoid the use of tea, coffee, or nicotine for at least 1 hour before the recording. qEEG was recorded for 15–20 min, while subjects rested with their eyes closed in an alert state in a soundproof, light-attenuated room, using 25 monopolar electrodes placed according to the international 10–20 system and referred to link earlobes. A four-pole filter with a 70 Hz cut-off frequency and a low-pass band filter with 0.1 Hz was used. The time constant was 0.1 s, and the electrode-skin impedance was kept below 5 kΩ. The qEEGs were digitized at 512 samples/s/channel using Neurofax EEG 2100K (Nihon Kohden, Japan).

Spectral power analysis

First 180 s epochs of artifact-free EEG data were visually selected from each recording after carefully excluding segments with eye movement, blink, electrocardiogram (ECG), EMG, movement, electrode, and perspiration artifacts or changes related to drowsiness. Selected EEG epochs were recomputed against a common average reference. qEEGs from 21 electrodes: FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T3, T4, T5, T6, FZ, CZ, PZ, T1, and T2 were used for analysis to calculate spectral power, expressed in μV, by fast-Fourier transformation (FFT) using Welch's averaged periodogram method.[28] Frequencies between 1.5 and 35 Hz were analyzed, divided into delta (1.5–3.5 Hz), theta (4–7.5 Hz), alpha (8–12.5 Hz), beta (whole, 13–35 Hz), slow beta (13–20 Hz), and fast beta (20.5–35 Hz) bands along with total spectral activities (1.5–35 Hz). Rhythm version 10.1 software (Stellate Systems, Canada) was used for qEEG analysis.

Statistical analysis

Descriptive analysis was performed to calculate the percentage, mean, and standard deviation of the clinical data of the experimental group and demographic data of both the groups. Calculated powers of absolute spectral activities were extracted from the bound files with (dot). BND extension created as a result of FFT. As the absolute spectral power was not normally distributed (Shapiro–Wilk test), normalization was achieved by log-transformation as recommended by "neurometrics."[29,30] *Post-hoc* classification of the sample was done on the basis of patients with depressive disorder as a group as compared to normal subjects. To compare the power spectral activities of the depressive disorder group and the control group, a separate multivariate analysis of variance (MANOVA) was conducted for each qEEG band, and if a significant relationship was found, it was followed by an ANOVA for the spectral powers at each electrode region. A linear regression analysis for patients with depressive disorder (n = 30) with SIGH-D, HAM-A, and BPRS scores as predictor variables for spectral power (in areas where significant variations across normal subjects were found) were performed using separate entry method. Subsequently, we computed Pearson correlation coefficients for patients with depressive disorder (n = 30) between SIGH-D, HAM-A, and BPRS scores and significant spectral measures separately. $P < 0.05$ was considered as statistically significant. Statistical analysis was done using Statistical Package for Social Sciences of International Business Machines Corporation, New York, USA (SPSS v 23).

RESULTS

Sociodemographic and clinical data

Though qEEG recording was done in case of 36 patients, six patients were excluded from the analysis due to the presence of various artifacts (ECG, EMG, eye

movement, sweat). Among 30 patients, 21 were drug-naive. Complete profiles of both the groups and the scores of various rating scales have been given in Table 1.

Spontaneous (<35 Hz) spectral power

MANOVA [Table 2] for comparison of the patient group and the healthy control group showed a significant difference for the spectral power in the delta band and the total band. A similar trend was observed in case of the theta band, though it did not reach the significance level of <0.05. No significant interaction was found for alpha band × group, beta band × group, slow beta band × group, fast beta band × group. Supplementary one-way ANOVA showed a significant difference between the patients and the healthy controls in delta band spectral power [Table 3a] at FP1, P3, FZ, and CZ electrode regions, and a trend toward significance was found at FP2 region. However, in ANOVA, no statistically significant difference was found in spectral powers over any of the electrode regions in theta and total bands.

In the delta band [Table 3a] at almost all the electrode regions except at T2, F7, F4, and P4, the values of the means were greater in the patient group than the normal subjects, indicating more delta power in drug-free patients with depressive disorder than the controls. In the theta band [Table 3a] at all the electrode regions, the mean values of spectral powers were lesser in the patient group, indicating lesser theta power in the patients with depressive disorder than the control group. In the alpha band [Table 3a] at most of the electrode regions except at T2, F7, T1, T3, and F4, the mean values of spectral powers were greater in the patients, indicating more alpha power in the drug-free patients with depressive disorder than the control group. In the beta (whole) band [Table 3b] at most of the electrode regions, the mean values of spectral powers were greater in patients than the control group except at T1, T2, FZ, and PZ electrode regions, indicating more beta power in the drug-free patients with depressive disorder than the normal controls. In slow beta band [Table 3b], mean values of spectral activities were found to be greater at FP2, T4, T6, C4, P4, O2, F3, C3, P3, O1, and FZ electrode regions and lesser at F8, T2, FP1, F7, T1, T3, T5, F4, CZ, and PZ electrode regions than the control group, indicating increased and decreased slow beta power, respectively, in patients with depressive disorder than the normal controls. In the fast beta band [Table 3b] at all the electrode regions, the mean values of spectral activities were greater in patients with depressive disorder, indicating higher fast beta power in the drug-free patients with depressive disorder than the normal control group. In the case of total spectral activities [Table 3b] at most of the electrode regions, the mean values were greater in patients with depressive disorder than that of control group except at T2, F7, T1, and F4 electrode regions, indicating increased total spectral power in the drug-free patients with depressive disorder than that of the normal control group.

Regression and correlation analysis

Linear regression analysis found SIGH-D score ($r = 0.448$; constant = 0.105; $P < 0.05$) as a predictor variable for the fast beta (beta2) spectral power at T3 electrode region (left temporal region) in patients with depressive disorder ($n = 30$). SIGH-D score also showed a significant correlation with the spectral power of the fast beta band at T3 electrode region ($r = 0.448$; $P < 0.05$). Figure 1 shows the scatter plot. No significant correlation between any of the HAM-A

Table 1: Details of both the groups

	Drug free patients with depressive disorder (Group A)	Normal control (Group B)
Total no (*n*)	30 (Drug naïve: *n*=21)	30
Male/Female	M=21, F=9	M=21, F=9
Mean age	31.77±10.10 years	32.07±8.76 years
Mean of total period of education	7.27±5.95 years	7.67±5.72 years
Handedness	Right handed: *n*=30, Left handed: *n*=0	Right handed: *n*=30, Left handed: *n*=0
Details of the drug free patients with depressive disorder		
Total duration of illness	Mean=36.59±68.48 months	
Duration of current episode	Mean=39.07±44.80 weeks	
Duration of episode	9 months or less: *n*=19 (63.3%)	
	More than 9 months: *n*=11 (36.7%)	
Number of episodes of depression	Single episode: *n*=21 (70%)	
	More than one episodes maximum up to 5: *n*=9 (30%)	
Family history of psychiatric disorders	Present: n=15 (50%) [8 patients (26.7%) had a history of affective disorder]	
	Absent: *n*=15 (50%)	
Structured interview guide for the hamilton depression (SIGHD)	Mean=27.30±5.59	
Hamilton anxiety rating scale score (HAM-A)	Mean=18.53±3.75	
Brief psychiatric rating scale score (BPRS)	Mean=18.13±5.32	

and BPRS scores and spectral power values of any other bands were found.

Table 2: Details of MANOVA (Wilks' Lambda) comparing the absolute powers of the drug-free patients with depressive disorder and the control group

Band	*F* (df=21,38)	*P*	Partial η^2
Delta	3.035	0.001	0.626
Theta	1.816	0.054	0.501
Alpha	1.547	0.119	0.461
Beta	1.612	0.098	0.471
Slow beta	1.164	0.333	0.392
Fast beta	1.479	0.144	0.450
Total	3.922	<0.001	0.684

DISCUSSION

In this study, the absolute power of spectral activities was found to be greater on both the sides in delta band in drug-free patients with depressive disorder than normal controls in almost all the areas of the brain. MANOVA showed a significant difference between the two groups (P = 0.001). Moreover, ANOVA revealed a significant difference between the two groups at the left frontal, left parietal, and especially the central regions. In previous qEEG studies in depression also, increased delta has been found.[11,12,14] This points toward decreased cortical activation in these brain

Table 3a: Mean, S.D. and *F* Ratio (ANOVA) of absolute powers of the drug free patients with depressive disorder and the control group

Electrode	Group	Delta		Theta		Alpha	
		Mean±S.D.	*F* (ANOVA)	Mean±S.D.	MANOVA	Mean±S.D.	MANOVA
FP2	A	1.66±0.20	3.46	1.16±0.23		1.49±0.42	
	B	1.57±0.19		1.25±0.40		1.44±0.49	
F8	A	1.57±0.23	0.73	1.12±0.21		1.41±0.37	
	B	1.52±0.24		1.22±0.40		1.40±0.50	
T2	A	1.50±0.24	0.21	1.23±0.23		1.51±0.36	
	B	1.53±0.30		1.32±0.38		1.54±0.46	
T4	A	1.29±0.27	0.49	1.05±0.26		1.42±0.36	
	B	1.24±0.29		1.12±0.42		1.39±0.43	
T6	A	1.35±0.26	0.23	1.30±0.39		1.93±0.46	
	B	1.31±0.38		1.40±0.52		1.88±0.56	
FP1	A	1.64±0.20	5.81	1.14±0.24		1.49±0.44	
	B	1.52±0.16		1.25±0.38		1.45±0.47	
F7	A	1.50±0.26	0.00	1.08±0.26		1.43±0.41	
	B	1.50±0.26		1.23±0.41		1.45±0.48	
T1	A	1.58±0.39	0.02	1.25±0.30		1.55±0.35	
	B	1.57±0.34		1.34±0.42		1.56±0.46	
T3	A	1.35±0.28	0.57	1.05±0.25		1.42±0.37	
	B	1.29±0.29		1.18±0.42		1.45±0.44	
T5	A	1.31±0.25	2.98	1.21±0.33		1.70±0.45	
	B	1.18±0.33		1.26±0.46		1.65±0.48	
F4	A	1.09±0.36	0.85	0.84±0.28	NS	1.20±0.45	NS
	B	1.16±0.22		1.00±0.42		1.20±0.49	
C4	A	0.83±0.35	1.51	0.46±0.28		0.88±0.47	
	B	0.72±0.33		0.50±0.42		0.80±0.47	
P4	A	0.86±0.28	0.33	0.68±0.31		1.27±0.57	
	B	0.91±0.39		0.77±0.49		1.20±0.57	
O2	A	1.47±0.23	1.89	1.39±0.33		1.98±0.51	
	B	1.37±0.35		1.44±0.53		1.91±0.55	
F3	A	1.15±0.31	0.99	0.88±0.30		1.28±0.47	
	B	1.06±0.32		1.03±0.46		1.22±0.47	
C3	A	0.50±0.33	0.06	0.36±0.30		0.86±0.46	
	B	0.48±0.25		0.43±0.42		0.76±0.48	
P3	A	0.90±0.37	4.74	0.66±0.32		1.15±0.46	
	B	0.71±0.32		0.67±0.52		1.07±0.59	
O1	A	1.50±0.24	2.90	1.37±0.35		1.95±0.51	
	B	1.37±0.34		1.41±0.52		1.91±0.56	
FZ	A	1.33±0.35	11.05	1.06±0.27		1.40±0.44	
	B	1.08±0.21		1.15±0.50		1.34±0.52	
CZ	A	0.92±0.31	4.67	0.66±0.30		0.99±0.39	
	B	0.76±0.28		0.70±0.43		0.93±0.46	
PZ	A	0.87±0.35	1.37	0.61±0.32		1.05±0.51	
	B	0.78±0.26		0.66±0.52		1.05±0.57	

Group A: Drug free patients with depressive disorder; Group B: Controls; NS – MANOVA not significant

Table 3b: Mean, S.D. and *F* Ratio (ANOVA) of absolute powers of the drug free patients with depressive disorder and control group

Electrode	Group	Slow Beta		Fast Beta		Beta		Total Activities	
		Mean±S.D	MANOVA	Mean±S.D	MANOVA	Mean±S.D	MANOVA	Mean±S.D	F (ANOVA)
FP2	A	0.77±0.33		1.01±0.37		1.22±0.35		2.09±0.23	0.86
	B	0.75±0.28		0.88±0.23		1.14±0.23		2.02±0.30	
F8	A	0.69±0.32		0.82±0.30		1.08±0.29		1.98±0.23	0.21
	B	0.73±0.34		0.77±0.24		1.06±0.27		1.97±0.32	
T2	A	0.77±0.30		0.84±0.26		1.11±0.27		2.00±0.23	0.52
	B	0.84±0.30		0.80±0.25		1.13±0.29		2.05±0.32	
T4	A	0.80±0.35		0.93±0.36		1.18±0.35		1.91±0.24	0.51
	B	0.78±0.29		0.78±0.22		1.09±0.23		1.86±0.32	
T6	A	0.90±0.34		0.96±0.31		1.24±0.31		2.21±0.35	0.05
	B	0.90±0.38		0.84±0.32		1.19±0.34		2.18±0.45	
FP1	A	0.74±0.34		0.98±0.34		1.19±0.23		2.06±0.23	0.60
	B	0.75±0.27		0.89±0.25		1.13±0.24		2.01±0.28	
F7	A	0.68±0.33		0.82±0.29		1.06±0.30		1.95±0.27	0.13
	B	0.74±0.32		0.73±0.25		1.05±0.28		1.98±0.33	
T1	A	0.76±0.33		0.86±0.28		1.12±0.30		2.07±0.31	0.02
	B	0.87±0.31		0.80±0.30		1.15±0.29		2.08±0.35	
T3	A	0.82±0.35		1.04±0.43		1.26±0.39		1.95±0.26	0.06
	B	0.85±0.30		0.83±0.28		1.16±0.27		1.93±0.32	
T5	A	0.80±0.32		0.85±0.29		1.14±0.29		2.05±0.31	0.28
	B	0.85±0.29		0.78±0.25		1.12±0.27		2.00±0.37	
F4	A	0.51±0.42		0.72±0.44		0.94±0.43		1.71±0.33	0.02
	B	0.54±0.30	NS	0.63±0.24	NS	0.89±0.26	NS	1.72±0.34	
C4	A	0.30±0.32		0.36±0.31		0.59±0.37		1.39±0.31	0.97
	B	0.28±0.31		0.30±0.30		0.59±0.32		1.31±0.33	
P4	A	0.41±0.30		0.45±0.30		0.71±0.34		1.63±0.38	0.05
	B	0.37±0.37		0.34±0.31		0.65±0.36		1.60±0.41	
O2	A	0.96±0.34		1.04±0.38		1.32±0.35		2.30±0.36	0.08
	B	0.93±0.36		0.87±0.32		1.21±0.34		2.22±0.43	
F3	A	0.54±0.39		0.74±0.41		0.95±0.42		1.75±0.33	0.01
	B	0.54±0.32		0.66±0.22		0.93±0.23		1.74±0.36	
C3	A	0.29±0.31		0.32±0.31		0.56±0.37		1.26±0.36	0.22
	B	0.26±0.30		0.28±0.29		0.55±0.32		1.21±0.34	
P3	A	0.39±0.31		0.44±0.30		0.70±0.35		1.57±0.33	0.88
	B	0.35±0.36		0.34±0.34		0.65±0.36		1.48±0.43	
O1	A	0.95±0.32		0.97±0.36		1.27±0.34		2.27±0.35	0.33
	B	0.93±0.35		0.89±0.30		1.22±0.32		2.21±0.45	
FZ	A	0.61±0.40		0.77±0.43		1.02±0.40		1.90±0.31	1.18
	B	0.56±0.35		0.64±0.27		0.92±0.28		1.80±0.39	
CZ	A	0.26±0.36		0.48±0.41		0.65±0.44		1.50±0.30	0.85
	B	0.29±0.30		0.36±0.30		0.63±0.32		1.42±0.33	
PZ	A	0.30±0.32		0.33±0.31		0.60±0.34		1.50±0.34	0.10
	B	0.32±0.33		0.28±0.32		0.61±0.34		1.47±0.39	

Group A: Drug free patients with depressive disorder; Group B: Controls; NS – MANOVA not significant

regions.[13,31] Interestingly, none of the studies we reviewed on qEEG in depression evaluated the total effect of all the frequency bands. Here, MANOVA showed a significant difference between the drug-free patients with depressive disorder group and normal control group ($P < 0.001$) in the total frequency band, though no significant difference was found in ANOVA in any individual electrode region.

The higher power of the total spectral activities in most of the areas of the brain was almost similar to the findings of delta and alpha bands and was also comparable to previous qEEG studies in affective disorders and depression.[2,3,10,32,33] On the contrary, in theta band, in the entire region of the brain, both on the right and the left sides, lesser powers of spectral activities than that of normal controls were found, indicating that power of theta decreases as a whole in patients with unipolar depression, especially if they are untreated. MANOVA also showed a trend toward significance ($P = 0.054$) Abnormalities in theta band had been found in previous quantitative EEG studies in depression, and it was linked to cerebral metabolism in the ACC.[11,17,34-36] However, the findings were inconsistent. In contrast to our findings, increased absolute theta power has been found in patients with depression compared to healthy controls in "the entire region of the brain" too.[12]

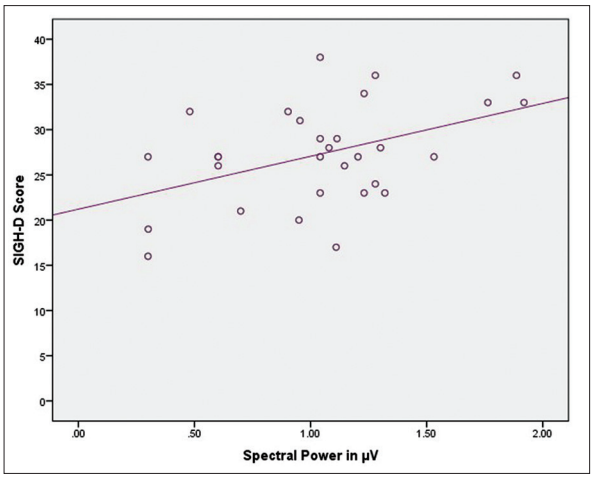

Figure 1: Scatter plot showing the correlation between Structured Interview Guide for the Hamilton Depression Rating Scale (SIGH-D) (SIGH-D) Score and Spectral power of Fast Beta Band at T3 electrode region in patients with depressive disorder. SIGH-D: Structured Interview Guide for the Hamilton Depression Rating Scale

Moreover, in yet another study, depressed subjects also showed significantly lesser theta activity as well as no significant difference compared to healthy controls in the ACC activities.[17,37] This may be due to the difference in methodology or different technique used for assessment.

In most areas of the brain, especially in parietal and occipital regions, the powers of spectral activities of alpha, beta (whole), and slow beta bands were found to be greater in drug-free patients with depressive disorder than the normal controls. In the alpha band, similar findings were found in most of the qEEG studies.[7,8,10,14,34,38-40] But decreased absolute alpha power was also reported in one study in patients with depression compared to healthy controls in all brain areas except in right parietal and occipital channels.[12] In beta (whole) band too, the findings of our study are comparable to previous qEEG studies in depression.[5,10,12] In slow beta band again, findings of our study repeated those of previous studies where a significant increase in spectral power in beta frequency band was found in depressed patients at parietal and occipital sites.[13,14,31,34] In the entire region of the brain and on both sides, the powers of fast beta activities were found to be greater in drug-free patients with depressive disorder than the normal controls. SIGH-D score predicted the fast beta spectral power at the left temporal region. Moreover, SIGH-D score was also found to be correlated with the fast beta power in the temporal region of the left side. This suggests that the fast beta spectral power at left temporal region was related to the severity of depression. In a previous study, though the depressed subjects showed significantly elevated current density in 19–21 Hz (beta2) frequency band relative to controls in anterior cingulate and prefrontal cortices, no significance was found in 22–30 Hz (beta3) band.[14] An increase in slow alpha activity in the EEG pattern might reflect a decreased cortical activation in these brain regions, but the enhancement of beta power might correlate with anxiety symptoms that most likely played an important role in the onset of depressive disorder.[13,31]

The present study has got the following significant new findings which were not found in any of the previously published studies: (a) statistically significant differences between the patients with depressive disorder and normal controls were found in the delta band and the total qEEG band. A similar trend was found in the theta band too. Moreover, SIGH-D score or severity of depression predicted the fast beta spectral power at the left temporal region. (b) The theta band as a whole demonstrated a difference between the patients with depressive disorder and normal controls; in the entire region of the brain, the power of spectral activities was found to be lesser in patients with depressive disorder. (c) The fast beta band too as a whole could show the difference between the patients with depressive disorder and normal controls; in all the areas of the brain, the power of spectral activities was found to be greater in patients with depressive disorder. (d) In all other bands including total spectral activities, the power of the spectral activities was found to be greater in patients with depressive disorder consistently in parietal and occipital regions, which could also illustrate the difference between the two groups.

On the basis of these findings, it can be suggested that the future qEEG studies in depression should preferably compare the absolute spectral power of the same subjects in the depressed state with that of their treated state to search for a biomarker of depression.[18,20] Moreover, future qEEG studies should explore whether the patterns "decreased theta absolute power," or "greater power in the fast beta band" or "the combination of lesser power in theta band and greater power in the fast beta band" in all the areas of the brain can be demonstrated in cases of other psychiatric disorders or not when compared with healthy controls before declaring them specific for depression. As fast beta band showed significant changes in cases of depression, future studies should be designed to include gamma band (EEG beyond 35 Hz) also to get additional information.

STRENGTHS AND LIMITATIONS OF THE STUDY

Using age, sex, education, and handedness-matched control group in the present study formed two relatively homogeneous groups, overcoming the problem of heterogeneity. There is evidence that drugs such as antidepressants, antipsychotics, carbamazepine, sodium valproate, and other psychotropic drugs,

even when given for brief periods, can induce slight EEG disturbances.[10,41-43] Also, the use of common reference for estimation, low sampling rate for qEEG data acquisition, analysis of less than half a minute qEEG segments, and statistical analysis without log transformation of spectral activities remain as issues in some studies. Drug-free or naïve status before EEG recording in our patients, use of averaged reference for estimation of spectral activities, the high resolution offered by qEEG digitized at the rate of 512 samples/s/channel, analyzing 180 s of qEEG power spectra in six frequency bands along with total activities separately, and log-transformed absolute powers before statistical analysis, making them more homogeneous and more normally distributed, added credibility to our findings.

Limited sample size, recruitment of an unequal number of male and female subjects, and applying JPMR in a few patients to reduce EMG artifacts are the major limitations of this study. Future studies with larger sample size, evenly divided gender groups, and clustering analysis or classification analysis to differentiate the two groups might provide more robust evidence for the association between depression and qEEG absolute spectral activities.

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Conflicts of interest

There is no conflict of interest.

REFERENCES

1. Hurst LA, Mundy-Castle AC, Beerstecher DM. The electroencephalogram in manic-depressive psychosis. J Ment Sci 1954;100:220-40.
2. Hudson JI, Lipinski JF, Frankenburg FR, Grochocinski VJ, Kupfer DJ. Electroencephalographic sleep in mania. Arch Gen Psychiatry 1988;45:267-73.
3. Shagass C, Roemer RA, Straumanis JJ, Josiassen RC. Psychiatric diagnostic discriminations with combinations of quantitative EEG variables. Br J Psychiatry 1984;144:581-92.
4. Primavera A, Novello P. Quantitative electroencephalography in Parkinson's disease, dementia, depression and normal aging. Neuropsychobiology 1992;25:102-5.
5. Flor-Henry P, Koles ZJ, Howarth BC, Burton L. Neurophysiological studies of schizophrenia, mania and depression. In: Gruzelier J, Flor-Henry P, editors. Hemesphere Asymmetry of Function in Psychopathology. Amsterdam: Elsevier; 1979. p. 189-222.
6. Kano K, Nakamura M, Matsuoka T, Iida H, Nakajima T. The topographical features of EEGs in patients with affective disorders. Electroencephalogr Clin Neurophysiol 1992;83:124-9.
7. Flor-Henry P. EEG spectral analysis in psychopathology. In: Giannitrapani D, Murri L, editors. The EEG of Mental Activities. Basel: Karger; 1988. p. 182-200.
8. Shagass C, Roamer RA, Josiassen RC. Some quantitative EEG findings in unmedicated and medicated major patients with depressive disorder. Neuropsychobiology 1988;19:169-75.
9. Pollock VE, Schneider LS. Topographic electroencephalographic alpha in recovered depressed elderly. J Abnorm Psychol 1989;98:268-73.
10. Pollock VE, Schneider LS. Quantitative, waking EEG research on depression. Biol Psychiatry 1990;27:757-80.
11. Kown JS, Youn T, Jung HY. Right hemisphere abnormalities in major depression: Quantitative electroencephalographic findings before and after treatment. J Affect Disord 1996;40:169-73.
12. Begić D, Popović-Knapić V, Grubišin J, Kosanović-Rajačić B, Filipčić I, Telarović I, *et al*. Quantitative electroencephalography in schizophrenia and depression. Psychiatr Danub 2011;23:355-62.
13. Grin-Yatsenko VA, Baas I, Ponomarev VA, Kropotov JD. EEG power spectra at early stages of depressive disorders. J Clin Neurophysiol 2009;26:401-6.
14. Korb AS, Cook IA, Hunter AM, Leuchter AF. Brain electrical source differences between depressed subjects and healthy controls. Brain Topogr 2008;21:138-46.
15. Fox MD, Liu H, Pascual-Leone A. Identification of reproducible individualized targets for treatment of depression with TMS based on intrinsic connectivity. Neuroimage 2013;66:151-60.
16. Jaworska N, Blier P, Fusee W, Knott V. Alpha power, alpha asymmetry and anterior cingulate cortex activity in depressed males and females. J Psychiatr Res 2012;46:1483-91.
17. Pizzagalli DA, Oakes TR, Davidson RJ. Coupling of theta activity and glucose metabolism in the human rostral anterior cingulate cortex: An EEG/PET study of normal and depressed subjects. Psychophysiology 2003;40:939-49.
18. Pizzagalli DA. Frontocingulate dysfunction in depression: Toward biomarkers of treatment response. Neuropsychopharmacology 2011;36:183-206.
19. Chang CC, Yu SC, McQuoid DR, Messer DF, Taylor WD, Singh K, *et al*. Reduction of dorsolateral prefrontal cortex gray matter in late-life depression. Psychiat Res Neuroim 2011;193:1-6.
20. Schmidt HD, Shelton RC, Duman RS. Functional biomarkers of depression: Diagnosis, treatment, and pathophysiology. Neuropsychopharmacology 2011;36:2375-94.
21. Olbrich S, Arns M. EEG biomarkers in major depressive disorder: Discriminative power and prediction of treatment response. Int Rev Psychiatry 2013; 25:604-18.
22. World Health Organization. The ICD-10 classification of mental and behavioral disorders: Diagnostic criteria for research. Geneva: World Health Organization; 1993.
23. Williams JB. A structured interview guide for the Hamilton Depression Rating Scale. Arch Gen Psychiatry 1988;45:742-7.
24. Hamilton M: The assessment of anxiety states by rating. Br J Med Psychol 1959;32:50-5.
25. Overall JE, Gorham DR. The Brief Psychiatric Rating Scale (BPRS): Recent developments in ascertainment and scaling. Psychopharmacol Bull 1988;24:97-9.

26. Mandal MK, Pandey G, Singh SK, Asthana HS. Hand preference in India. Int J Psychology 1992;27:433-42.
27. Shamasunder C, Sriram TG, Raj SGM, Shanmugam V. Validity of a short 5-item version of the general health questionnaire (G.H.Q.). Ind J Psychiatry 1986;28:217-9.
28. Welch PD. The use of fast Fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms. IEEE Trans Audio Electroacoust 1967;15:70-3.
29. John ER, Prichep L, Easton P. Normative data banks and neurometrics: Basic concepts, methods and results of norm constructions. In: Gevins A, Remond ÀŽ, Editors. Methods of Analysis of Brain Electric and Magnetic Signals. Handbook of Electroencephalography and Clinical Neurophysiology, Revised Series 1. Amsterdam: Elsevier; 1987. p. 449-95.
30. John ER, Prichep LS, Fridman J, Easton P. Neurometrics: Computer-assisted differential diagnosis of brain dysfunctions. Science 1988;239:162-9.
31. Grin-Yatsenko VA, Baas I, Ponomarev VA, Kropotov JD. EEG power spectra at early stages of depressive disorders. J Clin Neurophysiol 2009;26(6):401-6.
32. Armitage R, Hoffmann R, Fitch T, Morel C, Bonato R. A comparison of period amplitude and power spectral analysis of sleep EEG in normal adults and depressed outpatients. Psychiatry Res 1995;56:245-56.
33. Alper KR, Chabot RJ, Kim AH, Prichep LS, John ER. Quantitative EEG correlates of crack cocaine dependence. Psychiat Res-Neuroim 1990;35:95-105.
34. Grin-Yatsenko VA, Baas I, Ponomarev VA, Kropotov JD. Independent component approach to the analysis of EEG recordings at early stages of depressive disorders. Clin Neurophysiol 2010; 121:281-9.
35. Korb AS, Hunter AM, Cook IA, Leuchter AF. Rostral anterior cingulate cortex theta current density and response to antidepressants and placebo in major depression. Clin Neurophysiol 2009;120:1313-9.
36. Asada H, Fukuda Y, Tsunoda S, Yamaguchi M, Tonoike M. Frontal midline theta rhythms reflect alternative activation of prefrontal cortex and anterior cingulate cortex in humans. Neurosci Lett 1999;1999:29-32.
37. Mientus S, Gallinat J, Wuebben Y, Pascual-Marqui RD, Mulert C, Frick K, *et al*. Cortical hypoactivation during resting EEG in schizophrenics but not in depressives and schizotypal subjects as revealed by low resolution electromagnetic tomography (LORETA). Psychiat Res-Neuroim 2002;116:95-111.
38. Suffin SC, Emory WH. Neurometric subgroups in attentional and affective disorders and their association with pharmacotherapeutic outcome. Clin Electroencephalogr 1995;26:76-83.
39. Knott VJ, Telner JI, Lapierre YD, Browne M, Horn ER. Quantitative EEG in the prediction of antidepressant response to imipramine. J Affect Disord 1996;39:175-84.
40. Bell IR, Schwartz GE, Hardin EE, Baldwin CM, Kline JP. Differential resting quantitative electroencephalographic alpha patterns in women with environmental chemical intolerance, depressives and normals. Biol Psychiatry 1998;43:376-88.
41. Galderisi S, Mucci A, Bucci P, Mignone ML, Maj M. Influence of moclobemide on cognitive functions of nine depressed patients: Pilot trial with neurophysiological and neuropsychological indices. Neuropsychobiology 1996; 33:48-54.
42. Frost JD, Hrachovy RA, Glaze DG, Retting GM. Alpha rhythm slowing during initiation of carbamazepine therapy: Implications for future cognitive performance. J Clin Neurophysiol 1995;12:57-63.
43. Sannita WG, Gervasio L, Zagnoni P. Quantitative EEG effects and plasma concentration of sodium valproate: Acute and long term administration to epileptic patients. Neuropsychobiology 1989;22:231-5.