Received: 25 March 2024 | Revised: 28 April 2024 | Accepted: 10 May 2024
DOI: 10.48309/JMPCR.2024.449927.1156
Journal of Medicinal and Pharmaceutical Chemistry Research
SAMI

FULL PAPER

The benefits of quantitative electroencephalogram (QEEG) in depression

Susana Anggar Kusuma* |**Agustina Konginan**

Department of Psychiatry, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia, Department of Psychiatry, RSUD dr Soetomo Academic General Hospital, Surabaya, Indonesia

***Corresponding Author:**
Susana Anggar Kusuma
Email: susan310811@gmail.com
Tel.: +6285151455153

Depression is a psychological condition that affects mood and impacts the global population more extensively than other mental disorders. Assessments are typically conducted subjectively through interviews, which heavily rely on the examiner's experience. This reliance introduces numerous biases and discrepancies between examiners. Quantitative Electroencephalogram (QEEG) emerges as a tool capable of satisfying human curiosity about brain conditions affecting psychology more readily and non-invasively compared to the other examinations such as PET and MRI. By recognizing various waves on the Quantitative Electroencephalogram (QEEG), a novel understanding of the benefits stemming from this assessment method and its application to psychological conditions in general and depressed patients in particular is attained.

KEYWORDS

Brain waves; benefits; depression; QEEG.

Introduction

Behavior, brain function, and psychological elements represent three distinct dimensions utilized to evaluate the progression of human health and disease, exhibiting changes that are not always linear [1]. Depression, characterized by a lack of motivation, difficulty experiencing pleasure, disruption of daily activities, and, in severe cases, suicidal ideation, imposes a significant burden worldwide [2-4]. In addition, depression substantially diminishes quality of life and increases household expenses. According to the World Health Organization (WHO) 2020 estimates, 5% of adults experience depression, with women being affected more than men [5].

Neurology and psychiatry assign considerable importance to the physiological processes underlying emotion, cognition, and behavior when objectively evaluating brain disorders [1]. Depression assessment encompasses various tests, including instruments like the Beck Depression Inventory (BDI), Hamilton Depression Rating Scale (HDRS), Montgomery-Åsberg Depression Rating Scale (MADRS), and biomarkers for mental illnesses such as depression and schizophrenia, studied through neuroimaging technologies like electroencephalography (EEG), functional

magnetic resonance imaging (fMRI), and positron emission tomography (PET). While PET and fMRI offer superior spatial resolution compared to EEG, their operation is costly and requires significant expertise. Moreover, fMRI is unsuitable for claustrophobic patients, and PET requires injecting a radioactive substance into the subject. Electroencephalography (EEG), boasting advantages such as high temporal resolution, non-invasiveness, ease of use, and affordability, emerges as the ideal tool for in-depth exploration of mental illnesses, including depression [6,7].

Studies investigating depression detection using Quantitative Electroencephalography (QEEG) indicate high accuracy, comparable to assessment scales like the BDI, with figures ranging from 79% to 86%. Knott *et al.* reported approximately 91.3% accuracy utilizing EEG recordings from 21 scalp regions. Healey and Picard's research, aimed at emotion identification through feature pattern extraction from physiological signals, yielded accuracy rates between 61.8% and 78.4%. Kim *et al.* examined an emotion detection system for short-term monitoring of multi-user physiological data, utilizing a support vector machine (SVM) to extract features and identify three emotions, resulting in a 75% accuracy rate [8].

This literature review aims to stimulate discourse and contemplation regarding the advantages of employing Quantitative Electroencephalogram (QEEG) in psychiatry, particularly in cases of depression.

Electroencephalogram

Hans Berger's pioneering recording of an Electroencephalogram (EEG) in 1929 marked a milestone in the field of human brain recording. By the 1970s, computers began to be employed for EEG analysis, and in 1997, Marc Nuwer published the first digital EEG. Digital EEG offers numerous benefits, including simple feature selection for accurate EEG capture, the ability to adjust parameter sensitivity and frequency range to analyze specific EEG signal segments, a more detailed and focused interpretation, and its utility as a diagnostic tool. Conventional EEG parameters and features can be applied across all age groups, from neonates to the elderly, facilitating EEG examinations as routine procedures such as electrocardiogram (ECG) examinations or blood counts [9].

The advantages of EEG include [1]:

1. Being cost-effective: EEG is a cheap technique.
2. Being fast: EEG provides fast results.
3. Being non-invasive and portable: EEG is non-invasive and portable, enabling its use in various settings without the need for surgery or invasive procedures.
4. Providing high temporal resolution: EEG offers high temporal resolution, allowing for the measurement of brain activity in milliseconds and accurate real-time observations of changes in brain function and differentiation between various temporal information scales in mental and cognitive processes.
5. Providing improved spatial resolution: Recent advancements in EEG technology have led to improved spatial resolution. EEG can now provide information about brain activity with a spatial resolution of up to 3 mm^3, facilitating precise identification of brain regions involved in clinical disorders.
6. Being affordable: EEG is a relatively affordable technique compared to other neuroimaging methods, such as MRI or PET scans, making it more accessible for a wide range of clinical testing.
7. Enabling diagnosis of neurological and psychiatric disorders: EEG can assess a variety of neurological and mental conditions, including depression, anxiety, seizures, brain tumors, and sleep problems. It also provides valuable information about abnormal brain activity, aiding in the diagnosis and treatment of these disorders.
8. Not causing claustrophobia: EEG does not induce feelings of claustrophobia.

The disadvantages of QEEG include [10]:

1. Limited resources: QEEG requires trained technologists and professionals.

2. Storage challenges: QEEG generates large data files.
3. Retrospective review: The review process for QEEG data is often retrospective.
4. Spatial resolution limitations: Typical electrode placement in QEEG restricts the ability to localize brain disorders due to the limited spatial resolution.
5. Sensitivity limitations: Scalp EEG resolution may not detect minor anomalies.
6. Lack of specificity: QEEG findings may not exclusively indicate the type of injury causing the anomaly.
7. Influence of external factors: QEEG results can be affected by neuroactive drugs and movement.

Types of EEG include [11]:

1. Routine/Standard EEG: This type of EEG is utilized to detect abnormal brain activity associated with conditions such as epilepsy and typically lasts for 20 to 30 minutes.
2. Prolonged EEG: Conducted over a three-hour period, this type of EEG includes seizure stimulation techniques like hyperventilation (deep inhalation for several minutes) and photic stimulation flashing lights at different frequencies. It is recommended that this test be performed following a suspected seizure event.
3. 24-Hour EEG: This type of EEG is conducted over a 24-hour period, accompanied by video recording, to observe seizure activity continuously.
4. Long-term EEG: With video recording, this type of EEG spans three to ten days.
5. Ambulatory EEG: This type of EEG allows patients to move freely while wearing a portable device that is not connected to stationary equipment.
6. Sleep-deprived EEG: This type of EEG is used to examine brain activity related to sleep disorders, insomnia, and other sleep-related problems.

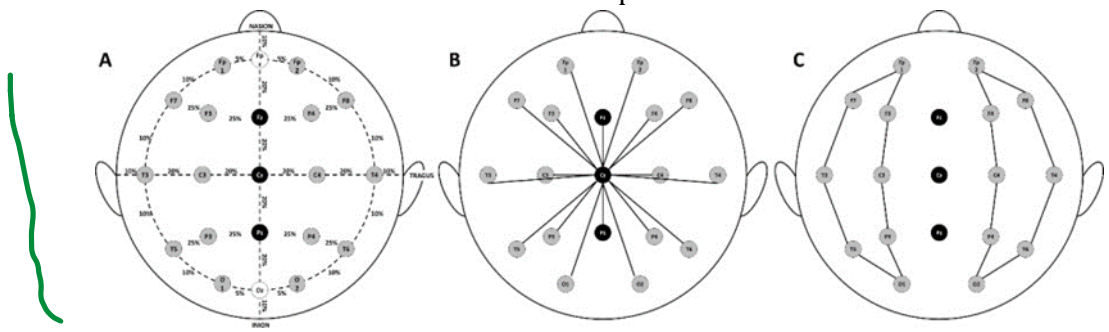

FIGURE 1 Electrode placement and montage: (A) example of standard electrode placement using the 10/20 system; (B) referential montage where the electrode in position Cz (middle of the head) serves as the reference for all electrodes; and (C) bipolar montage for each channel representing the difference between two adjacent electrodes [12]

Standards for electrode placement and montage

There are several standard sites for electrode placement on the scalp is shown in Figure 1, with the international 10/20 method being the most frequently applied. The predetermined landmarks on the head include the tragus (the tip of the jawbone), nasion (the indentation between the eyes), and inion (the protrusion at the base of the skull). Electrodes are then positioned at intervals of 10% or 20% of the distance between these landmarks. The location of each electrode on the head is designated, with labels such as "F" for frontal, "Fp" for frontopolar, and lateral locations indicated with numerical labels. Odd numbers denote the left hemisphere, while even numbers represent the right hemisphere [12].

Categories of the rhythmic spectrum of EEG frequency oscillations

Several types of rhythmic spectrum of EEG frequency oscillations is shown in Figure 2, include [1,13-15]:

1. Delta waves (<4 Hz): These are sleep waves, also known as slow waves. Delta waves are the slowest waves and typically appear in sleeping infants during the third and fourth stages of sleep.
2. Theta waves (4-8 Hz): Reflecting sleepiness, theta waves are also referred to as "dream" waves. They occur during activities such as prayer, meditation, dreaming, and emotional states.
3. Alpha waves (8-12 Hz): Accompanying a relaxed state, alpha waves signify calmness and are predominantly observed in the occipital lobe of the brain.
4. Beta waves (12-30 Hz): Reflecting an engaged or active brain, beta waves indicate a state of activity, alertness, or tension. These waves are most prominent at the front of the head. Beta waves occur between 12 and 15 cycles per second, corresponding to a frequency range of 12 to 15 Hz. This type of wave indicates focus, balance, and comfort. Also known as Sensory Motor Rhythm (SMR), they are typically observed bilaterally across the head and lobes.
5. Gamma waves (>35 Hz): Considered accompanying the fastest brain activity, gamma waves are associated with enhanced processes of perception, learning, and problem-solving tasks, particularly when various parts of the brain are engaged in information processing.

Quantitative electroencephalogram

Quantitative model-based electroencephalography (QEEG) is a technique for assessing brain electrical activity applicable to diagnostic information and cognitive impairments. The Fourier transform, a mathematical technique, is utilized to record and analyze brain waves across a frequency spectrum. The dominance and strength of each brain frequency are individually assessed. QEEG is frequently employed in clinical evaluation due to its validity and reliability, exceeding 90% [17].

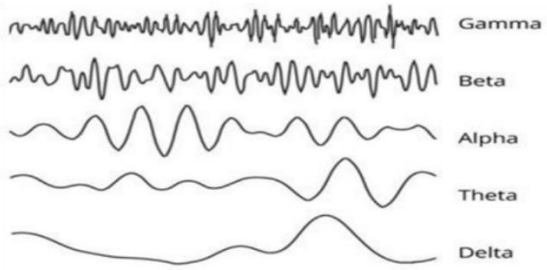

FIGURE 2 EEG waves [16]

QEEG holds a high predictive value for determining the functional "brain maturity" level, enabling assessment of QEEG maturation or regression, often concurrent with the onset of neuropsychopathology. Understanding oscillation patterns typical for specific stages of phylogenesis or ontogenesis is crucial. Immature QEEG may lower the threshold for aggressive and/or antisocial behavior and increase susceptibility to external stimuli [1].

Parallel QEEG abnormalities in adults, resulting from early life stressors such as low socioeconomic status, physical or emotional maltreatment, institutional care, and altered catecholamine levels, can impede the development of brain regions responsible for emotion regulation and cognitive function,

making individuals more susceptible to stress. Traumatic brain injury may also lead to such aberrations [1].

Indication

QEEG serves as both a diagnostic tool and a foundation for pharmacological and non-pharmacological therapies, as well as for following up on therapy results. QEEG abnormalities do not signify a specific disease but rather denote functional irregularities occurring in the brain [17].

According to the American Clinical Neurophysiology Society's Assessment, QEEG can be utilized as an assessment instrument to detect abnormalities in brain function and diagnose psychiatric and neurological disorders is shown in Table 1 [1].

QEEG's stability, reliability, and specificity

QEEG stability characteristics demonstrate up to 90% reliability, with internal consistency assessed during EEG recording sessions using Cronbach's alpha. Repetitive testing, conducted across hours, weeks, months, and years, exhibits a specificity of up to 99% and is considered highly repeatable and dependable, reaching up to 90%. This suggests that large groups of participants can be reliably and accurately identified using QEEG. Resting QEEG, reflecting a person's intrinsic brain activity, serves as a statistical neural signature representing their personality. It also suggests that genetic variables play a significant role in the QEEG variation [1].

TABLE 1 Indications for QEEG examination [17]

• Attention Deficit	• Mild or moderate head injury
• Hyperactivity Disorder	• Panic Disorder
• Bipolar Disorder	• Parkinson's disease
• Depression	• Post-concussion syndrome
• Drug Abuse	• Prediction of response to Psychotropic medication
• Fibromyalgia	• Schizophrenia
• Hypoxic Ischemic Encephalopathy	• Prognosis Encephalopathy associated with sepsis
• Insomnia	• Sport concussion (diagnosis and assessment from healing rate)
• Learning Disorders	• Tinnitus
• Asperger's syndrome	
• Other autism spectrum disorders	

QEEG oscillations, genes, and pathological Conditions [1] are as follow:

a. Beta oscillations (Electromagnetic oscillations in the frequency range of brain activity over 13 Hz are known as beta rhythms)

Existing studies mention the role of Gamma Amino Butyrate (GABA) A receptors, especially on chromosome 4p, and B on chromosome 6, in modulating beta oscillations as QEEG coherence recorded on the scalp. Similarly, alcohol dependency diagnosed by the DSM-IV is linked to A receptor.

b. Alpha oscillations (Alpha rhythms are electromagnetic oscillations originating from synchronous and coherent neuronal activity in the human brain, occurring in the frequency range of 8-13 Hz)

Alpha voltage, serotonin receptor (HTR3B), and exon seven variations have been associated with the GABA B receptor, suggesting that low voltage alpha oscillations are connected to the GABAergic system, alcoholism, and antisocial behavior.

Depression, anxiety, and alcoholism are linked to corticotropin-releasing hormone-binding protein release (CRH-BP). Low voltage alpha oscillations in women have also been linked to alcohol dependence subtypes with anxiety disorders, the Val66Met polymorphism of brain-derived neurotrophic factor (BDNF) in depression, and genetic variants causing low activity of catechol-O-methyltransferase (COMT), the enzyme metabolizing dopamine and norepinephrine. Alpha oscillations with high voltage are inherited in an autosomal dominant manner. The COMT gene has been linked to alpha peak frequency (APF), with the Val/Val genotype exhibiting a slower APF of 1.4 Hz.

c. Theta oscillations (Electromagnetic oscillations in the brain activity frequency range of 4 to 7.5 Hz are known as theta rhythms)

Posterior interhemispheric theta EEG coherence is linked to single nucleotide polymorphisms found in brain-expressed long intergenic non-coding RNAs (lincRNAs) on chromosome 18q23. Likewise, the posterior corpus callosum volume and alcohol use behavior are linked to the same variations. In patients with schizophrenia, anomalies in low-frequency oscillations are associated with the Val158Met COMT gene polymorphism.

QEEG/brain mapping preparation [17]

1. Patients should avoid consuming foods and drinks containing caffeine (e.g., tea, coffee, chocolate, and soft drinks) as they can stimulate changes in EEG waves. In addition, patients should monitor their blood sugar levels, as fluctuations can also impact brain waves.
2. Patients should wash their hair the night before or at least a day prior to the examination.
3. Patients should refrain from using hair products such as gel or spray on the day of the examination.

Quantitative electroencephalogram and depression

Prolonged periods of stress can adversely affect the human brain, and depression can lead to alterations in both brain structure and psychological well-being. Age-related cortical shrinkage, oxygen deprivation, inflammation, and other structural abnormalities in the human brain may disrupt normal function by impeding the transmission of signals and information [16].

The brain's adaptation to depression

The right and left hemispheres make up the two lobes of the human brain. Imagination, insight, and creativity are controlled by the right hemisphere of the brain. Analysis and reasoning are responsibilities of the left hemisphere. Each hemisphere has four lobes: the occipital, parietal, temporal, and frontal. Depression research indicates that depression primarily affects the frontal lobe or the frontal region in the midway position.

Depression affects three key areas of the brain which is shown in Figure 3:

- hippocampus,
- prefrontal cortex, and
- amygdala.

Memories are processed in the hippocampus located in the temporal lobe, which also regulates cortisol production. Excessive cortisol release during depression shrinks the hippocampus and hinders the growth of new neurons. The prefrontal cortex, located in the frontal lobe, controls memory formation, mood regulation, and critical decision-making. Depression-induced cortisol overabundance leads to prefrontal cortex atrophy. Emotional responses are controlled by the amygdala located in the frontal area of the temporal lobe. Sleep disturbances and altered activity patterns accompanying depression contribute to amygdala enlargement due to elevated cortisol levels [16,18].

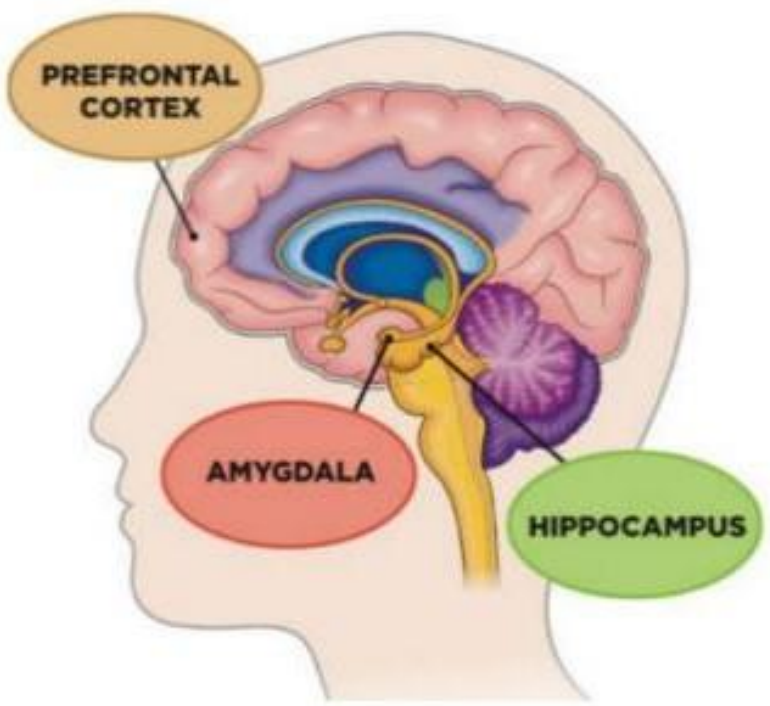

FIGURE 3 Brain [16]

Depression and biomarkers in QEEG

Depression manifests with heterogeneous symptoms and high comorbidity, posing challenges in identifying consistent biomarkers through examination. Waking and sleeping EEGs are believed to offer biomarkers in depression, rendering EEGs potentially valuable in detecting depressive symptoms and patients before the condition exacerbates. Approximately 20-40% of patients with depression exhibit abnormal EEG patterns [2,13]. The example pattern of EEG waves in normal and depression is shown in Figure 4.

There are several biomarkers in QEEG waveform assessment, including:

Power bands

One direct piece of information obtained from EEG is band power, facilitating the analysis of amplitude power in each band once the signal can be represented in the frequency domain and utilizing EEG band principles. Each band represents a distinct brain mechanism, with the following bands associated with depression [2]:

Alpha

According to the frontal alpha asymmetry (FAA) theory, depressed patients exhibit more cortical activity in the right frontal regions, characterized by lower alpha activity, and reduced cortical activity in the left frontal regions, linked to higher alpha activity. FAA primarily serves as a prognostic index rather than an ideal diagnostic biomarker. While consistent results have not been achieved, posterior alpha oscillations have also been proposed as a potential biomarker for diagnosing depression [20].

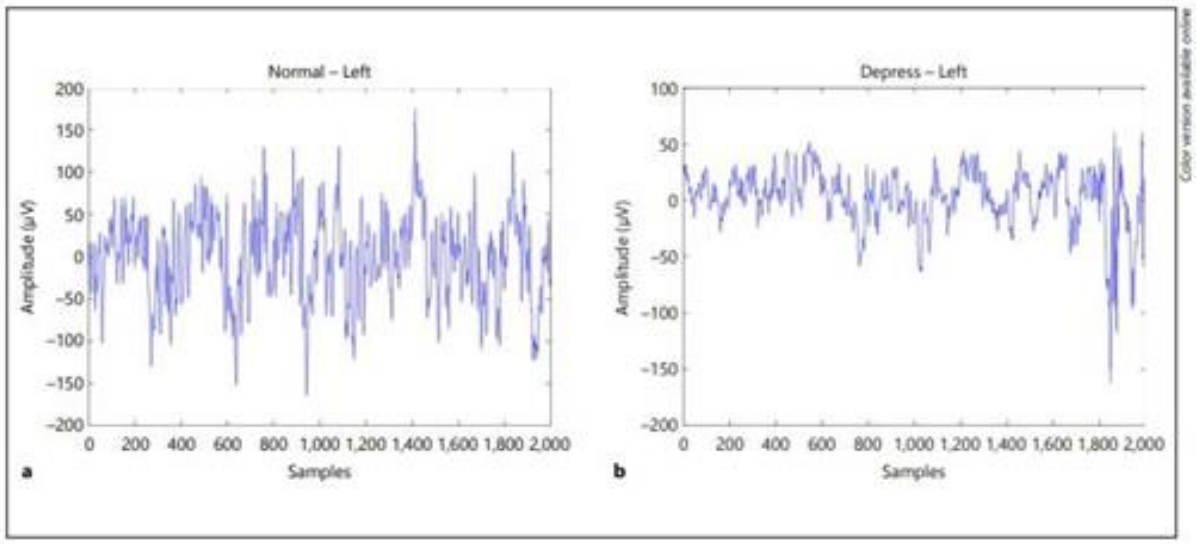

FIGURE 4 Examples of EEG waves in normal individuals and EEG waves in depressed individuals [19]

Theta

Research has demonstrated a correlation between theta power in different brain regions and depressive symptoms, suggesting that theta oscillations could serve as a biomarker for depression. Patients with major depressive disorder (MDD) have exhibited higher theta activity in the subgenual anterior cingulate cortex (sgACC) compared to healthy individuals, while increased theta power in the rostral anterior cingulate cortex (rACC) has been associated with milder depressive symptoms. However, due to inconsistent results and a dearth of solid evidence, the use of theta oscillations as a diagnostic marker of depression remains unproven. Greater resting theta activity in the ACC is being studied as a potential predictor of treatment response. Theta oscillations may serve as a predictive biomarker for antidepressant response. Following repetitive transcranial magnetic stimulation (rTMS) and electroconvulsive therapy (ECT) treatment, theta power has been observed to increase, while lower relative theta power in frontal regions has been linked to antidepressant response. Further research is necessary to verify the role of theta oscillations in antidepressant efficacy [20].

Gamma

One possible biomarker for Major Depressive Disorder (MDD) is gamma oscillations. Studies have demonstrated that, in comparison to healthy controls, individuals with MDD exhibit abnormal gamma oscillations during the resting state, characterized by higher gamma power and increased complexity in frontal and temporal areas. Amygdala gamma power has been found to correlate with the MDD severity. Furthermore, during emotional tasks, gamma oscillations have been shown to distinguish between bipolar depression and major depressive disorder. In addition, MDD has been associated with reduced gamma activity in the pre-supplementary motor region and left motor cortex, indicating decreased inhibitory function compared to healthy controls. These results imply that gamma oscillations may be crucial for diagnosing and understanding MDD [20].

Much research has explored band power, facilitating the differentiation of depressed subjects from healthy ones based on this classification. Increased gamma activity has been observed in monopolar depression and is associated with mood regulation, whereas theta and delta waves have shown efficacy in detecting attention. Studies vary widely

regarding alpha waves and their accuracy in detecting depression and its symptoms. This variability may be attributed to the number of electrodes and different installation locations, causing controversy and requiring other alpha tests, such as alpha asymmetry. Furthermore, some research states that an increase in the alpha band may also indicate suicidal ideation [2].

a. Signal-based features

Other QEEG waves that may serve as biomarkers include [2]:

1. Alpha Power Variation (APV): monitors changes in frequency and power in the alpha band;
2. C0-Complexity (C0-C): assesses a signal's variation;
3. Correlation Dimension (CD): indicates the degree of freedom of the signal; a lower value indicates less randomness of the signal;
4. Detrended Fluctuation Analysis (DFA): shows long-term signal correlation;
5. Higuchi's Fractal Dimension (HFD): suggests the signal's fractal dimension;
6. Lempel–Ziv Complexity (LZC): calculates a signal's complexity;
7. Maximum Lyapunov Exponent (MLE): calculates a signal's unpredictability;
8. Relative Gamma Power (RGP): determines the gamma power relative to the whole spectrum;
9. Spectral Asymmetry Index (SASI): determines how asymmetrically higher and lower frequency bands are relative to one another.

b. Network-based features

EEG electrodes record the activity of numerous neurons, allowing for the analysis of connections between different brain regions and the network structure of those connections. In general, depression is extensively studied to understand brain network characteristics [2]:

1. Alpha Wave Spread (AWS): represents the lack of activity in several brain regions.
2. Cluster Coefficient (CC): typically quantifying the density of connections when the node is directly connected to other nodes to form a cluster, indicates that random networks often have a lower average CC than complex networks, which have a higher CC.
3. Coherence (Coh): an expansive concept describing the relationship between various regions in the brain; it involves coherence to show synchronous activity between different parts of the brain. Therefore, it can be assessed in in various ways.
4. Functional Connectivity (FC): represents the degree of connectivity between different brain regions. Random or complicated networks typically have smaller path sizes than regular paths, indicating fewer nodes between two different nodes.
5. Path Length (PL): represents the number of nodes between two distinct nodes. The path widths of random or complicated networks are often smaller than those of regular paths, indicating fewer nodes between two different nodes.
6. Phase Synchronization (PS): represents the synchronization of oscillations with the same frequency, similar to coherence.
7. Small-Worldness (SW): describes the small-world organization of the human brain, where small areas are linked by a number of "hubs."

The results of the above studies on depressed patients indicate the following findings [2]:

- Coh: In mild depression, decreased gamma wave coherence is observed only in the right hemisphere during the presentation of facial emotions;
- Coh: By connecting three functional brain modules- self-awareness, rumination, and bodily tension- it is possible to link

hypersynchrony and awareness to depressed symptoms.

- PL, CC: Lengthening of PL for alpha and theta waves and decreasing CC;
- FC, PL: Weakness in FC and elongation of PL in the left hemisphere;
- PL, CC: Shortening of PL and decreasing CC; and
- AWS: Diffuse alpha.

c. Evoked potentials

Evoked potentials, which occur in response to specific stimuli such as different sounds, can reveal specific patterns of brain activity in individuals. Based on latency and direction, these potentials are investigated through various tasks like working memory and facial emotional presentation. The findings can indicate functional differences between the brains of healthy individuals and those with depression. The discussion gives rise to potentials, which are summarized below [2]:

1. Late Positive Potential (LPP): represents a late positive deflection (300 ms-600 ms), frequently appears during emotional processing, and is relevant to word stimulus encoding;
2. N1: represents a negative deflection that occurs approximately 150 ms after visual or auditory cue presentation, is related to stimulus encoding, and is modulated by emotional salience;
3. N200: represents a negative deflection linked to conflict monitoring that occurs 200 ms following a stimulus;
4. P100 or P1: represents a positive deflection that occurs approximately 100 ms after cue presentation. It is influenced by emotional salience and may be connected to the intensity of delusional thinking;
5. P200 or P2: represents a positive deflection associated with selective attention that occurs approximately 200 ms following a stimulus;
6. P300 or P3: represents a positive deflection approximately 300 ms following the presentation of an unusual stimulus, such as a unique beep. Patients with depression have higher delay and lower amplitude.

d. Other biomarkers include [2]*:*

EEG vigilance, which occurs when the brain prepares for sleep, is studied using alpha waves. It is a measurement of one's subjective level of attentiveness while at rest and a sign of brain activity. It may vary from being very awake, relaxed, and alert to feeling sleepy and starting to become drowsy. Despite the fact that Sander et al. (2018) discovered elevated alertness levels in depression even following sleep deprivation, this implies that additional research is necessary, and the findings could not be transferable to other studies [21].

- The frontal area of the brain exhibits flatter dissipation in the first episode of Non-Repid Eye Movement (NREM), which is linked to worsening depressive symptoms brought on by insufficient sleep regulation. This is also demonstrated by the decrease in theta and delta wave amplitude and wave strength.
- Adolescents with depression exhibit stronger pupillary reactions.
- Prefrontal theta chordance, a measure of brain connectivity and synchrony during sleep, is used to assess individuals with depression, especially during sleep [22].

QEEG waves, diagnosis, and prediction of depression therapy

Treatment selection is a challenge, and patients may spend months to years searching for effective treatment. Predictive biomarkers have been widely researched, but commercial efforts that promote predictive tests without evidence of clinical efficacy may increase healthcare costs without providing benefits to patients. Treatment-emergent biomarkers, which represent physiological changes that precede and predict treatment response, have the potential to guide treatment decisions more quickly. QEEG (quantitative EEG) is a

promising source of psychiatric biomarkers, as it directly measures brain activity and is more cost-effective and feasible than other neuroimaging techniques [1,22].

Biomarkers for diagnosing depression include [1-2,14]:

1. Alpha band: High alpha amplitude can indicate depression.
2. Theta band: Increased theta activity can also indicate depression.
3. Gamma band: Changing gamma amplitudes may correlate with depressive symptoms such as suicidal ideation.
4. Signal complexity: The complexity level of the EEG signal can also serve as a biomarker indicating the presence of depression.
5. Evoked Potentials: Evoked potentials involve the brain's response to certain stimuli, such as the P300 and N1. They can detect symptoms such as memory changes, emotional processes, or delusional thinking.

A map displaying, separately for MDD and healthy control patients, the median CE connection (coherence) between the Fp1-Fpz hub node and all other nodes in all frequency bands is presented. When comparing MDD participants (A, C, E, and G) to control subjects (B, D, F, and H), these nodes exhibited increased median connectivity. On the left side of the map, color bars represent coherence values. In both MDD and control participants, coherence values declined with increasing distance from the hub node; however, the decrease in coherence values was more pronounced in the control subjects.

The comparission of QEEG in depressed and normal patients is shown in figure 5. The effect of drugs and Antidepressants and their impacts on EEG waves is shown in Tables 2 and 3.

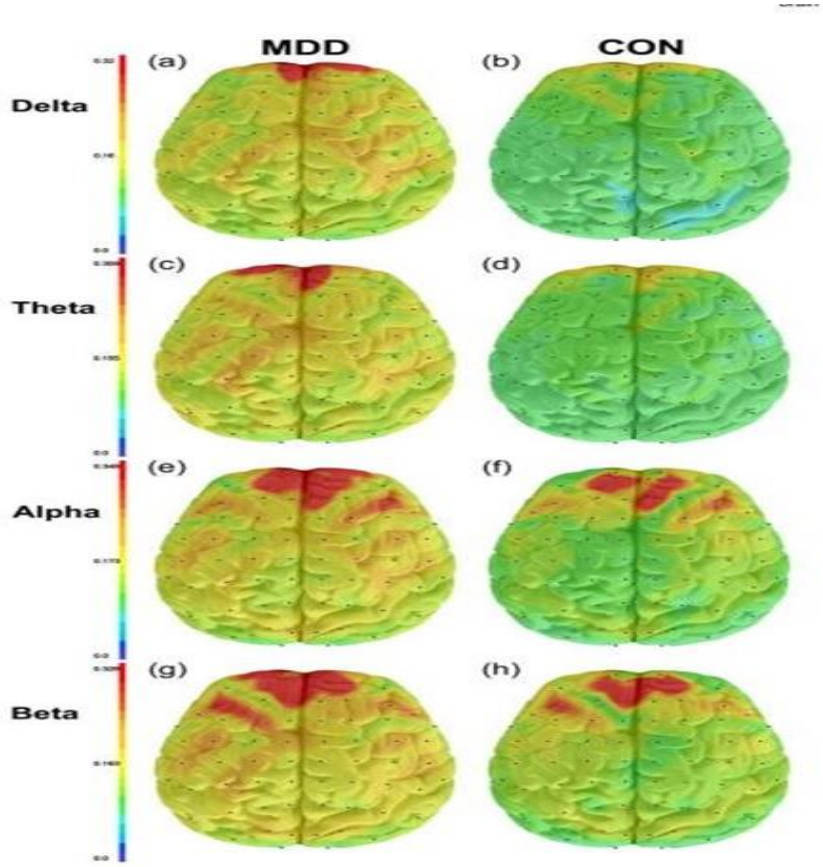

FIGURE 5 Comparison of QEEG in depressed patients and normal patients [23]

TABLE 2 The effect of drugs on EEG waves [19,24]

Anxiolytics	Improvement of lower beta frequency (beta 1), higher delta and theta oscillation power, and lower alpha rhythm power
Antipsychotic	Reduction in the frequency and power of alpha rhythm, beta one oscillations, and the power of theta and delta rhythms
Antidepressants	Increase in beta (beta 2) oscillations and theta frequencies, and decrease in alpha frequencies
Stimulants (amphetamine)	Reduction in theta oscillations, increase in beta and alpha power, and decrease in delta power.
Drugs nootropics	Enhancement of alpha oscillations and weakening of delta and theta rhythms
Lithium	Increase in delta and theta oscillations strength, additionally triggering slowing down of alpha rhythm

TABLE 3 Antidepressants and their impacts on EEG waves [19]

Antidepressants with thymoleptic characteristics (e.g., imipramine)	Result in a decrease in alpha activity and an increase in slow and fast activity
Antidepressant without thymoleptic properties (e.g., amitriptyline)	Produce EEG patterns that are slightly different from those with thymoleptic properties
Antidepressant with thymoretic properties (e.g., desipramine)	Induce decline in beta fast and increase in alpha activity

One limitation of this article is the scarcity of resources and materials on depression assessment using QEEG. In addition, there is no definitive marker in depression evaluation through QEEG, indicating the need for further research to provide a more focused examination of depression. Rapid and accurate assessment of depression may help prevent negative consequences such as alterations in neurotransmitters and brain morphology.

Conclusion

The depression examination using QEEG provides objective evidence that psychiatric disorders are genuine processes occurring in the brain [25,26]. Examination using QEEG serves as an alternative choice due to its numerous advantages, including its cost-effectiveness and less invasive nature compared to other examinations. EEG can also be valuable for diagnosing depression and predicting the efficacy of therapy, as well as for other psychological interventions such as PET, MRI, and CT scans. However, due to variations in studies regarding bands at the same frequency, differing conclusions may arise. Notably, asymmetry in EEG alpha waves in patients with depression was observed with more consistent results. This asymmetry was linked to hyper-activation of the right prefrontal brain, possibly linked to withdrawal behavior [14,27-28].

Acknowledgements

The authors express their gratitude to the Department of Psychiatry, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia.

Funding

The authors declare that they did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contributions

All authors contributed to the preparation of this literature review.

Conflict of Interest

The authors declare no conflict of interest regarding this study.

Consent to participate

Not applicable.

Ethics Statement

Not applicable.

Data Availability

Not applicable.

Orcid:
Susana Anggar Kusuma:*
https://orcid.org/0009-0006-9381-3925
Agustina Kongina:
https://orcid.org/0000-0001-7776-9051

References

[1] A.A. Fingelkurts, A.A. Fingelkurts, Quantitative electroencephalogram (qEEG) as a natural and non-invasive window into living brain and mind in the functional continuum of healthy and pathological conditions, *Applied Sciences*, **2022**, *12*, 9560. [Crossref], [Google Scholar], [Publisher]

[2] F.S. de Aguiar Neto, J.L.G. Rosa, Depression biomarkers using non-invasive EEG: A review, *Neuroscience & Biobehavioral Reviews*, **2019**, *105*, 83-93. [Crossref], [Google Scholar], [Publisher]

[3] P.P. Siregar, R. Sutan, A. Baharudin, Prevalence of stress, anxiety and depression among Indonesian immigrant workers in Malaysia, *Bali Medical Journal*, **2021**, *10*, 863-868. [Crossref], [Google Scholar], [Publisher]

[4] F.F. Alkaff, A.T. Syamlan, M. Jonatan, R.A. Nugraha, T.N. Octora, A. Karimah, Depression level difference between gifted and non-gifted medical students, *Biomolecular and Health Science Journal*, **2018**, *1*, 105-108. [Crossref], [Google Scholar], [Publisher]

[5] W.H.O. WHO, Depression and other common mental disorders, **2017**. [Publisher]

[6] A.S. Widge, M.T. Bilge, R. Montana, W. Chang, C.I. Rodriguez, T. Deckersbach, L.L. Carpenter, N.H. Kalin, C.B. Nemeroff, Electroencephalographic biomarkers for treatment response prediction in major depressive illness: A meta-analysis, *American Journal of Psychiatry*, **2019**, *176*, 44-56. [Crossref], [Google Scholar], [Publisher]

[7] D.P. Windriya, R.A. Wiryawan, W.R. Islamiyah, A. Machin, Non-motor seizure diagnosed after mild traumatic brain injury: a case report, *Bali Medical Journal (Bali MedJ)*, **2023**, *12*, 1407-1409. [Google Scholar], [Publisher]

[8] H. Cai, J. Han, Y. Chen, X. Sha, Z. Wang, B. Hu, J. Yang, L. Feng, Z. Ding, Y. Chen, J. Gutknecht, A pervasive approach to EEG-based depression detection, *Complexity*, **2018**, *2018*, 5238028. [Crossref], [Google Scholar], [Publisher]

[9] L. Livint Popa, H. Dragos, C. Pantelemon, O. Verisezan Rosu, S. Strilciuc, The role of quantitative EEG in the diagnosis of neuropsychiatric disorders, *Journal of Medicine and Life*, **2020**, *13*, 8-15. [Crossref], [Google Scholar], [Publisher]

[10] G.M. Benedetti, R.M. Guerriero, C.A. Press, Review of noninvasive neuromonitoring modalities in children II: EEG, qEEG. *Neurocritical Care*, **2023**, *39*, 618-638. [Crossref], [Google Scholar], [Publisher]

[11] Mammoguide, Mammographic appearance of the sternalis muscle. [Publisher]

[12] Z. Khakim, S. Kusrohmaniah, Dasar-Dasar Electroencephalography (EEG) bagi Riset Psikologi, *Buletin Psikologi*, **2021**, *29*, 92-115. [Crossref], [Google Scholar], [Publisher]

[13] D.P.X. Kan, P.F. Lee, May. Decrease alpha waves in depression: An electroencephalogram (EEG) study, In 2015 International Conference on BioSignal Analysis, *Processing and Systems (ICBAPS)*

2015, 156-161 [Crossref], [Google Scholar], [Publisher]

[14] C. Greco, O. Matarazzo, G. Cordasco, A. Vinciarelli, Z. Callejas, A. Esposito, Discriminative power of EEG-based biomarkers in major depressive disorder: A systematic review, *IEEE Access*, **2021**, *9*, 112850-112870. [Crossref], [Google Scholar], [Publisher]

[15] L. Puspa, N. Ibrahim, P.T. Brown, Wanting'and 'liking'brain mechanisms in coaching: A qEEG study using the CARE coaching model, *Biomolecular and Health Science Journal*, **2019**, *2*, 89-95. [Crossref], [Google Scholar], [Publisher]

[16] A. Dev, N. Roy, M.K. Islam, C. Biswas, H. Ahmed, M. Amin, F. Sarker, R. Vaidyanathan, K. Mamun, Exploration of EEG-based depression biomarkers identification techniques and their applications: A systematic review, *IEEE Access,* **2022**, *10*, 1-1. [Crossref], [Google Scholar], [Publisher]

[17] M. K, W. EA, N. IM, Technical manual of psychiatric electrophysiology, Association of Indonesian Psychiatric Medicine Specialists, PDSKJI, **2018.** [Publisher]

[18] K. Apriliani, Soetjipto, Sleep disorders in late-life depression, *Jurnal Psikiatri Surabaya*, **2020**, *9*, 1. [Crossref], [Pdf], [Publisher]

[19] V.K. Sudarshan, J. Santhosh, J.E. Koh, Computer-aided diagnosis of depression using EEG Signals, *European Neurology*, **2015**, 73. [Crossref], [Google Scholar], [Publisher]

[20] Y.C. Tsai, C.T. Li, C.H. Juan, A review of critical brain oscillations in depression and the efficacy of transcranial magnetic stimulation treatment, *Frontiers in Psychiatry* **2023**, *14*, 1073984. [Crossref], [Google Scholar], [Publisher]

[21] C. Sander, J.M. Schmidt, R. Mergl, F.M. Schmidt, U. Hegerl, Changes in brain arousal (EEG-vigilance) after therapeutic sleep deprivation in depressive patients and healthy controls, *Scientific Reports*, **2018**, *8*, 15087. [Crossref], [Google Scholar], [Publisher]

[22] I.E. Ohiorhenuan, V.L. Fredrickson, M.A. Liker, The deep brain connectome, *Neurophotonics and Brain Mapping*, **2017**, 479-486. [Google Scholar], [Publisher]

[23] A.F. Leuchter, I.A. Cook, A.M. Hunter, C. Cai, S. Horvath, Resting-state quantitative electroencephalography reveals increased neurophysiologic connectivity in depression, *PloS One*, **2012**, *7*, 32508. [Crossref], [Google Scholar], [Publisher]

[24] M. Skalski, A. Mach, P. Januszko, B. Ryszewska-Pokraśniewicz, A. Biernacka, G. Nowak, A. Pilc, E. Poleszak, M. Radziwoń-Zaleska, Pharmaco-electroencephalography-based assessment of antidepressant drug efficacy—The use of magnesium ions in the treatment of depression, *Journal of Clinical Medicine*, **2021**, *10*, 3135. [Crossref], [Google Scholar], [Publisher]

[25] M.B. Stone, Z.S. Yaseen, B.J. Miller, K. Richardville, S.N. Kalaria, I. Kirsch, Response to acute monotherapy for major depressive disorder in randomized, placebo controlled trials submitted to the US Food and Drug Administration: individual participant data analysis, *BMJ*, **2022**, *378*, 67606. [Crossref], [Google Scholar], [Publisher]

[26] A. Fitrikasari, N.D. Wardani, T.A. Sumekar, F. Saktini, H.G. Asikin, M. Sulchan, The role of psychosocial stressors, carbohydrate and protein intake on serum serotonin and cortisol levels in patients with depression: a preliminary evaluation, *Bali Medical Journal*, **2021**, *10*, 137-141. [Crossref], [Google Scholar], [Publisher]

[27] C. Gold, J. Fachner, J. Erkkilä, Validity and reliability of electroencephalographic frontal alpha asymmetry and frontal midline theta as biomarkers for depression, *Scandinavian Journal of Psychology*, **2013**, *54*, 118-26. [Crossref], [Google Scholar], [Publisher]

[28] A.N.M. Ansori, M.H. Widyananda, Y. Antonius, A.A.A. Murtadlo, V.D. Kharisma, P.A. Wiradana, S. Sahadewa, F.D. Durry, N. Maksimiuk, M. Rebezov, R. Zainul, A review of cancer-related hypercalcemia: Pathophysiology, current treatments, and future directions, *Journal of Medicinal and Pharmaceutical Chemistry Research*, **2024**, *6,* 944-952. [Crossref], [Publisher]

How to cite this article: Susana Anggar Kusuma, Agustina Konginan, The benefits of quantitative electroencephalogram (QEEG) in depression. *Journal of Medicinal and Pharmaceutical Chemistry Research*, 2024, 6(11), 1662-1676. **Link:** https://jmpcr.samipubco.com/article_196338.html