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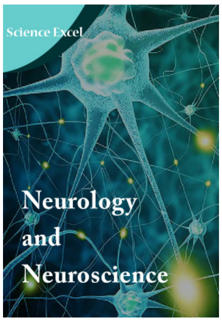

Bipolar Disorder and Beta Frequency Band: Neurophysiological Impacts During the COVID-19 Pandemic

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Abstract

The COVID-19 pandemic posed significant challenges to mental health, particularly for individuals with bipolar disorder. This review study aimed to investigate the relationship between bipolar disorder and electroencephalographic activity in the beta frequency band (13–30 Hz), analyzing its role in attentional and sensorimotor integration processes. The literature indicates that beta activity is associated with alertness and cognitive functions, serving as a potential biomarker for diagnosis and clinical monitoring. During the pandemic, factors such as stress, social isolation, and circadian rhythm disruption intensified the symptoms of the disorder, which were reflected in beta band activity alterations. Furthermore, the methodological variability of the reviewed studies highlights the need for improved experimental paradigms and analytical techniques. These findings emphasize the importance of future research on neurophysiological activity in bipolar patients and therapeutic interventions targeting beta band modulation.

Introduction

The COVID-19 pandemic has posed unprecedented challenges to global mental health, intensifying pre-existing conditions and triggering new psychological disorders. Among the most vulnerable groups are individuals with bipolar disorder (BD), a psychiatric condition characterized by alternating episodes of mania and depression, affecting approximately 1–3% of the global population [1].

Studies have associated BD with alterations in electroencephalographic (EEG) activity, particularly within the beta frequency band (13–30 Hz), which is linked to cognitive processes such as alertness, attention, and motor planning [2,3]. These cognitive impairments—particularly deficits in attention, working memory, and executive function—are observed across manic, depressive, and euthymic states [4-6].

In this context, oculomotor control, especially saccadic eye movements, has been investigated to understand sensorimotor integration and how sensory inputs are processed for motor responses [6,7]. Saccadic tasks are considered cognitive biomarkers due to their strong association with attentional processes and neural circuitry involved in behavioral regulation [8,9].

Quantitative Electroencephalography (qEEG) provides a non-invasive approach for measuring cortical activity. It enables the analysis of neural oscillations and coherence between brain regions in various cognitive states. Among its metrics, beta-band coherence has emerged as a potential biomarker for neuropsychiatric disorders, including BD, especially under stressful conditions such as those imposed by the COVID-19 pandemic [10-12].

Given the known association between beta oscillations, attentional control, and motor planning, and the pandemic's impact on stress regulation and circadian rhythms, this study aims to review the neurophysiological implications of beta-band activity in individuals with bipolar disorder during the COVID-19 pandemic.

Electroencephalography, Coherence, And Brain Frequency Bands

Electroencephalography (EEG) is a non-invasive method used to record the brain's electrical activity through electrodes placed on the scalp. These electrodes detect the electrical potentials generated by pyramidal neurons in the cerebral cortex. Since the first human EEG recording by Hans Berger in 1924, EEG has become a valuable clinical and research tool for monitoring brain function [13,14].

One of EEG's key advantages is its excellent temporal resolution, allowing for real-time

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monitoring of neural processes. However, its spatial resolution is limited due to the diffusive nature of electrical signals across the scalp. To overcome the subjectivity of visual EEG interpretation, Quantitative EEG (qEEG) has been developed, incorporating mathematical signal processing techniques to provide more objective data analysis [10].

The qEEG enables the computation of several metrics, including absolute and relative power, coherence, and asymmetry. Absolute power refers to the energy within a specific frequency band, while relative power reflects the proportion of energy relative to total signal power. Coherence, in turn, measures the degree of synchronization between two brain regions, serving as an indicator of functional connectivity [15]. Asymmetry assesses imbalances in power distribution across homologous brain areas, contributing to clinical diagnoses [16].

EEG signals are typically categorized into five frequency bands: delta (<4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (>30 Hz). Each band corresponds to distinct cognitive and physiological states [17,18]. Beta band activity is particularly relevant in tasks involving somatosensory processing, motor preparation, decision-making, and attentional engagement [19,20].

The 10–20 international system [21] is the standard protocol for electrode placement, allowing reproducibility across studies and longitudinal evaluations. Electrodes are positioned to cover frontal, central, temporal, parietal, and occipital brain regions. In the context of bipolar disorder, beta-band coherence has shown promise as a neurophysiological biomarker, with implications for both diagnosis and treatment monitoring [11,12]. Beta oscillations are associated with cortical activation and mental engagement, particularly in attention-demanding tasks. Changes in beta activity may reflect underlying cognitive and emotional dysfunctions common in BD patients, especially under stress-inducing circumstances such as the COVID-19 pandemic [22,23].

Bipolar Disorder and the Beta Frequency Band

Bipolar disorder (BD) is a psychiatric condition characterized by cyclical mood changes, including manic/hypomanic and depressive episodes. These mood fluctuations are often accompanied by cognitive dysfunctions that impair social functioning, decision-making, and attention [24-26].

During manic episodes, patients commonly display heightened motor activity, reduced need for sleep, impulsivity, and distractibility, which are linked to deficits in executive function and attentional regulation [12,27]. Depressive phases, on the other hand, are marked by low energy, psychomotor retardation, and decreased attentional capacity. Even in euthymic states, cognitive impairments persist, including difficulties with verbal and visual memory, selective attention, and processing speed [28].

From a neurophysiological standpoint, BD has been associated with alterations in neural oscillations, particularly within the beta frequency band (13–30 Hz), which plays a critical role in motor planning and attentional control [15,29]. Beta-band coherence is considered a key oscillatory parameter and has been proposed as a biomarker for diagnosis and treatment monitoring in BD [11,30].

Saccadic eye movement tasks—particularly antisaccade paradigms—have demonstrated sensitivity in detecting cognitive control deficits in BD. These tasks require inhibition of reflexive responses and are dependent on prefrontal cortex activation. Bipolar patients often exhibit increased error rates and prolonged reaction times, which vary according to mood phase and may reflect alterations in frontostriatal and parietal connectivity [31-33].

Additionally, fluctuations in mood throughout the day can affect task performance, contributing to variability in behavioral and electrophysiological data [34]. Compared to schizophrenic patients, individuals with BD display less consistency in saccadic responses over time, suggesting unstable cognitive control [35].

Studies have also highlighted deficits in facial emotion recognition, problem-solving, and working memory in BD, further linking these impairments to dysfunctional beta oscillations and impaired functional connectivity [23,36]. These disruptions appear to intensify under conditions that require sustained attention and sensory integration, reinforcing the role of beta-band activity in the neurocognitive profile of BD patients [12]. Taken together, the evidence suggests that beta-band dynamics—particularly coherence and power—are essential markers of cognitive stability and attentional capacity in BD, with potential clinical utility for diagnostic and therapeutic interventions.

Bipolar Disorder, Beta Frequency Band, and the Covid-19 Pandemic

The reviewed literature reveals that the COVID-19 pandemic significantly intensified bipolar disorder symptoms, leading to more frequent manic and depressive episodes (37). These exacerbations were associated with altered beta frequency activity, reflecting increased anxiety, irritability, and impaired concentration.

Almeida et al. [1] observed elevated beta power in bipolar patients during periods of intense stress related to social isolation. This increase was correlated with higher cortisol levels, suggesting a neurophysiological stress response that may worsen mood instability. Such findings reinforce the hypothesis that chronic stress exposure disrupts cognitive and emotional regulation in BD.

Disruptions in sleep and circadian rhythms, which were commonly reported during the pandemic, are known to influence neural oscillatory patterns. Fernandes et al. [38] noted that these disruptions were mirrored in beta band instability—marked by increased activity during wakefulness and reduced coherence during sleep—which may contribute to rapid cycling and emotional dysregulation.

The beta band, implicated in cognitive alertness and behavioral control, appears to be sensitive to the emotional volatility characteristic of BD. Studies suggest that elevated beta activity is observed during manic episodes, while reductions occur in depressive states [2]. The pandemic's persistent stressors may have amplified these oscillatory fluctuations, complicating symptom management and functional recovery.

Emerging treatments such as transcranial magnetic stimulation (TMS) have shown potential in modulating beta activity. Fernandes et al. [38] demonstrated that TMS may help stabilize beta oscillations, leading to improved emotional regulation and cognitive performance. Additionally, neurofeedback and biofeedback techniques aimed at beta regulation are being explored as supportive interventions during periods of heightened symptomatology.

The long-term neurophysiological consequences of the pandemic on individuals with BD remain unclear. However, continued research into beta band modulation offers promising avenues for understanding post-pandemic mental health trajectories and improving relapse prevention strategies [22].

Conclusion

This literature review highlights the impact of the COVID-19 pandemic on the neurophysiological functioning of individuals with bipolar disorder, with a particular focus on beta-band activity. The pandemic's psychosocial stressors—such as prolonged isolation, circadian disruption, and heightened anxiety—intensified bipolar symptoms and were reflected in significant alterations in beta oscillations.

These findings support the role of the beta frequency band as a potential biomarker for mood regulation and attentional control in BD. Beta coherence and power variations, particularly under stress, provide valuable insights into the cognitive and emotional dysregulation characteristic of this disorder.

Therapeutic strategies such as transcranial magnetic stimulation and biofeedback have shown promise in modulating beta activity, pointing toward novel clinical interventions. However, the heterogeneity of current studies underscores the need for standardized methodologies and longitudinal approaches to better understand beta-band dynamics in bipolar disorder.

Continued research in this field is essential for improving diagnostic precision, developing personalized treatment protocols, and ultimately enhancing the quality of life for individuals living with bipolar disorder—especially in the wake of global crises such as the COVID-19 pandemic.

Conflict of Interests

The authors have no conflict of interests to declare

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