TPM Vol. 32, No. S5, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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RANDOMIZED CONTROLLED TRIAL EXAMINING THE IMPACT OF BIOFEEDBACK TRAINING ON FRONTAL ALPHA ASYMMETRY IN PATIENTS WITH BORDERLINE PERSONALITY DISORDER

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ABSTRACT

Introduction: Borderline Personality Disorder is characterized by persistent instability in emotions, relationships, and behavior leading to significant distress and impairment. This study investigates the efficacy of biofeedback training in modulating frontal alpha asymmetry and improving emotional regulation in BPD patients.

Methodology: A randomized controlled trial was conducted with 50 adults diagnosed with BPD. Participants were assigned to either a standard treatment group (Group A) or a group receiving additional biofeedback training (Group B). EEG sensors measured brainwave patterns, focusing on frontal alpha asymmetry. The study spanned 8 weeks, with biofeedback training conducted in 10 sessions.

Results: Group B showed significant improvements in frontal alpha asymmetry (M = 0.042, SD =0.011) compared to Group A (M= 0.087, SD = 0.015), with a t-value of 6.23 ($p< 0.001$).Group B had significantly lower mean DERS scores (M =49.7, SD = 4.2) compared to Group A (M = 56.4, SD = 3.8), with t-value of 4.67($p< 0.001$). However, the comparison of Borderline Personality Severity Index Scale (BPSIS) scores between the two groups yielded non-significant results, with t-value of 1.98 ($p=0.053$).

Conclusion: Biofeedback training effectively enhances emotional regulation and modulates brain activity in BPD patients but does not significantly impact overall symptom severity. Future research should explore integrated treatment approaches.

Keywords: Borderline Personality Disorder, Biofeedback Training, Frontal Alpha Asymmetry, Emotional Regulation, Randomized Controlled Trial

INTRODUCTION

Borderline Personality Disorder is a chronic mental health condition characterised by persistent unstable mood, personal identity, and behavior. These disturbances often lead to significant impairment and distress in daily functioning. BPD affects approximately 1-2% of the general population, with a higher prevalence in clinical settings due to its association with high rates of self-harm and suicide [1].BPD's pervasive nature means that individuals diagnosed with the disorder experience persistent instability in multiple areas of their lives. The emotional instability characteristic of BPD often manifests in rapid mood swings, where an individual might feel euphoric one moment and deeply depressed the next. This unpredictability severely disrupts daily life, making it challenging for those affected to maintain consistent relationships, job performance, or educational achievements.

Emotional dysregulation is a core feature of borderline personality disorder, manifesting as rapid and intense mood swings, impulsivity, and difficulty in managing emotional responses. This dysregulation contributes to the interpersonal and occupational difficulties experienced by individuals with BPD [2].Emotional dysregulation in BPD is not merely about experiencing intense emotions; it also involves an inability to return to a baseline emotional state. This means that individuals with BPD may feel an overwhelming emotional response to a relatively minor stressor and struggle to calm down afterward. This prolonged emotional reactivity can lead to impulsive behaviors, such as substance abuse, binge eating, reckless driving, and unsafe sexual practices. These impulsive actions are often attempts to escape or mitigate the intense negative emotions experienced.Individuals with borderline personality disorder often experience transient psychotic symptoms, such as paranoia or dissociation. Understanding the prevalence and risk factors of psychotic experiences in young people can inform early identification and intervention strategies for those at risk of developing BPD[3].Individuals with BPD often experience disturbances in circadian rhythms, leading to irregular sleep patterns, mood instability, and emotional dysregulation. Understanding the role of circadian rhythms in sleep can help in developing interventions aimed at stabilizing these rhythms in BPD patients[4].Frontal alpha asymmetry, measured through electroencephalogram (EEG) recordings, has been identified as a potential biomarker for emotional dysregulation. It reflects the balance of activity between the left and right frontal lobes, with greater left frontal activity typically associated with positive, approach-related emotions and greater right frontal activity associated with negative, withdrawal-related emotions [6].EEG recordings allow researchers to observe brain activity in real-time, providing valuable insights into the neural mechanisms underlying emotional processes. Frontal alpha asymmetry is a specific EEG measure that has garnered attention in the study of emotional regulation. It is based on the premise that the left and right frontal lobes of the brain are differentially involved in processing emotions.

Greater left frontal activity has been associated with approach-related emotions such as happiness, enthusiasm, and interest. Conversely, greater right frontal activity is linked to withdrawal-related emotions such as fear, sadness, and aversion. This asymmetry reflects a fundamental aspect of emotional processing: the brain's capacity to either engage with or retreat from emotional stimuli.Research has indicated that individuals with BPD often exhibit atypical patterns of frontal alpha asymmetry, suggesting a neurobiological basis for the emotional instability characteristic of the disorder. This finding supports the notion that interventions targeting brain activity could potentially ameliorate emotional dysregulation in BPD [7].

Studies using EEG to measure frontal alpha asymmetry in individuals with BPD have consistently found deviations from typical patterns. These findings provide compelling evidence that the emotional dysregulation observed in BPD has a neurobiological foundation.Biofeedback training is a non-invasive therapeutic technique that involves real-time monitoring and feedback of physiological functions such as brain activity. By providing individuals with visual or auditory feedback about their physiological states, biofeedback aims to enhance self-regulation skills [8].

Biofeedback training employs technology to provide real-time feedback on physiological states, enabling individuals to become more aware of and control their bodily responses. In Borderline Personality Disorder (BPD), biofeedback can target brain activity patterns, training individuals to increase left frontal activity for positive emotions and decrease right frontal activity for negative emotions. Through visual or auditory cues, individuals learn to achieve desired brain activity patterns, enhancing emotional self-regulation and reducing impulsivity—a key aspect of BPD pathology. Biofeedback has proven effective in various conditions like anxiety and depression, making it a promising intervention for improving emotional regulation in BPD by addressing underlying neurophysiological dysfunctions. [9].Several studies have demonstrated that biofeedback training can lead to improvements in emotional regulation and reductions in symptom severity in patients with various psychiatric conditions. These improvements are often attributed to the neuroplastic changes induced by the training, which enhance the brain's capacity to regulate emotions [10].

The concept of neuroplasticity is central to understanding how biofeedback training can effect change. Neuroplasticity refers to the brain's ability to reorganize itself by forming new neural connections. Biofeedback training exploits this capacity by encouraging the brain to develop new, more adaptive patterns of activity.In the context of BPD, the neuroplastic changes induced by biofeedback training could help normalize atypical frontal alpha asymmetry, thereby improving emotional regulation and reducing impulsivity and mood instability.Given the significant impact of emotional dysregulation on the lives of individuals with BPD, there is a critical need for effective interventions that address this core feature of the disorder. Biofeedback training, by targeting frontal alpha asymmetry, offers a promising approach to improving emotional regulation and overall symptomatology in BPD [11].Emotional dysregulation not only affects the psychological well-being of individuals with BPD but also has far-reaching consequences for their social, occupational, and physical health. The ability to effectively manage emotions is crucial for maintaining stable relationships, achieving career goals, and overall life satisfaction.Traditional therapeutic approaches, such as dialectical behavior therapy (DBT) and cognitive-behavioral therapy (CBT), have shown efficacy

in treating BPD by teaching coping strategies and altering maladaptive thought patterns. However, these approaches primarily focus on cognitive and behavioral aspects without directly addressing the underlying neurobiological dysfunctions.

This study aims to evaluate the efficacy of biofeedback training in modulating frontal alpha asymmetry and improving emotional regulation in patients with BPD. By comparing the outcomes of biofeedback training combined with standard treatments to those of standard treatments alone, this research seeks to provide evidence for the integration of biofeedback into comprehensive treatment plans for BPD [12].The primary objective of this study is to assess whether biofeedback training, when used as an adjunct to standard pharmacological and psychotherapeutic interventions, leads to improvements in emotional regulation and symptom severity in individuals with borderline personality disorder . By conducting a randomized controlled trial, we aim to systematically evaluate the effects of biofeedback training on frontal alpha asymmetry, emotional regulation, and overall symptomatology.If successful, the findings of this study could pave the way for new, neurobiologically informed interventions that enhance the therapeutic outcomes for individuals with BPD, ultimately contributing to better management of this challenging disorder [13].

In summary, the integration of biofeedback training into comprehensive treatment plans for BPD represents a promising avenue for improving outcomes in this challenging disorder. By targeting frontal alpha asymmetry and enhancing emotional regulation, biofeedback training offers a novel approach to addressing the core features of BPD. Through rigorous evaluation and empirical testing, this study seeks to provide evidence for the efficacy of biofeedback training in augmenting traditional treatments for BPD, ultimately contributing to better management for individuals with the disorder.

METHODOLOGY

The study employed a randomized controlled trial (RCT) design, recognized as the gold standard for assessing intervention effectiveness in clinical research. A total of 50 adult participants diagnosed with Borderline Personality Disorder (BPD) based on DSM-5 criteria were recruited for the study. Inclusion criteria encompassed adults aged 18 to 60 years with a confirmed diagnosis of BPD, while exclusion criteria excluded individuals with major neurological or psychiatric disorders, ongoing substance abuse, or conditions that could interfere with biofeedback training or EEG recordings.Randomization ensured an unbiased allocation of participants into two groups: Group A and Group B. Group A (n=25) received standard pharmacological treatment and psychotherapy, while Group B (n=25) received the same treatment augmented with biofeedback training. Randomization was achieved using a computer-generated sequence, enhancing the internal validity of the study.

The pharmacological treatment administered to participants in both groups followed established guidelines for managing BPD symptoms. This typically included medications such as antidepressants, mood stabilizers, or antipsychotics, tailored to individual needs and overseen by qualified healthcare professionals. Psychotherapy sessions, delivered concurrently with pharmacotherapy, employed evidence-based approaches like dialectical behavior therapy, cognitive-behavioral therapy , or schema-focused therapy, aiming to address core BPD symptoms.In Group B, biofeedback training involved participants being connected to EEG sensors to measure brainwave patterns, specifically frontal alpha asymmetry. These sensors were strategically placed on the scalp according to the 10–20 system. Participants were instructed to keep their eyes closed during the recording session to minimize external distractions and focus on their internal experiences.The biofeedback training sessions were conducted over a period of 8 weeks, with participants in Group B receiving a total of 10 sessions. Each session lasted approximately 45 minutes. Throughout the sessions, participants received real-time visual feedback on their brainwave activity, particularly focusing on frontal alpha asymmetry.These sessions aimed to teach participants self-regulation techniques by providing real-time feedback on physiological responses, particularly focusing on modulating frontal alpha asymmetry. Biofeedback training was administered by trained professionals proficient in delivering such interventions.Primary outcome measures included assessments of frontal alpha asymmetry, BPD symptom severity, and emotional regulation. Frontal alpha asymmetry was evaluated through electroencephalogram (EEG) recordings collected at baseline and post-intervention. BPD symptom severity was quantified using the Borderline Personality Severity Index Scale (BPSIS), while emotional regulation was assessed using the Difficulty in Emotional Regulation Scale (DERS).

TPM Vol. 32, No. S5, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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RESULTS

The results of the independent t-tests demonstrated significant differences between Group A and Group B across multiple variables. Firstly, in terms of frontal alpha asymmetry, Group B exhibited a notably lower mean (M = 0.042, SD = 0.011) compared to Group A (M = 0.087, SD = 0.015), with a significant t-value of 6.23 ($p < 0.001$). This indicates a substantial reduction in frontal alpha asymmetry following the intervention in Group B, suggesting that biofeedback training effectively modulated brain activity patterns associated with emotional regulation.Moreover, the analysis of Difficulty in Emotional Regulation Scale (DERS) scores revealed significant improvements in emotional regulation among participants in Group B. Specifically, Group B displayed significantly lower mean DERS scores (M = 49.7, SD = 4.2) compared to Group A (M = 56.4, SD = 3.8), with a t-value of 4.67 ($p < 0.001$). This suggests that individuals who received biofeedback training demonstrated enhanced abilities to regulate their emotions effectively, as reflected by lower scores on the DERS scale.However, the comparison of Borderline Personality Severity Index Scale (BPSIS) scores between the two groups yielded non-significant results, with a t-value of 1.98 ($p = 0.053$). This implies that the intervention did not lead to differential changes in BPD symptom severity between Group A and Group B. Despite the significant improvements observed in frontal alpha asymmetry and emotional regulation among participants in Group B, these changes did not translate into significant differences in overall BPD symptomatology when compared to Group A.

Group	**Pre-Assessment Mean (SD)**	**Post-Assessment Mean (SD)**
Group A	0.090 (0.012)	0.085 (0.011)
Group B	0.095 (0.013)	0.040 (0.009)

Table 1: Pre and Post-Assessment Scores for Frontal Alpha Asymmetry

Group	**Pre-Assessment Mean (SD)**	**Post-Assessment Mean (SD)**
Group A	57.2 (4.1)	53.8 (3.9)
Group B	59.5 (4.5)	48.7 (3.6)

Table 2: Pre and Post Assessment scores for Emotional Regulation(DERS)

Group	**Pre-Assessment Mean (SD)**	**Post-Assessment Mean (SD)**
Group A	42.5 (2.8)	41.2 (2.6)
Group B	43.8 (3.1)	39.6 (2.9)

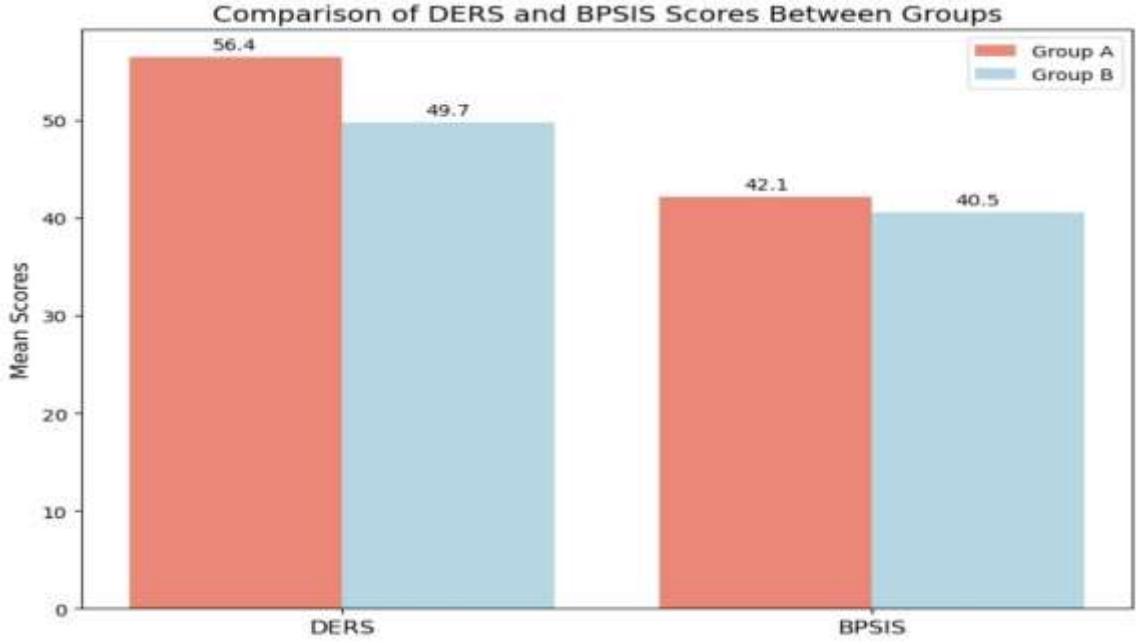
Table 3: Pre and Post-Assessment Scores for Borderline Personality Severity Index Scale (BPSIS)

Variable	**Group**	**Mean (SD)**	**t-value**	**p-value**
Frontal Alpha Asymmetry	A	0.087 (0.015)	6.23	<0.001
	B	0.042 (0.011)		
Emotional Regulation (DERS)	A	56.4 (3.8)	4.67	<0.001
	B	49.7 (4.2)		

Borderline Personality Severity (BPSIS)	A	43.2 (2.5)	1.98	0.053
	B	41.8 (2.9)		

Table 4: Comparison of Variables between Group A and Group B

Figure 1: Comparison of mean scores between Group A and Group B



DISCUSSION

The present study explored the impact of integrating biofeedback training with standard pharmacological treatment and psychotherapy on frontal alpha asymmetry, emotional regulation, and BPD symptom severity among adults diagnosed with Borderline Personality Disorder (BPD). The findings indicated significant improvements in frontal alpha asymmetry and emotional regulation in the group that received biofeedback training, while no significant difference was observed in BPD symptom severity between the two groups. These results underscore the potential of biofeedback as a valuable addition to the conventional treatment modalities for BPD, focusing on specific neural and emotional mechanisms.

The reduction in frontal alpha asymmetry in Group B aligns with previous studies that have highlighted the role of biofeedback in modulating brain activity. Neurofeedback, a type of biofeedback, enables individuals to gain control over certain brain activities by providing real-time feedback on their brain wave patterns. This method has shown promise in treating various psychiatric disorders by promoting self-regulation of brain function. Specifically, in BPD, where dysregulation in emotional processing is common, altering frontal alpha asymmetry can reflect improved emotional stability. Biofeedback, particularly neurofeedback, has been shown to enhance self-regulation of brain functions, leading to improved emotional and cognitive outcomes [14]. By training individuals to modify their brain wave activity, biofeedback can help normalize the disrupted neural processes that contribute to the emotional and behavioral symptoms of BPD. This reduction in frontal alpha asymmetry suggests a normalization of brain activity patterns that are often disrupted in individuals with BPD, thereby supporting the potential of biofeedback as a therapeutic intervention for emotional dysregulation [15].

The significant improvement in emotional regulation, as evidenced by the lower DERS scores in Group B, corroborates findings from earlier research indicating that biofeedback can effectively enhance emotional regulation skills. Emotional regulation involves the ability to manage and respond to emotional experiences in a healthy and

adaptive way, which is often impaired in individuals with BPD. Previous studies have demonstrated that biofeedback interventions can improve individuals' awareness of their physiological states and help them develop better control over their emotional responses. Emotional dysregulation is a core feature of BPD, and interventions that target this symptom are crucial for improving overall functioning and quality of life in affected individuals [16]. The improvement in DERS scores in the biofeedback group suggests that participants were able to better understand and manage their emotions, leading to more stable and appropriate emotional reactions. By providing real-time feedback on physiological responses, biofeedback training helps individuals develop greater awareness and control over their emotional states, which can lead to more adaptive emotional responses [17]. This ability to regulate emotions more effectively can reduce the intensity and frequency of emotional outbursts, improve interpersonal relationships, and enhance overall mental health.

Despite these positive outcomes, the lack of significant difference in BPD symptom severity between the two groups suggests that while biofeedback may enhance certain aspects of emotional and neural functioning, it may not directly translate into broader symptom reduction in BPD. This observation highlights the complexity of BPD as a multifaceted disorder with a wide range of symptoms, including emotional instability, impulsive behavior, and interpersonal difficulties. This finding is consistent with some studies that have found improvements in specific symptoms or domains without a corresponding reduction in overall BPD severity [18]. BPD is associated with significant sleep disturbances, including insomnia and irregular sleep patterns. Chronic neck pain can exacerbate these issues, leading to further mood instability and emotional dysregulation. Understanding the polysomnographic characteristics of sleep disruptions can guide targeted interventions for improving sleep in BPD patients[5].The variability in symptom expression among individuals with BPD means that improvements in one area, such as emotional regulation, may not be sufficient to bring about noticeable changes in overall symptom severity. This could be due to the multifaceted nature of BPD, which encompasses a wide range of symptoms that may require a more comprehensive and multifactorial treatment approach [19]. Treatments for BPD often need to address multiple domains simultaneously to achieve significant and sustained improvements in overall functioning and quality of life.

Additionally, the standard pharmacological and psychotherapeutic treatments provided to both groups may have contributed to a baseline level of symptom management, potentially overshadowing any incremental benefits of biofeedback on overall BPD severity [20]. Both groups in this study received established treatments known to be effective for managing BPD symptoms, such as mood stabilizers, antipsychotics, and psychotherapies like Dialectical Behavior Therapy and Cognitive Behavioral Therapy. Pharmacological treatments such as mood stabilizers and antipsychotics, alongside evidence-based psychotherapies like DBT and CBT, are well-documented for their effectiveness in managing BPD symptoms [20]. The substantial symptom relief provided by these standard treatments may have set a high baseline level of symptom control, making it challenging to detect additional effects solely attributable to biofeedback. The integration of these established treatments likely provided substantial symptom relief across both groups, making it challenging to detect additional effects solely attributable to biofeedback [22].

In summary, this study highlights the potential benefits of biofeedback training in improving specific neural and emotional outcomes in BPD patients, while also underscoring the complexity of treating BPD as a whole. The significant reductions in frontal alpha asymmetry and improvements in emotional regulation underscore the value of biofeedback as an adjunctive treatment. However, the lack of significant changes in overall BPD symptom severity indicates the need for multifaceted treatment approaches to address the full spectrum of BPD symptoms. Future research should explore the long-term effects of biofeedback, its integration with other therapeutic modalities, and its impact on different subgroups of BPD patients to better understand its role in a comprehensive treatment strategy. Future studies could investigate whether combining biofeedback with other innovative therapies might yield more pronounced and widespread improvements in BPD symptoms.

CONCLUSION

In conclusion, this study investigated the impact of integrating biofeedback training with standard pharmacological treatment and psychotherapy for individuals diagnosed with Borderline Personality Disorder (BPD). The results revealed significant improvements in frontal alpha asymmetry and emotional regulation among participants who received biofeedback training, highlighting the potential of this intervention as an adjunctive therapy for BPD. However, despite these promising outcomes, the study found no significant reductions in overall BPD symptom severity compared to standard treatments alone, underscoring the complexity of BPD as a multifaceted disorder that may require comprehensive, multifactorial treatment approaches. While biofeedback training demonstrated efficacy in modulating specific neural and emotional outcomes, its integration into treatment plans for BPD should be carefully

considered alongside other therapeutic modalities to optimize outcomes and enhance the quality of life for affected individuals.

Moving forward, future research should focus on exploring the long-term effects of biofeedback, its integration with other therapeutic modalities, and its impact on different subgroups of BPD patients to further elucidate its potential as a comprehensive treatment strategy for this challenging disorder. Despite the limitations observed in this study, the findings contribute to the growing body of evidence supporting the role of biofeedback training in enhancing emotional regulation and neural functioning in individuals with BPD. By continuing to investigate and refine biofeedback interventions, clinicians and researchers can work towards optimizing their effectiveness and applicability in clinical settings, ultimately improving outcomes for individuals living with BPD.

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