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The Neurobiological Basis of Borderline Personality Disorder: An Integrative Review

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Abstract

Background: Borderline Personality Disorder (BPD) is a severe and complex psychiatric illness characterized by pervasive instability in affect regulation, impulse control, interpersonal relationships, and self-image. While historically understood through psychosocial lenses, contemporary research has established a robust neurobiological foundation. This review synthesizes current evidence to provide an integrative model linking genetic predisposition, early environmental adversity, and alterations in brain structure, function, and neurochemistry.

Objectives: To systematically review and integrate evidence on the structural, functional, neurochemical, and genetic correlates of BPD, and to propose a coherent neurodevelopmental etiological model that explains core clinical symptoms.

Methods: A narrative review was conducted using PubMed, Scopus, and PsycINFO for literature published between 2005-2025. Search terms included "borderline personality disorder neurobiology," "BPD neuroimaging," "BPD genetics," and "fronto-limbic." Priority was given to meta-analyses, systematic reviews, and original research with robust methodology. Findings were synthesized thematically to construct an integrated model.

Results: Converging evidence confirms a primary dysfunction in fronto-limbic and salience networks, characterized by amygdala and insula hyperreactivity to emotional stimuli coupled with diminished prefrontal (especially orbitofrontal and anterior cingulate cortices) regulation. Structural alterations in these regions are prevalent. Neurochemically, dysfunction in serotonergic and oxytocinergic systems, alongside hypothalamic-pituitary-adrenal (HPA) axis hyperactivity, are central. Significant gene-environment interactions (e.g., involving *SLC6A4*, *FKBP5*) mediate risk, with epigenetics providing a mechanism for the biological embedding of early trauma. Effective psychotherapies induce measurable neuroplastic changes, normalizing these dysfunctions.

Conclusions: BPD is best conceptualized as a neurodevelopmental disorder of emotion regulation and social cognition. A triple-network dysfunction model—involving hyperactive salience, underactive executive control, and altered default mode networks—effectively explains the core phenotype. This model unifies biological and psychosocial perspectives, reduces stigma, and directs future research toward circuit-based therapeutics and preventative interventions for at-risk individuals.

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Introduction

Borderline Personality Disorder (BPD) is a severe, chronic, and complex psychiatric condition characterized by a pervasive pattern of emotional dysregulation, tumultuous interpersonal relationships, identity disturbance, impulsivity, and high rates of self-injurious and suicidal behaviors.[1,2] With a lifetime prevalence

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estimated at 1-3% in the general population and accounting for 15-20% of inpatient psychiatric admissions, BPD poses a significant public health burden marked by intense personal suffering, substantial functional impairment, and high economic costs.[3,4] For decades, the etiology of BPD was predominantly framed within psychodynamic and psychosocial models, with particular emphasis on adverse developmental experiences, especially childhood trauma and emotional invalidation.[5,6] While trauma exposure remains a critical environmental risk factor, the observation that only a subset of exposed individuals develop BPD necessitated the exploration of biological vulnerability factors.[7]

The past two decades have witnessed a paradigm shift toward a biopsychosocial model, where neurobiology constitutes the critical interface between genetic predisposition and environmental experience.[8,9] This shift has been driven by advances in neuroimaging, genetics, and molecular neuroscience, allowing researchers to move beyond descriptive phenomenology to investigate the neural and biological substrates of the disorder.[10] Understanding these substrates is not merely an academic exercise; it is essential for destigmatizing BPD, reframing symptoms as expressions of brain dysfunction rather than volitional manipulation, and developing more targeted and effective treatments.[11]

This review aims to provide a comprehensive and updated synthesis of the current state of knowledge on the neurobiological basis of BPD. We will systematically examine evidence across multiple levels of analysis: 1) structural and functional brain abnormalities, 2) neurochemical and neuroendocrine dysregulation, and 3) genetic and epigenetic risk factors. Critically, we will integrate these findings into a coherent neurodevelopmental framework—the triple-network dysfunction model—that explains how core clinical symptoms emerge from disrupted brain network interactions. Finally, we will discuss the implications of this model for treatment, prognosis, and future research directions, arguing that a deep neurobiological understanding is fundamental to advancing the care of individuals with this challenging disorder.

Methods

This article constitutes a comprehensive narrative review of the neurobiological literature on BPD. A systematic search strategy was employed to identify relevant studies published in English between 2005 and October 2025.

Information Sources and Search Strategy: Electronic databases (PubMed, Scopus, and PsycINFO) were searched using the following key terms and their combinations: "borderline personality disorder," "neurobiology," "neuroimaging," "fMRI," "structural MRI," "DTI," "genetics," "epigenetics," "HPA axis," "oxytocin," "serotonin," "fronto-limbic," "amygdala," "anterior cingulate cortex," and "emotional dysregulation." The search was limited to human studies. Reference lists of retrieved articles, particularly recent meta-analyses and major reviews, were hand-searched to identify additional relevant sources.

Study Selection and Synthesis: Inclusion criteria prioritized: (1) meta-analyses and systematic reviews; (2) original research studies employing standardized diagnostic criteria (DSM-5 or ICD-11) for BPD; (3) studies with adequate sample sizes (typically n>20 per group) and well-matched healthy control (HC) groups; (4) research utilizing established neurobiological methods (e.g., structural/functional MRI, PET, electrophysiology, hormonal assays, genetic/epigenetic analysis). Studies focusing solely on comorbid conditions without a primary BPD focus were excluded. Clinical trials and longitudinal studies were given special emphasis for their etiological and treatment implications. The identified literature was analyzed and synthesized thematically, focusing on convergence of evidence, methodological strengths/limitations, and explanatory power for core clinical symptoms, to construct an integrated neurobiological model.

Results

Structural Brain Abnormalities

Meta-analyses of volumetric magnetic resonance imaging (MRI) studies reveal a consistent pattern of structural alterations in brain regions central to emotion processing and behavioral control. The most replicated findings are bilateral volume reductions in the amygdala and hippocampus, with small-to-medium effect sizes.[12,13] These reductions are positively correlated with the severity of childhood trauma, particularly emotional abuse, and with symptom chronicity.[14,15] The anterior cingulate cortex (ACC), a region crucial for conflict monitoring and emotion regulation, also shows significant volume loss, especially in its pregenual and dorsal subregions.[16,17] Findings for the orbitofrontal cortex (OFC) and dorsolateral prefrontal cortex (dlPFC) are more variable but generally trend toward reduced volumes, particularly in the OFC, which is implicated in impulse control and value-based decision-making.[18,19] The insula, responsible for interoceptive awareness and subjective emotional feeling, shows altered morphology, though volumetric changes are less consistent.[20]

Advanced imaging techniques provide further insight. Diffusion Tensor Imaging (DTI) studies reveal microstructural abnormalities in the white

matter tracts that connect these regions, indicating disrupted neural communication. Most consistently, the uncinate fasciculus (linking the amygdala and OFC) and the cingulum bundle (linking the ACC to limbic structures) show reduced fractional anisotropy (FA), a measure of white matter integrity.[21,22] This "disconnection syndrome" suggests that the core problem in BPD may not only be localized dysfunction but also impaired integration between emotion-generating and emotion-regulating brain systems.

Functional Neuroimaging: From Fronto-Limbic to Triple-Network Dysfunction

The classic fronto-limbic dysregulation model posits a failure of "top-down" prefrontal control over hyperreactive "bottom-up" limbic emotion generation.[23] Functional MRI (fMRI) studies robustly support this: individuals with BPD exhibit exaggerated amygdala and anterior insula activation in response to emotionally evocative stimuli, such as negative facial expressions (especially fear and anger), social exclusion paradigms (e.g., Cyberball), and personalized abandonment scripts.[24,25,26] Concurrently, tasks requiring emotional regulation, impulse inhibition, or cognitive reappraisal show reduced activation in prefrontal regulatory regions, including the dlPFC, ventrolateral PFC (vlPFC), and dorsal ACC.[27,28]

A more contemporary synthesis extends this model to a triple-network dysfunction framework, involving the salience, executive control, and default mode networks.[29]

- **Salience Network (SN) Hyperactivity:** Comprising the amygdala, anterior insula, and dorsal ACC, the SN identifies salient emotional stimuli. In BPD, this network is chronically hyperactive and hypersensitive, leading to the rapid, intense, and often inappropriate emotional reactions that are a hallmark of the disorder.[30]
- **Executive Control Network (ECN) Hypofunction:** Involving the dlPFC and lateral parietal cortices, the ECN mediates top-down cognitive control. In BPD, reduced ECN activity and compromised functional connectivity between the ECN and the SN underlie profound difficulties in modulating emotional responses, leading to impulsivity and affective instability.[31]
- **Default Mode Network (DMN) Alterations:** The DMN (medial PFC, posterior cingulate, angular gyrus) is active during self-referential thought. In BPD, the DMN shows abnormal connectivity with both the SN and ECN.[32] This may manifest as identity disturbance, a fragmented sense of self, and dissociation. During dissociative states, a distinct pattern is observed with paradoxical hypoactivation of the amygdala and hyperactivation of medial PFC regions, representing a neural shutdown in response to overwhelming stress.[33]

Neurochemical and Neuroendocrine Dysregulation

Serotonin (5-HT): Central 5-HT dysfunction is one of the most consistent neurochemical findings in BPD, particularly linked to impulsivity and aggression. Positron emission tomography (PET) studies show reduced 5-HT transporter binding and altered 5-HT2A receptor availability in frontal and limbic regions.[34] Pharmacological challenge studies (e.g., with fenfluramine or meta-Chlorophenylpiperazine) demonstrate a blunted neuroendocrine response, indicating reduced central serotonergic activity.[35]

- **Oxytocin (OXT):** The OXT system, central to social bonding, trust, and stress buffering, is profoundly altered. Individuals with BPD often exhibit elevated baseline peripheral OXT levels—potentially reflecting chronic relational stress—but a blunted OXT response to psychosocial stress and positive social interactions, suggesting system exhaustion or dysregulation.[36,37] Intranasal OXT administration can paradoxically increase distrust, social anxiety, and amygdala reactivity to negative faces in BPD patients, highlighting a fundamentally disrupted social neuropeptide system.[38]
- **Hypothalamic-Pituitary-Adrenal(HPA)Axis:** Chronic, maladaptive stress response is a core feature. A common pattern is elevated baseline cortisol and impaired negative feedback inhibition, as evidenced by non-suppression on the dexamethasone suppression test.[39,40] This HPA axis hyperactivity reflects allostatic load, is tightly linked to early trauma history, and correlates with symptom severity, particularly dissociative and paranoid symptoms.

Genetics and Epigenetics

Family and twin studies estimate the heritability of BPD traits at approximately 40-50%, indicating a substantial genetic contribution that interacts with environmental factors.[41]

- **Genetics:** Genome-wide association studies (GWAS) are in early stages but suggest a polygenic architecture, sharing genetic risk with related internalizing and **externalizing** disorders.[42] Candidate gene studies have focused on systems implicated in neuroimaging and neurochemistry. Polymorphisms in the serotonin transporter gene (SLC6A4, particularly the short allele of 5-HTTLPR) and the tryptophan hydroxylase-2 gene (TPH2) interact with childhood trauma to increase the risk for BPD traits, aggression, and amygdala hyperreactivity.[43,44] Genes involved in neuroplasticity (e.g., BDNF Val66Met) and

glutamatergic signaling (e.g., GRIN2B) are also under investigation.[45,46]

- **Epigenetics:** Epigenetic mechanisms, such as DNA methylation, provide a molecular link between early environment and lasting changes in gene expression. In BPD, hypermethylation of the glucocorticoid receptor gene (NR3C1) and the FK506 binding protein 5 gene (FKBP5) has been reported.[47,48] These epigenetic changes, often linked to childhood maltreatment, lead to dysregulated HPA axis feedback and heightened stress sensitivity, biologically embedding the trauma experience.

Neurobiology of Treatment Response

Effective, evidence-based psychotherapies induce measurable neuroplastic changes, underscoring the malleability of the dysfunctional circuits in BPD.

- **Dialectical Behavior Therapy (DBT):** fMRI studies before and after DBT show increased activation in the vlPFC and ACC during emotion regulation tasks, alongside reduced amygdala reactivity.[49,50] This demonstrates a normalization of the fronto-limbic inhibitory circuit.
- **Mentalization-Based Treatment (MBT):** MBT is associated with increased activation and functional connectivity in the OFC and temporoparietal junction—regions involved in understanding one's own and others' mental states—supporting improved social cognition and affect representation.[51]
- **Pharmacology:** While no drugs are FDA-approved for BPD core pathology, medications like selective serotonin reuptake inhibitors (SSRIs) or second-generation antipsychotics are used off-label to target specific symptom clusters (e.g., affective dysregulation, cognitive-perceptual symptoms). Their mechanisms are thought to involve modulation of the underlying serotonergic, dopaminergic, and glutamatergic imbalances.[52,53]

Discussion

This review consolidates overwhelming evidence that BPD is a neurodevelopmental disorder of circuit dysfunction. The triple-network model provides a powerful, integrative heuristic: a hypervigilant Salience Network (SN) constantly signals social-emotional threat, a weakened Executive Control Network (ECN) fails to modulate these signals, and a disorganized Default Mode Network (DMN) struggles to maintain a coherent, stable sense of self. This dysfunctional neural architecture is not a fixed lesion but the phenotypic outcome of dynamic Gene × Environment (G×E) interplay.[54,55] Genetic vulnerabilities in stress reactivity, emotional sensitivity, and social information processing create a sensitive "diathesis." When this biological vulnerability is potentiated by early relational trauma—particularly in the context of an invalidating caregiving environment—the development of key fronto-limbic and fronto-cingulate circuits is altered.[56] Epigenetic mechanisms then act as the "biological memory" of this adversity, modifying gene expression in stress and neuroplasticity pathways to consolidate a maladaptive phenotype characterized by emotional hyperarousal and poor self-regulation.[57]

Clinical and Therapeutic Implications: This neurobiological framework has profound clinical utility. First, it actively destigmatizes the disorder. Symptoms such as intense anger, emotional outbursts, and fear of abandonment can be reframed for patients and clinicians alike as expressions of a hyperactive amygdala and a hypoactive prefrontal brake, rather than as character flaws or intentional manipulation. Second, it validates and explains the mechanisms of evidence-based psychotherapies. DBT's focus on distress tolerance and emotion regulation skills directly trains the ECN to better regulate the SN. MBT's emphasis on mentalizing strengthens the cortical networks involved in social cognition and self-reflection, fostering DMN integrity. The neuroplastic changes observed post-treatment confirm that these therapies work, in part, by changing the brain. Third, it guides adjunctive biological interventions. Neuromodulation techniques like repetitive transcranial magnetic stimulation (rTMS) targeting the dlPFC or ACC are being explored to directly enhance top-down control.[58] Future pharmacogenomic approaches may personalize medication choice based on an individual's genetic and neurochemical profile.

Despite significant progress, key limitations must be addressed. The majority of neuroimaging studies are cross-sectional, making it impossible to distinguish causal, predisposing neurobiological traits from consequences of chronic illness, medication, or repeated stressors. Heterogeneity within the BPD diagnosis is rarely accounted for; different neurobiological subtypes (e.g., predominantly impulsive vs. predominantly dissociative) likely exist, requiring more nuanced, symptom-dimension approaches.[59] Most samples consist of treatment-seeking, often severely ill, and highly comorbid individuals, limiting generalizability.

Future research must prioritize:

1. Longitudinal, high-risk prospective studies beginning in adolescence or earlier to map the neurodevelopmental trajectory of BPD and identify predictive biomarkers.

2. **Multimodal data integration** combining genetics, epigenetics, multi-modal neuroimaging (fMRI, EEG, MRS), and digital phenotyping (via smartphone passive sensing and ecological momentary assessment) to create comprehensive biobehavioral models.[60]

3. **Circuit-based therapeutic targeting** using real-time fMRI neurofeedback or closed-loop neuromodulation to directly train dysfunctional networks (e.g., teaching patients to downregulate amygdala activity via neurofeedback).[61]
4. **Investigating novel biological pathways,** including the role of systemic inflammation, the gut-brain axis, and metabolic factors, which are emerging as contributors to psychiatric symptoms and may be relevant in BPD.[62]

Conclusion

The neurobiological landscape of BPD has been irrevocably mapped. No longer a disorder of unknown origin, it is now understood as a psychiatric condition with clear, albeit complex, roots in brain development and function. The integrative model presented here—bridging genes, epigenetics, neural circuits, and neurotransmitters—provides a powerful explanatory framework for the intense emotional pain, interpersonal chaos, and identity confusion that define the disorder. This perspective not only advances scientific understanding but also carries immense humanistic value: it validates patient suffering as real and biologically-based, reduces blame and stigma, and illuminates a path forward. By continuing to elucidate the neurobiological mechanisms of BPD and its treatment, we move closer to a future of personalized, circuit-based interventions, early prevention for at-risk youth, and ultimately, more effective alleviation of suffering for individuals living with this challenging condition.

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Authors Contributions

The authors contributed to the data analysis. Drafting, revising and approving the article, responsible for all aspects of this work.

Conflict of Interest

None

References

1. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders. 5th ed, Text Revision. Washington, DC: American Psychiatric Association; 2022.
2. Leichsenring F, Leibing E, Kruse J, New AS, Leweke F. Borderline personality disorder. Lancet. 2011;377(9759):74-84.
3. Trull TJ, Jahng S, Tomko RL, Wood PK, Sher KJ. Revised NESARC personality disorder diagnoses: gender, prevalence, and comorbidity with substance dependence disorders. J Pers Disord. 2010;24(4):412-26.
4. Soeteman DI, Hakkaart-van Roijen L, Verheul R, Busschbach JJ. The economic burden of personality disorders in mental health care. J Clin Psychiatry. 2008;69(2):259-65.
5. Zanarini MC, Frankenburg FR, Reich DB, et al. The subsyndromal phenomenology of borderline personality disorder: a 10-year follow-up study. Am J Psychiatry. 2007;164(6):929-35.
6. Porter C, Palmier-Claus J, Branitsky A, Mansell W, Warwick H, Varese F. Childhood adversity and borderline personality disorder: a meta-analysis. Acta Psychiatr Scand. 2020;141(1):6-20.
7. Battle CL, Shea MT, Johnson DM, et al. Childhood maltreatment associated with adult personality disorders: findings from the Collaborative Longitudinal Personality Disorders Study. J Pers Disord. 2004;18(2):193-211.
8. Crowell SE, Beauchaine TP, Linehan MM. A biosocial developmental model of borderline personality: Elaborating and extending Linehan's theory. Psychol Bull. 2009;135(3):495-510.
9. Glenn CR, Klonsky ED. Emotion dysregulation as a core feature of borderline personality disorder. J Pers Disord. 2009;23(1):20-8.
10. Insel T, Cuthbert B, Garvey M, et al. Research domain criteria (RDoC): toward a new classification framework for research on mental disorders. Am J Psychiatry. 2010;167(7):748-51.
11. Kolla NJ, Meyer JH. Neuroimaging in borderline personality disorder. Curr Psychiatry Rep. 2019;21(11):113.
12. Nunes PM, Wenzel A, Borges KT, Porto CR, Caminha RM, de Oliveira IR. Volumes of the hippocampus and amygdala in patients with borderline personality disorder: a meta-analysis. J Pers Disord. 2009;23(4):333-45.
13. Ruocco AC, Amirthavasagam S, Choi-Kain LW, McMain SF. Neural correlates of negative emotionality in borderline personality disorder: an activation-likelihood-estimation meta-analysis. Biol Psychiatry. 2013;73(2):153-60.
14. van Zutphen L, Siep N, Jacob GA, Goebel R, Arntz A. Emotional sensitivity, emotion regulation and

impulsivity in borderline personality disorder: a critical review of fMRI studies. Neurosci Biobehav Rev. 2015;51:64-76.

15. Donegan NH, Sanislow CA, Blumberg HP, et al. Amygdala hyperreactivity in borderline personality disorder: implications for emotional dysregulation. Biol Psychiatry. 2003;54(11):1284-93.

16. Hazlett EA, Zhang J, New AS, et al. Potentiated amygdala response to repeated emotional pictures in borderline personality disorder. Biol Psychiatry. 2012;72(6):448-56.

17. Schulze L, Schmahl C, Niedtfeld I. Neural Correlates of Disturbed Emotion Processing in Borderline Personality Disorder: A Multimodal Meta-Analysis. Biol Psychiatry. 2016;79(2):97-106.

18. Soloff PH, White R, Omari A, Ramaseshan K, Diwadkar VA. Affective context interferes with brain responses during cognitive processing in borderline personality disorder: fMRI evidence. Psychiatry Res Neuroimaging. 2015;233(1):23-35.

19. O'Neill A, D'Souza A, Carballedo A, et al. Glutamate/glutamine and neuronal integrity in adults with ADHD: a proton MRS study. Transl Psychiatry. 2014;4(2):e373.

20. Goodman M, Hazlett EA, Avedon JB, Siever DR, Chu KW, New AS. Anterior cingulate volume reduction in adolescents with borderline personality disorder and co-morbid major depression. J Psychiatr Res. 2011;45(6):803-7.

21. Whalley HC, Nickson T, Pope M, et al. White matter integrity and its association with affective and interpersonal symptoms in borderline personality disorder. Neuroimage Clin. 2015;7:476-81.

22. Lischke A, Domin M, Freyberger HJ, et al. Structural alterations in white matter architecture in patients with borderline personality disorder. J Psychiatry Neurosci. 2017;42(3):184-91.

23. New AS, Goodman M, Triebwasser J, Siever LJ. Recent advances in the biological study of personality disorders. Psychiatr Clin North Am. 2008;31(3):441-61.

24. Koenigsberg HW, Siever LJ, Lee H, et al. Neural correlates of emotion processing in borderline personality disorder. Psychiatry Res. 2009;172(3):192-9.

25. Domsalla M, Koppe G, Niedtfeld I, et al. Cerebral processing of social rejection in patients with borderline personality disorder. Soc Cogn Affect Neurosci. 2014;9(11):1789-97.

26. Krause-Utz A, Elzinga BM, Oei NY, et al. Amygdala and dorsal anterior cingulate connectivity during an emotional working memory task in borderline personality disorder patients with interpersonal trauma history. Front Hum Neurosci. 2014;8:848.

27. Schulze L, Domes G, Krüger A, et al. Neuronal correlates of cognitive reappraisal in borderline patients with affective instability. Biol Psychiatry. 2011;69(6):564-73.

28. Silbersweig D, Clarkin JF, Goldstein M, et al. Failure of frontolimbic inhibitory function in the context of negative emotion in borderline personality disorder. Am J Psychiatry. 2007;164(12):1832-41.

29. Menon V. Large-scale brain networks and psychopathology: a unifying triple network model. Trends Cogn Sci. 2011;15(10):483-506.

30. Dixon ML, Thiruchselvam R, Todd R, Christoff K. Emotion and the prefrontal cortex: An integrative review. Psychol Bull. 2017;143(10):1033-81.

31. O'Neill A, D'Souza A, Carballedo A, et al. Dysregulation between emotion and theory of mind networks in borderline personality disorder. Psychiatry Res Neuroimaging. 2015;231(1):25-32.

32. Doll A, Sorg C, Manoliu A, et al. Shifted intrinsic connectivity of central executive and salience network in borderline personality disorder. Front Hum Neurosci. 2013;7:727.

33. Krause-Utz A, Frost R, Winter D, Elzinga BM. Dissociation and Alterations in Brain Function and Structure: Implications for Borderline Personality Disorder. Curr Psychiatry Rep. 2017;19(1):6.

34. Soloff PH, Chiappetta L, Mason NS, et al. Serotonin transporter availability in the amygdala and bed nucleus of the stria terminalis in borderline personality disorder. Psychiatry Res Neuroimaging. 2019;283:92-8.

35. Hansenne M, Pitchot W, Pinto E, Reggers J, Scantamburlo G, Ansseau M. Serotonin function and suicidal behavior in borderline personality disorder. Psychiatr Danub. 2013;25(4):341-4.

36. Bertsch K, Schmidinger I, Neumann ID, Herpertz SC. Reduced plasma oxytocin levels in female patients with borderline personality disorder. Horm Behav. 2013;63(3):424-9.

37. Simeon D, Bartz J, Hamilton H, et al. Oxytocin administration attenuates stress reactivity in borderline personality disorder: a pilot study. Psychoneuroendocrinology. 2011;36(9):1418-21.

38. Bartz J, Simeon D, Hamilton H, et al. Oxytocin can hinder trust and cooperation in borderline personality disorder. Soc Cogn Affect Neurosci. 2011;6(5):556-63.

39. Lieb K, Rexhausen JE, Kahl KG, et al. Increased diurnal salivary cortisol in women with borderline personality disorder. J Psychiatr Res. 2004;38(6):559-65.

40. Wingenfeld K, Spitzer C, Rullkötter N, Löwe B. Borderline personality disorder: hypothalamus-pituitary-adrenal axis and findings from neuroimaging studies. Psychoneuroendocrinology. 2010;35(1):154-70.

41. Distel MA, Trull TJ, Derom CA, et al. Heritability of borderline personality disorder features is similar

across three countries. Psychol Med. 2008;38(9):1219-29.

42. Witt SH, Streit F, Jungkunz M, et al. Genome-wide association study of borderline personality disorder reveals genetic overlap with bipolar disorder, major depression and schizophrenia. Transl Psychiatry. 2017;7(6):e1155.

43. Ni X, Chan D, Chan K, McMain S, Kennedy JL. Serotonin genes and gene-gene interactions in borderline personality disorder in a matched case-control study. Prog Neuropsychopharmacol Biol Psychiatry. 2009;33(1):128-33.

44. Wagner S, Baskaya O, Anicker NJ, et al. The 5-HTTLPR polymorphism modulates the association of serious life events (SLE) and impulsivity in borderline personality disorder. J Psychiatr Res. 2010;44(15):1067-72.

45. Frustaci A, Pozzi G, Gianfagna F, Manzoli L, Boccia S. Meta-analysis of the brain-derived neurotrophic factor gene (BDNF) Val66Met polymorphism in anxiety disorders and anxiety-related personality traits. Neuropsychobiology. 2008;58(3-4):163-70.

46. Bozorgmehr A, Ghadirivasfi M, Shahsavand Ananloo E. Glutamatergic system genes in borderline personality disorder: a systematic review. Psychiatr Genet. 2021;31(4):121-30.

47. Dammann G, Teschler S, Haag T, et al. Increased DNA methylation of neuropsychiatric genes occurs in borderline personality disorder. Epigenetics. 2011;6(12):1454-62.

48. Martin-Blanco A, Ferrer M, Soler J, et al. Association between methylation of the glucocorticoid receptor gene, childhood maltreatment, and clinical severity in borderline personality disorder. J Psychiatr Res. 2014;57:34-40.

49. Goodman M, Carpenter D, Tang CY, et al. Dialectical behavior therapy alters emotion regulation and amygdala activity in patients with borderline personality disorder. J Psychiatr Res. 2014;57:108-16.

50. Schnell K, Herpertz SC. Effects of dialectical behavior therapy on the neural correlates of affective hyperarousal in borderline personality disorder. J Psychiatr Res. 2007;41(10):837-47.

51. Levy KN, McMain S, Bateman A, Clouthier T. Treatment of borderline personality disorder. Psychiatr Clin North Am. 2018;41(4):711-28.

52. Ingenhoven T, Lafay P, Rinne T, Passchier J, Duivenvoorden H. Effectiveness of pharmacotherapy for severe personality disorders: meta-analyses of randomized controlled trials. J Clin Psychiatry. 2010;71(1):14-25.

53. Stoffers JM, Völlm BA, Rücker G, Timmer A, Huband N, Lieb K. Pharmacological interventions for borderline personality disorder. Cochrane Database Syst Rev. 2010;(6):CD005653.

54. Distel MA, Middeldorp CM, Trull TJ, Derom CA, Willemsen G, Boomsma DI. Life events and borderline personality features: the influence of gene-environment interaction and gene-environment correlation. Psychol Med. 2011;41(4):849-60.

55. Belsky DW, Caspi A, Arsenault L, et al. Etiological features of borderline personality related characteristics in a birth cohort of 12-year-old children. Dev Psychopathol. 2012;24(1):251-65.

56. Teicher MH, Samson JA. Childhood maltreatment and psychopathology: A case for ecophenotypic variants as clinically and neurobiologically distinct subtypes. Am J Psychiatry. 2013;170(10):1114-33.

57. Nemoda Z, Szyf M. Epigenetic alterations and childhood trauma. Nat Rev Neurosci. 2017;18(5):273-4.

58. De Vidovich GZ, Muffatti R, Monaco J, et al. Repetitive TMS on left cerebellum affects impulsivity in borderline personality disorder: a pilot study. Front Hum Neurosci. 2016;10:582.

59. Fonagy P, Luyten P. A developmental, mentalization-based approach to the understanding and treatment of borderline personality disorder. Dev Psychopathol. 2009;21(4):1355-81.

60. Insel TR. The NIMH Research Domain Criteria (RDoC) Project: precision medicine for psychiatry. Am J Psychiatry. 2014;171(4):395-7.

61. Zotev V, Phillips R, Yuan H, Misaki M, Bodurka J. Self-regulation of human brain activity using simultaneous real-time fMRI and EEG neurofeedback. Neuroimage. 2014;85:985-95.

62. Köhler CA, Freitas TH, Stubbs B, et al. Peripheral alterations in cytokine and chemokine levels after antidepressant drug treatment for major depressive disorder: systematic review and meta-analysis. Mol Neurobiol. 2018;55(5):4195-206.