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Original Article

Bio-Dialectical Behavior Therapy: Enhancing Partial Dialectical Behavior Therapy Skills Training with Biofeedback for Borderline Personality Disorder: A Pilot Feasibility Study

Mohammad Mahdi Mehrabi Tavana[1*], Fereshte Momeni[1], Behrouz Dolatshahi[1], Peyman Hassani Abharian[2]

1. University of Social Welfare and Rehabilitation Sciences, Tehran, Iran
2. Institute for Cognitive Science Studies (IRICSS), Tehran, Iran

***Corresponding author:**
Mohammad Mahdi Mehrabi Tavana, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran
Tel: +989305080855

Email: mmh.mehrabitavana@uswr.ac.ir, mehditavaana@gmail.com

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Abstract

Background and Objective: This pilot study assessed the feasibility and preliminary outcomes of integrating biofeedback into a 12-session Dialectical Behavior Therapy Skills Training (DBT-ST) program for individuals diagnosed with Borderline Personality Disorder (BPD).

Materials and Methods: This pilot study was conducted at an outpatient psychology and biofeedback clinic in Tehran, Iran, between 2020 and 2021. Patients with an initial diagnosis of BPD were interviewed using the Borderline Personality Disorder Severity Index (BPDSI-IV). Participants were assigned to either a biofeedback-enhanced DBT-ST group or a standard DBT-ST group. The outcomes were assessed using the BPDSI-IV, Difficulties in Emotion Regulation Scale, Toronto Alexithymia Scale, Beck Depression Inventory-II, and Barratt Impulsiveness Scale. Data were analyzed using IBM SPSS (version 20); effect sizes, Reliable Change Index, and remission rates were calculated.

Results: Biofeedback-enhanced DBT-ST cases showed larger reductions in BPD symptom severity (40% and 35%) than standard DBT-ST cases (5% and 13.8%). The intervention cases also showed greater improvements in alexithymia, emotion dysregulation, depressive symptoms, and impulsivity than the standard DBT-ST cases.

Conclusions: The findings suggest that adding biofeedback to DBT-ST may be a promising way to improve emotion regulation and mindfulness-related outcomes in BPD.

Keywords: Biofeedback, Borderline personality disorder (BPD), Dialectical behavior therapy (DBT), Emotion regulation, Skin conductance response

Background

Borderline personality disorder (BPD) is diagnosed based on nine criteria outlined in the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) [1]. Clinical guidelines recommend psychotherapy as the primary treatment for BPD [2]; however, no single therapy has consistently achieved remission for the majority of patients. Even after treatment, many individuals with BPD continue to struggle with social and professional functioning. A recent meta-analysis of 28 trials involving well-established psychotherapies, including 2,436 participants and an average treatment duration of 11 months, found that approximately half of patients did not respond to treatment [3]. Given the substantial time and financial commitments required for evidence-based psychotherapies and their limited effectiveness, psychotherapy remains a burdensome option for both individuals with BPD and healthcare systems. This underscores the urgent need for a modified, short-term, and effective intervention that benefits both patients and healthcare providers [3, 4].

Dialectical behavior therapy (DBT) is the most extensively researched psychotherapy for BPD [5]. DBT identifies emotion dysregulation as the disorder's core feature, attributing it to heightened emotional reactivity, intense emotions, and insufficient skills to manage them. Recognizing and describing emotions are fundamental components of DBT skills training [6, 7]. However, another line of research suggests that alexithymia - deficits in emotional interoception - is central to BPD [8]. Alexithymia is characterized by three primary traits: (1) difficulty identifying and distinguishing between emotions and bodily sensations, (2) difficulty describing and verbalizing emotions, and (3) an externally oriented thinking style [9]. The emphasis on emotion recognition in DBT, coupled with the inherent challenges of alexithymia in individuals with BPD, highlights an opportunity to design a

novel protocol targeting these complexities and skill deficits.

Traditional DBT typically requires at least one year of individual therapy, group skills training, telephone consultations, and a staff consultation team. DBT skills training focuses on teaching techniques to reduce dysfunctional behaviors and foster new patterns of thinking, feeling, and acting. Clinical trials of dialectical behavior therapy skills training (DBT-ST) as a stand-alone intervention for various clinical conditions have shown promising outcomes, including reduced emotional dysregulation and self-injurious behaviors. DBT-ST emphasizes four key skill areas: (1) mindfulness to enhance attention control, (2) emotion regulation to manage environmental emotional triggers, (3) interpersonal skills to navigate needs and conflicts, and (4) distress tolerance to prevent maladaptive responses to high-stress situations. For this study, mindfulness and emotion regulation skills were selected to address emotion dysregulation and shorten the intervention [6, 7].

Linehan's conceptualization of emotions is comprehensive and nuanced, viewing emotions as systemic responses in which changes in any component can influence the overall emotional reaction. During stress or danger, the sympathetic nervous system triggers physiological changes, such as increased heart rate, blood pressure, and respiration, along with sweating and decreased body temperature [10]. Biofeedback can measure arousal levels during emotional states by providing external information about one's physiological state, enhancing self-awareness and potentially improving treatment outcomes [11]. Moreover, meditation, as a subjective experience, presents challenges for monitoring, evaluation, and communication because it lacks precise vocabulary or objective measures. Without real-time feedback, individuals practicing mindfulness may struggle to assess its effectiveness, potentially slowing skill development [12].

Biofeedback and Its Role in Emotional Regulation

Biofeedback

Biofeedback is a therapeutic method developed to facilitate the self-regulation of bodily processes. It involves connecting sensors to the body to receive signals from muscles, sweat glands, body temperature, and heart rate. This technology aims to control or enhance physiological responses by providing real-time information. Biofeedback helps individuals expand their awareness by displaying physiological parameters, improving emotional regulation and modifying disproportionate behaviors. It provides a shortcut to becoming aware of the body's internal states and emotions. However, biofeedback is not considered the primary treatment for any mental disorder [13, 14]. Therefore, it can serve as a supplementary treatment due to its outlined advantages.

Autonomic Nervous System and Skin Conductance Response (SCR)

The autonomic nervous system consists of two subsystems: the sympathetic and parasympathetic systems. The sympathetic system supports the stress ("fight or flight") response to threatening events and is a central component of emotional experience. Its activity can be measured through physiological responses, such as heart rate, sweating, breathing, and eye blinking. Skin conductance response (SCR) is a common measure of emotional arousal in laboratory settings. Changes in perspiration cause fluctuations in skin conductivity, which skin conductance sensors can detect. SCR was selected for this trial due to its accessibility, objectivity, and cost-effectiveness [15, 16].

Electroencephalography (EEG)-based Mindfulness

According to Linehan, mindfulness is the act of non-judgmentally and consciously focusing on the present moment. In a mindful state, individuals recognize the fluidity and transience of each moment. Moreover, mindfulness is associated with increased alpha amplitude compared to the resting state. Electroencephalography (EEG)-based audio feedback deepens the mindfulness experience. When practicing mindfulness, integrating EEG-based biofeedback can help both the patient and therapist maintain awareness of the skill's learning progress [6, 7, 12, 17, 18].

Objectives

This pilot feasibility study aimed to evaluate the preliminary effects of integrating biofeedback into partial DBT-ST on BPD symptom severity, emotion dysregulation, alexithymia, depressive symptoms, and impulsivity in individuals with BPD.

Materials and Methods

Participants

This pilot feasibility study was conducted at the Brain and Cognition Clinic, a private outpatient psychology and biofeedback clinic in Tehran, Iran, between 2020 and 2021. Ten patients with an initial diagnosis of BPD, referred from the outpatient clinic of the Razi Educational and Therapeutic Psychiatric Center in Tehran, were interviewed by two certified clinical psychologists using the Borderline Personality Disorder Severity Index (BPDSI-IV). All patients provided written informed consent after receiving all necessary information

about the study. Of the 10 patients, six who met the inclusion criteria were randomly assigned to two groups. The other four patients did not meet the inclusion criteria at screening and were not enrolled. Two of the six randomized participants withdrew after randomization and before completing the 12 sessions; therefore, the four cases reported here are those who finished the full course of treatment and the follow-up assessment. Two different cognitive behavioral therapy clinicians delivered treatments based on the DBT Skills Training Manual, Second Edition, by Marsha M. Linehan. All screening interviews, treatment sessions, biofeedback recordings, and follow-up assessments were carried out at the Brain and Cognition Clinic.

No formal a priori power calculation was performed to determine the sample size. Pilot and feasibility studies are not designed to test hypotheses about treatment efficacy, and variance estimates derived from very small samples are too imprecise to support a meaningful power calculation [19]. Published guidance for pilot and feasibility trials distinguishes between a sample size justification, which every trial requires, and a formal sample size calculation, which may not be appropriate for a pilot trial [20]. The CONSORT extension for randomized pilot and feasibility trials likewise asks for a rationale for the numbers included rather than a power calculation, and states that pilot size should be based on feasibility objectives [21]. Accordingly, the number of participants here was determined by the number of eligible patients who could be recruited, treated, and followed within the capacity of the clinic during the study period, and by the intensity of the protocol, in which each participant attended 12 individual sessions involving repeated physiological recording and five assessment points. Because outcomes were evaluated at the individual level using the Reliable Change Index and remission rates [22] rather than by between-group inferential testing, the design did not rely on a group-level power calculation. Of the 10 patients screened, six met the inclusion criteria and were randomly assigned to the two conditions (three per condition). Four participants completed the full course of treatment and the follow-up assessment and are reported here; two discontinued after randomization and were not included in the analysis.

Inclusion Criteria

The inclusion criteria included diagnostic signs of BPD based on the DSM-5, diagnosis of BPD confirmed by BPDSI-IV, at least a high school diploma, absence of signs and symptoms of other mental disorders, including substance abuse, not receiving benzodiazepines or other psychological or pharmacological treatments, and age between 18 and 35 years.

Exclusion Criteria

The exclusion criteria included signs and symptoms of other mental disorders and exacerbation of suicidal ideation, non-suicidal self-injury (NSSI), or suicide attempts.

Procedure

The intervention was reported in accordance with the TIDieR checklist for intervention description and replication [23] and the CRED-nf reporting standard for clinical neurofeedback studies [24]. The protocol combines three types of components: skills training content taken directly from published DBT manuals [7, 25]; biofeedback procedures based on established neurofeedback and electrodermal recording practice [13, 26, 27, 28]; and a small number of parameters developed by the authors for the present study, which are identified as such at the point where they are described.

All physiological signals were acquired using a ProComp Infiniti encoder (model SA7500, serial number CA5215, manufactured in 2011; Thought Technology Ltd., Montreal, QC, Canada). Signal acquisition, processing, and feedback delivery were performed using BioGraph Infiniti software (version 6.7, Thought Technology Ltd., Montreal, Canada) [24].

Biofeedback-Enhanced Condition

Participants in this condition attended 12 individual sessions. Sessions 1-6 comprised mindfulness skills training with EEG-based mindfulness training. Sessions 7-12 comprised emotion regulation skills training with concurrent skin conductance feedback.

First Part: Mindfulness Skills Training and Electroencephalography (EEG)-Based Mindfulness Training (Sessions 1 to 6)

Each of the first six sessions began with 30 minutes of mindfulness skills training, followed by 15 minutes of EEG-based mindfulness training. Skill content, teaching sequence, and practice assignments were taken from the mindfulness module of the DBT Skills Training Manual, Second Edition [25], using the accompanying handouts and worksheets [7] (Table 1). Only the mindfulness and emotion regulation modules of DBT skills training were delivered; the interpersonal effectiveness and distress tolerance modules were omitted to shorten the protocol. This abbreviation is an adaptation made by the authors for the present study and does not correspond to a previously published protocol. Delivery of DBT skills training without the other DBT treatment modes has precedent in the stand-

alone skills training literature. However, that literature provides preliminary rather than conclusive evidence of efficacy [29].

15-Minute Electroencephalography (EEG)-Based Mindfulness Training Protocol Preparation

Prior to electrode placement, the skin was prepared using NuPrep abrasive gel, and electrodes were affixed with adhesive conductive paste. Electrode placement followed the international 10-20 system [26]. A single active electrode was placed at Pz, with separate reference electrodes attached to the right and left earlobes. Impedance was maintained at or below 5 kΩ.

Calibration and Neurofeedback

Each session began with a 3-minute calibration period allowing participants to acclimatize to the recording environment. This was followed by 15 minutes of continuous neurofeedback, during which participants were instructed to close their eyes and apply the mindfulness techniques taught earlier in the same session. EEG alpha activity was extracted online and reinforced by auditory feedback delivered through a speaker [24].

Alpha enhancement was selected as the training target on two grounds: alpha activity increases during mindfulness and meditative states [17], and alpha-based neurofeedback has previously been applied to support mindfulness training [12].

The reward threshold was referenced to the participant's first one-minute average within each session and was set so that reinforcement was delivered approximately 65% of the time. Across sessions, the threshold was progressively adjusted toward increasing alpha amplitude, following the shaping principle of operant conditioning as applied to neurofeedback [27]. The threshold was also updated continuously within each session. We note that Sherlin et al. [27] recommend against thresholds that are recalculated automatically within a session, because reinforcement may then continue to be delivered while the trained signal moves in the undesired direction. The within-session procedure used here therefore departs from that recommendation. It is reported explicitly so that its contribution can be evaluated and varied in subsequent work [24].

Second Part: Emotion Regulation Skills Training with Skin Conductance Feedback (Sessions 7 to 12)

45-Minute Emotion Regulation Training Protocol

Each of the final six sessions comprised 45 minutes of emotion regulation skills training delivered with concurrent skin conductance feedback. Skill content was taken from the emotion regulation module of the DBT Skills Training Manual, Second Edition [25], using the accompanying handouts and worksheets [7] (Table 1).

Electrodermal feedback was paired with emotion regulation practice on three grounds: skin conductance indexes sympathetic arousal during emotional experience [15]; skin conductance changes measurably during attempts at emotion regulation [16]; and rendering an interoceptive signal externally perceptible is a proposed mechanism through which biofeedback supports emotion regulation [18].

Recording and Electrode Placement

Skin conductance was recorded with a constant-voltage skin conductance sensor connected to the same encoder, corresponding to exosomatic recording with direct current, which is the most widely applied electrodermal recording method [28]. Two dry contact electrodes were attached with Velcro straps to the volar surfaces of the distal phalanges of the index and ring fingers of the non-dominant hand. No electrode gel was applied, in accordance with the manufacturer's specification for this sensor. Participants were asked not to wash their hands with soap immediately before the session.

Baseline Establishment

For each participant, the baseline was calculated as the arithmetic mean of the skin conductance values recorded during that participant's last three neurofeedback sessions (sessions 4-6). An individualized rather than a normative baseline was used because absolute skin conductance level differs substantially between individuals; therefore, a single fixed value would not represent a comparable degree of arousal across participants. The authors developed this baseline procedure for the present study.

Feedback Delivery

An increase of 30% or more above the participant's baseline triggered auditory feedback from a speaker, audible to both the participant and the therapist, so that the change in arousal could be addressed within the session as it occurred.

No published criterion specifies the magnitude of skin conductance increase that should trigger feedback during in-session emotion regulation practice. Therefore, the authors set the 30% criterion, choosing it to be low enough to capture arousal increases during emotionally salient discussion and high enough to avoid feedback being triggered by spontaneous fluctuations. This criterion has not been externally validated. This is explicitly reported here so that it can be replicated or varied

in future work [23, 24].

Standard Dialectical Behavior Therapy Skills Training (DBT-ST) Condition

Participants in the comparison condition attended 12 sessions of 45 minutes each. Session content covered the same mindfulness and emotion regulation skills shown in Table 1, drawn from the same sources [7, 25] and delivered from the same manual. No physiological recording or feedback was conducted in this condition.

Table 1. Dialectical Behavior Therapy (DBT) Skills Training Components

Mindfulness Skills	Emotion Regulation Skills
Observe: This skill involves paying attention on purpose to the present moment without trying to terminate or prolong the experience. You notice body sensations, thoughts, and feelings as they arise and fall away, practicing "wordless watching" both inside and outside yourself.	**Identifying and Describing Emotions:** This skill teaches you to label your emotions by observing the entire system: the prompting event, interpretations, body sensations, action urges, expressive behaviors, and aftereffects. Accurately naming an emotion is a crucial first step in regulating it.
Describe: Describing is the act of labeling what you have observed with words. It requires sticking strictly to the facts (the who, what, when, and where) and distinguishing your interpretations or opinions from observable reality.	**Functions of Emotions:** Emotions serve three essential purposes: motivating us to act, communicating with others, and communicating with ourselves. They function like a rapid-response system or alarm to help us survive and solve common problems.
Participate: To participate is to enter wholly into an activity, becoming "one" with whatever you are doing. It involves acting intuitively from Wise Mind, letting go of self-consciousness, and responding with spontaneity to the current moment.	**PLEASE:** This acronym helps reduce emotional vulnerability by caring for the body: treating physical illness, balancing eating, avoiding mood-altering substances, balancing sleep, and exercising. A balanced body increases emotional resilience.
Non-Judgmental: This "how" skill means taking a non-evaluative approach by not judging things as "good" or "bad". You focus on observable consequences and facts, letting go of "shoulds" and demands on reality to be different than it is.	**Opposite Action:** You practice acting opposite to an emotion's urge when that emotion does not fit the facts or is ineffective. For example, if fear is unjustified, you approach the threat instead of avoiding it to change the emotional reaction.
One-Mindfully: This involves riveting yourself to the now and doing only one thing at a time. You bring undivided attention to a single task, the opposite of multitasking or being distracted by the past or future.	**Problem Solving:** When an emotion fits the facts, and the situation is the problem, you use problem solving to change the environment. This involves defining the problem, brainstorming solutions, and implementing a plan to reduce negative emotions by solving their cause.
Effectively: Acting effectively means focusing on what works to achieve your goals rather than what is "right" or "fair". It involves playing by the rules and using skillful means to act as effectively as the current situation requires.	**Build Mastery and Positive Experiences:** Building mastery involves doing activities that make you feel competent to combat helplessness. Positive experiences are built by increasing pleasant events now (short-term) and working toward long-term goals and values to create a life worth living.

Data Collection Tools

Borderline Personality Disorder Severity Index (BPDSI-IV)

Arntz et al. developed the BPDSI in 2003 as a clinician-administered semi-structured interview [30]. Giesen-Bloo et al. revised it and published the psychometric evaluation of the fourth version in 2010 [31]. The interview has 70 items covering the nine DSM-IV criteria for BPD, which DSM-5 carries over unchanged: abandonment, interpersonal relationships, identity disturbance, impulsivity, parasuicide, affective instability, feelings of emptiness, anger control, and dissociation. Each item is scored for frequency and severity over the preceding three months on an 11-point scale from 0 (never) to 10 (daily). Cronbach's alpha was 0.85 in patients with BPD and ranged from 0.68 to 0.93 across subscales, with acceptable discriminant, construct, and concurrent validity [30, 31]. Cronbach's alpha for the Persian version is 0.85 [32].

Difficulties in Emotion Regulation Scale (DERS)

Gratz and Roemer developed the DERS in 2004 [33]. It is a 36-item self-report questionnaire rated on a five-point Likert scale, covering six factors:

- Non-acceptance of emotional responses (non-acceptance)
- Difficulties engaging in goal-directed behavior (goals)
- Impulse control difficulties (impulse)
- Lack of emotional awareness (awareness)
- Limited access to emotion regulation strategies (strategies)
- Lack of emotional clarity (clarity)

Cronbach's alpha was 0.93 for the total scale and above 0.80 for every subscale [33]. In the Persian translation, alpha ranges from 0.66 to 0.88, and test-retest coefficients for the subscales range from 0.79 to 0.91 [34].

Toronto Alexithymia Scale (TAS-20)

Bagby, Parker, and Taylor developed the TAS-20 at the University of Toronto in 1994 [35]. Its 20 items are rated from 1 (strongly disagree) to 5 (strongly agree) and form three subscales:

- Difficulties identifying feelings (7 items)
- Difficulties describing feelings (5 items)
- Externally oriented thinking (8 items)

The total alexithymia score is the sum of the three subscales. Taylor and colleagues later reviewed the scale's reliability and factorial validity across different languages and cultures [36]. In the Persian

version, Cronbach's alpha is 0.85 for the total score and 0.82, 0.75, and 0.72 for the three subscales [37].

Beck Depression Inventory-II (BDI-II)

Beck, Steer, and Brown published the BDI-II in 1996 as a revision of the original inventory [38]. It follows the DSM criteria for depression more closely than the first version and covers the components of depression described in cognitive theory. Respondents rate 21 items, choosing one of four statements that match the severity of each symptom. Reported internal consistency for the original version ranges from 0.73 to 0.93, with alpha of 0.86 in patient samples and 0.81 in non-patient samples [39]. In the Persian adaptation, alpha is 0.92 in outpatients and 0.93 in students [40].

Barratt Impulsiveness Scale (BIS-11)

Patton, Stanford, and Barratt developed the BIS-11 in 1995 [41]. It is a 30-item self-report instrument rated on a four-point Likert scale, with three subscales:

- Attentional Impulsiveness
- Motor Impulsiveness
- Non-Planning Impulsiveness

Validity and reliability for the original scale have been reported as 0.87 and 0.79 [41]. For the Persian version, validity is 0.75 and reliability is 0.83 [42].

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 20. Data from the semi-structured interviews and self-report questionnaires were analyzed to evaluate the intervention's effects. Effect sizes were calculated using Cohen's d to quantify the magnitude of the intervention effects, and remission rates were determined. According to Cohen (1988), effect size values of 0.20, 0.50, and 0.80 are interpreted as small, medium, and large effects, respectively.

Results

Patient Characteristics

"Four participants completed the full 12-session protocol and the follow-up assessment, and their results are reported here. Cases I and II received the biofeedback-enhanced DBT-ST, and Cases III and IV received the standard DBT-ST. Participants were between 29 and 33 years of age (mean = 31.0 years). Three identified as female and one as bigender; two held a bachelor's degree and two a master's degree; two were divorced, and two were single; and three were employed at the time of enrolment. Table 2 presents the demographic characteristics of the four cases".

Table 2. Patient Characteristics

Case Number	Age	Gender	Education	Marital Status	Occupation
I	32	Female	B.Sc.*	Divorced	Unemployed
II	29	Female	M.Sc.**	Single	Beauty salon assistant
III	33	Bigender	B.Sc.	Divorced	Tattoo artist
IV	30	Female	M.Sc.	Single	Painter

*B.Sc., Bachelor of Science; **M.Sc., Master of Science.

Table 3. Results of Questionnaires, RCI, and Remission Rate for Cases I and II

Measure	Baseline	Appraisal I	Appraisal II	Appraisal III	Follow-up	RCI	Remission Rate (%)
Case I							
TAS-20	59	53	51	45	40	2.28	32.2
DERS	132	102	70	55	57	1.98	56.8
BDI-II	17	15	6	4	8	2.20	52.9
BIS-11	89	94	74	63	69	2.54	22.4
BPDSI-IV	63.94	—	—	38.51	38.53	1.68	39.7
Case II							
TAS-20	65	64	75	52	44	2.54	32.3
DERS	106	105	93	105	69	3.92	34.9
BDI-II	37	35	9	17	14	2.21	62.1
BIS-11	99	98	93	90	86	2.09	13.1
BPDSI-IV	63.43	—	—	40.84	41.35	1.08	34.8

Abbreviations: RCI, reliable change index; TAS-20, Toronto Alexithymia Scale; DERS, Difficulties in Emotion Regulation Scale; BDI-II, Beck Depression Inventory-II; BIS-11, Barratt Impulsiveness Scale; BPDSI-IV, Borderline Personality Disorder Severity Index.

Table 4. Results of Questionnaires, RCI, and Remission Rate for Cases III and IV

Measure	Baseline	Appraisal I	Appraisal II	Appraisal III	Follow-up	RCI	Remission Rate (%)
Case III							
TAS-20	64.00	63.00	64.00	64.00	65.00	3.29	-1.6
DERS	86.00	104.00	105.00	105.00	118.00	1.98	-37.2

Measure	Baseline	Appraisal I	Appraisal II	Appraisal III	Follow-up	RCI	Remission Rate (%)
BDI-II	32.00	36.00	37.00	37.00	34.00	2.01	-6
BIS-11	102.00	106.00	108.00	108.00	100.00	2.27	1
BPDSI-IV	75.66	—	—	69.67	71.69	1.58	5
Case IV							
TAS-20	65.00	53.00	55.00	51.00	55.00	3.24	15.3
DERS	136.00	106.00	108.00	101.00	115.00	2.15	15.4
BDI-II	32.00	28.00	28.00	27.00	27.00	2.68	15.6
BIS-11	93.00	93.00	95.00	91.00	84.00	1.99	9
BPDSI-IV	58.90	—	—	49.56	50.45	1.27	13.8

Abbreviations: RCI, reliable change index; TAS-20, Toronto Alexithymia Scale; DERS, Difficulties in Emotion Regulation Scale; BDI-II, Beck Depression Inventory-II; BIS-11, Barratt Impulsiveness Scale; BPDSI-IV, Borderline Personality Disorder Severity Index.

Borderline Personality Disorder Severity

Cases I and II, who underwent the integrated protocol combining DBT skills training with biofeedback, exhibited reductions in BPD symptom severity by 40% and 35%, respectively. In contrast, Cases III and IV, who received standard DBT-ST, showed only modest improvements of 5% and 13.8%, respectively.

Alexithymia

Cases I and II achieved remission rates of approximately 32% and demonstrated satisfactory Reliable Change Index (RCI) scores, indicating that the combination of DBT-ST with biofeedback significantly reduced alexithymia. Conversely, the control group (Cases III and IV) experienced no notable improvement in alexithymia symptoms following treatment. Figure 1 shows these changes.

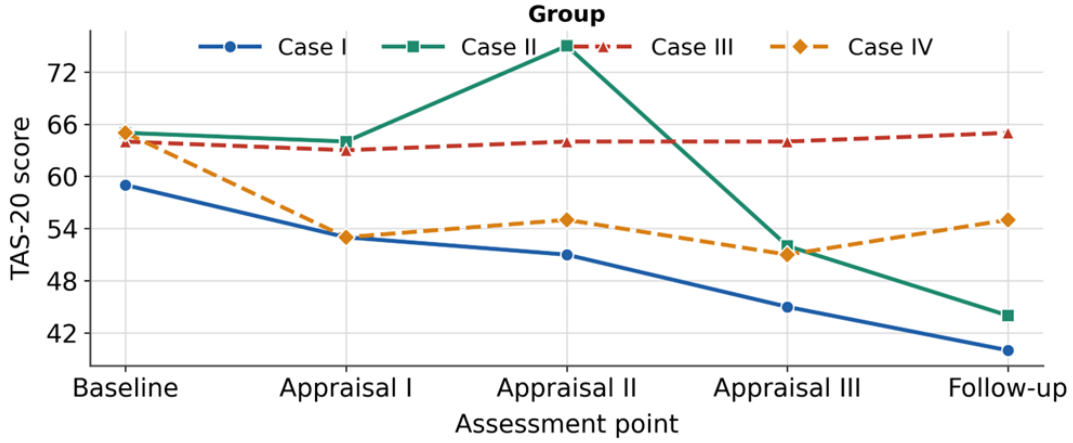

Figure 1. Changes in Toronto Alexithymia Scores (TAS-20) Across the Treatment Timeline for All Cases

Emotion Dysregulation

Cases I and II, who underwent the biofeedback-based DBT-ST, exhibited decreases in DERS scores by 57% and 35%, respectively, indicating changes in emotion dysregulation. In contrast, the stand-alone DBT skills training provided to group 2 resulted in negative and non-significant changes in emotion regulation. Figure 2 shows these changes.

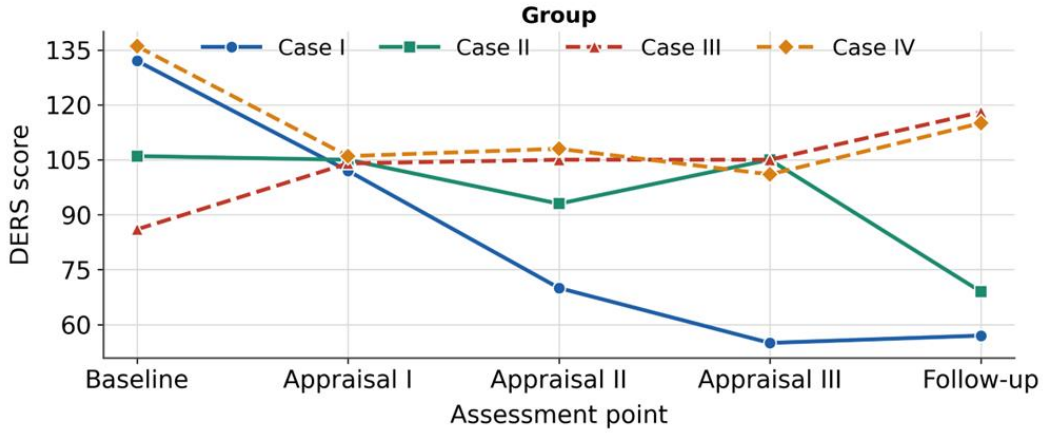

Figure 2. Changes in Difficulties in Emotion Dysregulation Scores (DERS) Across the Treatment Timeline for All Cases

Depression

The integrated treatment resulted in substantial improvements in depressive symptoms for the two individuals undergoing the intervention, with reductions of 53% and 62%, respectively. These findings highlight the procedure's efficacy in addressing depression among BPD patients. In contrast, the two patients in the control group did not show consistent benefit. The BDI-II score of Case III was 6.2% higher at follow-up than at baseline, indicating a slight worsening, whereas Case IV improved by 15.6%. Figure 3 shows these changes.

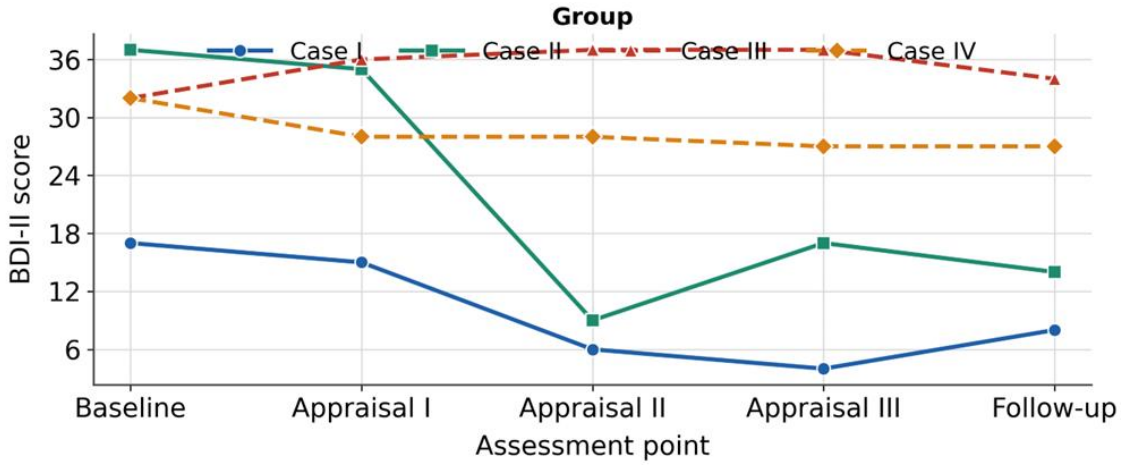

Figure 3. Changes in Beck Depression Scores (BDI-II) Across the Treatment Timeline for All Cases

Impulsivity

As shown in Tables 3 and 4, Cases I and II, which received the integrated treatment, exhibited reductions in impulsivity of 22.4% and 13%, respectively. However, these decreases were less pronounced compared to the improvements observed in other measures. Changes in the second group were negligible, indicating that the standard DBT skills training had minimal effect on impulsivity. Figure 4 shows these changes.

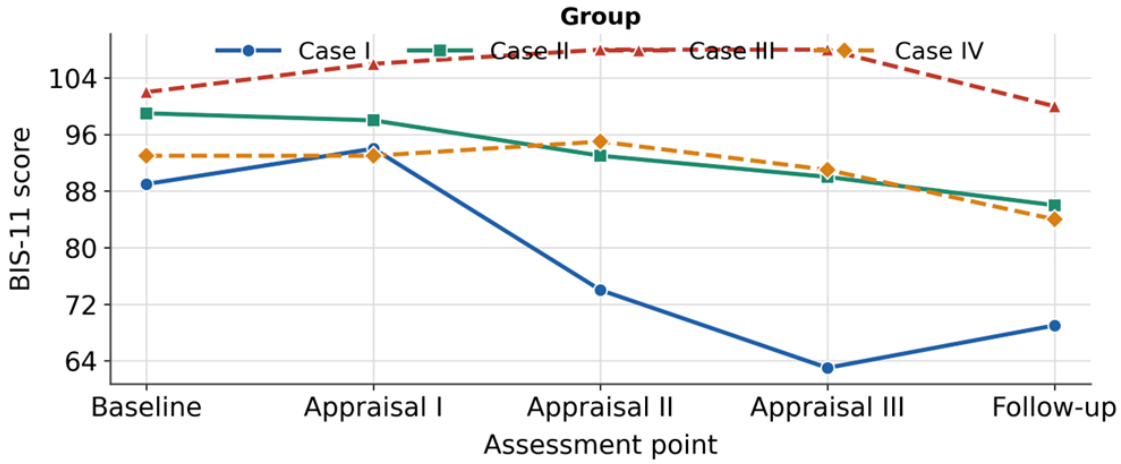

Figure 4. Changes in Barratt Impulsiveness Scores (BIS-11) Across the Treatment Timeline for All Cases

Discussion

The findings suggest that the integrated protocol combining DBT-ST with biofeedback may be more effective in managing BPD symptoms than standard DBT-ST. They also support the need for scalable, short-term BPD treatments.

The primary aim of this study was to design and evaluate a modified protocol for patients with BPD. The results suggest that the integrated protocol - combining DBT-ST with biofeedback - may be more effective than standard DBT-ST alone. Participants who underwent the integrated treatment exhibited significant improvements, whereas those receiving stand-alone DBT-ST showed minor, insignificant, and in some cases, adverse responses.

These less favorable outcomes in the control group may be attributed to the severity of BPD, which often necessitates more intensive interventions. This finding underscores the importance of developing intensive, short-term treatments for BPD. The larger improvements observed in the biofeedback-enhanced cases can be explained within Linehan's biosocial theory, which attributes BPD to a biological vulnerability to emotion dysregulation marked by high baseline emotional intensity, heightened sensitivity, and a slow return to baseline [43]. Consistent with this account, patients with BPD show elevated resting arousal, including heightened baseline skin conductance and reduced respiratory sinus arrhythmia [44], while the emotion regulation and mindfulness skills taught in DBT depend on accurately observing internal states, for which standard treatment offers no objective referent [45]. By displaying skin conductance and alpha activity in real time, the biofeedback component converted the covert task of observing arousal into a concrete perceptual task, and heightened interoceptive awareness of this kind has been shown to facilitate downregulation of negative affect [46]; because skills acquisition and use mediate DBT outcomes [47], a procedure that strengthens observation and self-regulation of arousal would be expected to amplify change in BPD severity, emotion dysregulation, alexithymia, depressive symptoms, and impulsivity, as observed here. This pattern converges with previous research: real-time fMRI amygdala neurofeedback trials in BPD reported reductions in borderline symptoms, affective instability, and lack of emotional awareness [48, 49], and meta-analytic evidence indicates that biofeedback and neurofeedback reduce anxiety-related symptoms relative to waiting-list control [50].

Several factors contribute to poor treatment outcomes in BPD, including a lack of clinical and diagnostic education, cultural stigma, insufficient medical research recognizing BPD as a distinct psychiatric condition with a strong biological foundation, high treatment costs, experiential avoidance, and anxiety [4, 51]. Elevated alexithymia is also associated with poorer outcomes and strongly predicts NSSI. Moreover, alexithymia is substantially correlated with emotion regulation difficulties and other aspects of BPD [52, 53, 54]. To our knowledge, no prior protocol has directly incorporated the RCI for alexithymia. Future research should further explore the role of emotional interoception and the potential value of biofeedback in addressing alexithymia and related BPD symptoms.

To our knowledge, this is the first study to integrate biofeedback into DBT skills training for BPD in a randomized pilot design. Although a prior study examined the efficacy of brief biofeedback sessions in emotion regulation [55], our findings align with existing research highlighting deficits in alexithymia, depression, impulsivity, and emotion dysregulation among individuals with BPD.

Despite these promising results, this pilot study has several limitations. The most notable is the small sample, determined by feasibility rather than power analysis, which precludes inferential between-group testing. The results should therefore be read as preliminary estimates of effect and of protocol feasibility, intended to inform the sample size of an adequately powered trial rather than to establish efficacy. Consequently, the findings should be considered preliminary and interpreted with caution until validated in larger-scale studies. Additionally, the conclusions rely on self-report questionnaires and semi-structured interviews, which may introduce bias. Future research should incorporate more precise and objective measurements - such as functional magnetic resonance imaging (fMRI), MRI, EEG, and wearable technology assessments - to enhance the validity and reliability of the findings.

Conclusion

The integrated protocol combining DBT-ST with biofeedback appears to be a promising approach for managing BPD symptoms compared to standard DBT-ST alone. Participants receiving the biofeedback-enhanced intervention showed improvements in emotion regulation, alexithymia, depression, and overall BPD symptom severity. These preliminary findings support developing scalable, short-term interventions for BPD treatment. Because this was a pilot study with a small sample, the findings should be interpreted cautiously and validated in larger-scale studies using more objective measurements.

Ethical Considerations

The participants were informed about the study purpose and procedures before participating. The authors obtained written informed consent from all participants and ensured the confidentiality of their information. Participation was voluntary, and participants were free to withdraw from the study at any time. The study was registered in the Iranian Registry of Clinical Trials (IRCT) under registration number IRCT20210421051033N1.

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Author Contributions

Author contributions are provided in the non-blinded version of the manuscript.

Conflicts of Interest

The authors declared no conflicts of interest.

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