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Comparison of the Effectiveness of Cognitive Behavioral Therapy and Repetitive Transcranial Magnetic Stimulation on Adaptive and Maladaptive Cognitive Emotion Regulation Strategies in Patients with Multiple Sclerosis

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ABSTRACT

The present study aimed to compare the effectiveness of cognitive behavioral therapy (CBT) and repetitive transcranial magnetic stimulation (rTMS) on adaptive and maladaptive cognitive emotion regulation strategies in patients with multiple sclerosis (MS). This applied, quasi-experimental study employed a pretest–posttest design with a one-month follow-up and a control group. The statistical population consisted of all patients with multiple sclerosis who attended a specialized clinic in Kerman, Iran, during 2025–2026. Using convenience sampling, 45 eligible patients were selected and randomly assigned to three groups of 15 participants each: a cognitive behavioral therapy group, a cognitive behavioral therapy combined with repetitive transcranial magnetic stimulation group, and a control group. Data were collected using the Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski & Kraaij, 2006). The experimental groups received, respectively, a 12-session CBT protocol and CBT combined with 30 sessions of rTMS, whereas the control group received no intervention. Data were analyzed using mixed analysis of variance (ANOVA) with repeated measures in SPSS version 26. The findings indicated that the group × time interaction effect was statistically significant for both primary study variables, namely adaptive and maladaptive cognitive emotion regulation strategies ($p < .001$). Compared with the control group, both interventions significantly increased adaptive cognitive emotion regulation strategies and decreased maladaptive cognitive emotion regulation strategies ($p < .001$), and these effects were maintained at the one-month follow-up. A direct comparison of the two interventions indicated no substantial difference between the two approaches in terms of the overall scores. The results demonstrated that both interventions were effective in improving emotion regulation and that repetitive transcranial magnetic stimulation contributed to an increase in adaptive strategies and a reduction in maladaptive strategies. Given the maintenance of the observed effects, the combined application of these interventions is recommended in the treatment of patients with multiple sclerosis.

Keywords: *multiple sclerosis, cognitive behavioral therapy, repetitive transcranial magnetic stimulation, emotion regulation.*

1. Introduction

Multiple sclerosis (MS) is a chronic, immune-mediated, and potentially disabling neurological disorder characterized by inflammatory and neurodegenerative processes within the central nervous system. Although its clinical manifestations are highly heterogeneous, MS commonly affects motor functioning, sensory processing, cognition, fatigue, mood, and psychosocial adjustment. Because the disease often develops during early or middle adulthood and follows a fluctuating or progressive course, its consequences extend beyond neurological impairment and can substantially influence emotional well-being, interpersonal functioning, occupational roles, perceived quality of life, and the individual's capacity to adapt to chronic illness. Psychological difficulties such as anxiety, depressive symptoms, negative affect, cognitive avoidance, intolerance of ambiguity, and emotion dysregulation are therefore clinically important components of the overall burden of MS rather than merely secondary reactions to physical disability (1-3).

Among these psychological processes, emotion regulation has particular relevance because patients with chronic neurological disorders are repeatedly required to manage uncertainty, physical symptoms, changing functional abilities, concerns about disease progression, treatment demands, and disruptions in personal and social roles. Emotion regulation refers broadly to the processes through which individuals monitor, evaluate, and modify emotional reactions in accordance with situational demands and personal goals. Cognitive emotion regulation specifically concerns the conscious cognitive strategies individuals employ to manage emotionally arousing events and their consequences. Such strategies can be broadly classified as adaptive or maladaptive. Adaptive strategies, including acceptance, positive refocusing, refocusing on planning, positive reappraisal, and putting events into perspective, may facilitate psychological adjustment by helping individuals reinterpret stressful experiences and maintain goal-directed behavior. In contrast, maladaptive strategies such as self-blame, rumination, catastrophizing, and blaming others may prolong negative emotional states, reinforce helplessness, and increase vulnerability to anxiety and depressive symptoms. The relevance of these cognitive processes is especially pronounced in MS because individuals frequently encounter uncontrollable and unpredictable stressors that cannot always be changed behaviorally and therefore require effective cognitive adaptation (1, 4, 5).

Emotion regulation in MS is also closely intertwined with broader cognitive and affective functioning. Difficulties in attentional control, repetitive negative thinking, negative emotional reactivity, and cognitive fatigue can contribute to the persistence of maladaptive emotional responses. When patients repeatedly interpret physical symptoms or uncertain future events in catastrophic terms, engage in excessive self-blame, or remain cognitively preoccupied with distressing experiences, emotional recovery can be delayed. Conversely, the ability to redirect attention, formulate practical plans, reinterpret negative events in a balanced manner, and accept difficult circumstances without excessive cognitive struggle may support more effective adaptation. Research on attentional control and emotion dysregulation has similarly emphasized that regulation of attention and cognition is central to the modulation of emotional experiences and that interventions targeting these processes may influence both cognitive and affective functioning (6). Within the context of MS, the relationship between cognitive processing and emotional distress therefore provides a strong rationale for interventions that directly modify maladaptive thoughts and strengthen adaptive cognitive regulatory strategies.

Cognitive behavioral therapy (CBT) is one of the most established psychological approaches for modifying dysfunctional cognitive and behavioral patterns. The theoretical basis of CBT proposes that emotional responses are influenced not simply by external events but by the meanings, interpretations, assumptions, and beliefs attributed to those events. Accordingly, maladaptive emotional states can be maintained by distorted appraisals, rigid beliefs, attentional biases, avoidance, rumination, and ineffective coping responses. CBT seeks to identify and modify these processes through techniques such as cognitive restructuring, examination of evidence, behavioral activation, problem solving, relaxation training, self-monitoring, and the development of more adaptive behavioral and cognitive responses. For patients with chronic physical illnesses such as MS, CBT may be particularly useful because it does not require complete

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elimination of the medical stressor; instead, it aims to alter how individuals interpret, respond to, and cope with the challenges associated with the illness.

Empirical evidence supports the application of CBT in MS populations. Studies have indicated that cognitive-behavioral interventions can reduce negative emotional experiences and improve psychological functioning among individuals with MS. Comparative research in women with MS has shown that CBT can produce significant reductions in negative emotions and may perform comparably with other structured psychotherapeutic approaches such as schema therapy (7, 8). These findings are clinically meaningful because persistent negative emotional states can exacerbate perceived disease burden and interfere with adaptive coping. Moreover, a study examining CBT specifically in women with MS demonstrated beneficial effects on cognitive emotion regulation and anxiety, suggesting that CBT may influence not only general emotional distress but also the cognitive strategies through which emotional experiences are processed (5).

More recent research has extended these findings by integrating CBT with other therapeutic components. Fakhrmand et al. examined a cognitive-behavioral intervention integrated with mindfulness and reported improvements in negative affect and cognitive emotion regulation among patients with MS (4). This is important because mindfulness-based elements may strengthen awareness of internal experiences and reduce automatic engagement with distressing cognitions, while CBT provides structured methods for evaluating and modifying maladaptive thoughts. Similarly, brief and technology-mediated CBT formats have shown promise for emotional problems associated with MS. An online single-session CBT intervention targeting depression and anxiety in individuals with MS demonstrated the feasibility of applying focused cognitive-behavioral principles even in a highly condensed format (2). Collectively, such findings indicate that CBT is adaptable across formats and can address multiple emotional and cognitive difficulties associated with MS.

Evidence at the review level further supports the role of CBT in this population. A recent systematic review and meta-analysis evaluating CBT for depression in patients with MS concluded that CBT is an effective psychological treatment for depressive symptoms in this clinical group (3). Although depression and cognitive emotion regulation are not identical constructs, they are closely related because maladaptive strategies such as rumination, catastrophizing, and self-blame contribute to the onset and maintenance of depressive affect, whereas adaptive strategies may facilitate recovery and resilience. Therefore, the documented effectiveness of CBT for depression in MS also supports investigation of its effects on more specific cognitive regulatory mechanisms. Earlier work has likewise suggested that cognitive-behavioral and acceptance-oriented approaches can be feasibly implemented in MS rehabilitation settings, highlighting the broader therapeutic value of structured psychological interventions for improving adjustment to chronic neurological disease (9).

Despite the established value of psychotherapy, growing attention has been directed toward neurostimulation techniques capable of directly modulating cortical activity. Repetitive transcranial magnetic stimulation (rTMS) is a noninvasive neuromodulation method in which repeated magnetic pulses are applied to targeted cortical regions to alter neuronal excitability and functional connectivity. Depending on the stimulation parameters and cortical target, rTMS may enhance or inhibit neural activity and influence networks involved in cognition, mood, attention, executive control, and emotion regulation. The dorsolateral prefrontal cortex (DLPFC), particularly the left DLPFC, has been frequently targeted because of its central role in cognitive control, affective processing, executive functioning, and top-down modulation of emotional responses. Contemporary research increasingly conceptualizes TMS not merely as a local stimulation procedure but as a method capable of influencing distributed neural circuits involved in complex psychological and behavioral processes (10, 11).

The therapeutic potential of rTMS has been most extensively investigated in mood disorders, particularly treatment-resistant depression. However, emerging research suggests that its effects may extend to other domains relevant to cognitive emotion regulation. Personalized TMS protocols have been discussed as potentially valuable for individuals with complex medical and psychiatric presentations, particularly when conventional treatments produce insufficient benefit (11). Investigations combining dual-hemispheric rTMS with other neurotechnology-based approaches have also reported reductions in comorbid

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depressive and anxiety symptoms, further supporting the capacity of rTMS to influence emotional and neurobehavioral functioning (12). From a neurobiological perspective, TMS has been linked to modulation of neural networks associated with affective regulation, stress, and neuroimmune processes, which may help explain its potential usefulness in conditions characterized by intertwined neurological and psychological disturbances (10).

Importantly, rTMS has also demonstrated effects on cognitive processes that overlap with emotion regulation. In individuals with obsessive-compulsive disorder, repetitive transcranial magnetic stimulation has been associated with improvements in emotion regulation, suggesting that neuromodulation of prefrontal networks may alter the capacity to manage maladaptive affective and cognitive responses (13). Similarly, research in mothers of premature infants found that rTMS reduced depression and ruminative responding, which is particularly relevant because rumination represents one of the central maladaptive cognitive emotion regulation strategies assessed in the present study (14). rTMS has also been investigated in relation to attentional performance and risky decision-making in children with specific learning disorders, indicating that its effects may extend to executive and regulatory functions beyond mood symptoms alone (15).

Evidence from neurological populations further supports the possibility that rTMS may enhance cognitive and neural recovery. In patients with acute ischemic stroke, rTMS combined with pharmacological treatment has been reported to improve cognitive and neurological functioning, suggesting that repeated magnetic stimulation may facilitate neurofunctional recovery in conditions involving central nervous system impairment (16). Although stroke and MS differ considerably in etiology and neuropathology, such findings are relevant because both conditions involve disruptions in neural networks that can affect cognitive, emotional, and executive processes. These observations provide a rationale for examining whether rTMS may complement psychological interventions in MS by enhancing the neural systems involved in cognitive control and emotion regulation.

The possible combination of CBT and rTMS is theoretically compelling because the two interventions operate at partly different but potentially complementary levels. CBT primarily targets explicit cognitive appraisals, behavioral responses, learned patterns, and coping processes. rTMS, in contrast, directly modulates cortical excitability and neural network functioning. When stimulation is applied to the left DLPFC, it may enhance prefrontal regulatory capacity and improve neural conditions for cognitive control. This may, in turn, facilitate engagement with cognitive restructuring, attentional shifting, problem solving, and reappraisal during CBT. In principle, neuromodulation could strengthen the neural substrate required for patients to use adaptive cognitive strategies, while psychotherapy could translate these changes into structured, contextually meaningful behavioral and cognitive skills. Such a combined approach is consistent with increasing interest in multimodal treatments that integrate neurobiological and psychological mechanisms rather than treating them as competing alternatives (11, 12).

This combined perspective may be especially relevant for patients with MS. The psychological burden of MS arises from the interaction of biological disease processes, neurological changes, uncertainty, chronic stress, emotional responses, and cognitive coping patterns. Research has shown that anxiety in MS can be linked to behavioral brain systems, cognitive avoidance, and tolerance of ambiguity, indicating that emotional difficulties in these patients are embedded within complex interactions between neurobehavioral tendencies and cognitive coping processes (1). Accordingly, an intervention focused only on conscious cognitive restructuring may not fully address the neurofunctional contributors to regulatory difficulties, whereas a purely neurostimulatory intervention may not provide patients with explicit skills for recognizing, challenging, and replacing maladaptive cognitive patterns. The integration of CBT and rTMS therefore offers a plausible strategy for simultaneously addressing cognitive-behavioral and neurophysiological dimensions of emotion regulation.

Nevertheless, the available literature also reveals an important gap. Most CBT studies in MS have focused on depression, anxiety, negative emotions, general psychological adjustment, or combinations of CBT with mindfulness rather than directly comparing CBT alone with CBT combined with rTMS on adaptive and maladaptive

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cognitive emotion regulation strategies (2-4, 7, 8). Similarly, although rTMS has been associated with changes in depression, rumination, emotion regulation, attention, decision-making, and neurological functioning across different populations, evidence concerning its specific contribution to cognitive emotion regulation in patients with MS remains limited (13-16). This distinction is important because demonstrating that an intervention reduces general distress does not necessarily establish that it changes the cognitive strategies through which patients regulate emotional experiences.

Furthermore, evaluating both adaptive and maladaptive strategies provides a more comprehensive picture of therapeutic change. Effective intervention should ideally do more than reduce dysfunctional processes such as rumination and catastrophizing; it should also increase constructive strategies such as positive reappraisal, planning, acceptance, and putting events into perspective. This dual focus is particularly important in chronic illnesses, in which many stressors cannot be completely eliminated. Patients therefore need not only fewer maladaptive cognitive reactions but also stronger adaptive mechanisms for responding to persistent and recurrent challenges. Previous research on cognitive-behavioral, mindfulness-based, and acceptance-oriented interventions suggests that strengthening adaptive cognitive and attentional processes can contribute to better emotional adjustment (4, 6, 9). At the same time, emerging findings on rTMS suggest that neuromodulation may influence the neural systems underlying these regulatory processes (10, 13).

A further methodological consideration concerns the persistence of treatment effects. In chronic neurological conditions, immediate post-intervention improvements are clinically valuable, but sustained changes are more meaningful because patients continue to face disease-related stressors after treatment ends. Follow-up assessment is therefore necessary to determine whether gains in adaptive cognitive regulation and reductions in maladaptive strategies are maintained beyond the active treatment period. Evidence supporting the efficacy of CBT in MS is encouraging, but additional comparative studies incorporating follow-up measurement are needed to clarify whether combining CBT with neuromodulation produces stronger or more durable benefits than CBT alone (2, 3, 9). Determining whether rTMS provides incremental benefit is also important from a clinical decision-making perspective because rTMS requires specialized equipment, trained personnel, repeated treatment sessions, and medical screening, whereas CBT is more widely available and can be delivered in multiple formats.

Taken together, existing evidence demonstrates that cognitive-behavioral interventions can improve emotional functioning in patients with MS, while rTMS has shown therapeutic potential for affective, cognitive, attentional, and regulatory outcomes across psychiatric and neurological populations (4, 5, 14, 16). However, direct evidence comparing CBT alone with CBT combined with rTMS in relation to adaptive and maladaptive cognitive emotion regulation in MS remains insufficient. Clarifying this issue may contribute to the development of more targeted, multimodal, and mechanism-oriented interventions for patients who must cope simultaneously with neurological symptoms and persistent emotional demands.

Therefore, the present study aimed to compare the effectiveness of cognitive behavioral therapy with cognitive behavioral therapy combined with repetitive transcranial magnetic stimulation on adaptive and maladaptive cognitive emotion regulation strategies in patients with multiple sclerosis.

2. Methods and Materials

2.1. Study Design and Participants

The present study was an applied, quasi-experimental investigation employing a pretest–posttest design with a follow-up assessment and a control group. The study population consisted of patients with a confirmed diagnosis of multiple sclerosis (MS) who attended Javaneh Clinic, a specialized clinical center operating under the supervision and authorization of the medical sciences authorities in Kerman, Iran, during 2025–2026. Participants were recruited through convenience sampling. Patients who had received a definitive diagnosis of MS and attended the clinic during the study period were invited by the researcher to participate. Following initial agreement, each potential participant underwent an individual screening interview conducted by the researcher to assess eligibility according to the predetermined inclusion and exclusion criteria. Patients who met the eligibility criteria and provided both verbal and written informed consent were randomly allocated by a lottery procedure to one of three study groups: cognitive behavioral therapy (CBT), cognitive behavioral therapy combined with repetitive transcranial magnetic stimulation (CBT + rTMS), or the control group. Recruitment and allocation continued until 45 eligible participants had been enrolled, with 15 participants assigned to each group. Before the initiation of the interventions, all participants completed the pretest assessment. Participants assigned to either intervention condition subsequently received the corresponding treatment protocol, whereas those assigned to the control group received no study-specific psychological or neuromodulatory intervention during the treatment period. Following completion of the intervention phase, all participants completed the posttest assessment, and the measures were administered again two months later as the follow-up assessment. The psychological intervention was delivered by a trained practitioner with relevant professional expertise, while rTMS was administered by a trained operator under medical supervision at the clinic.

Eligibility criteria were established to ensure that participants could safely and meaningfully engage in the study procedures. Inclusion required a definitive diagnosis of multiple sclerosis established by a neurologist, sufficient reading and writing ability to understand and complete the study questionnaires, provision of informed consent and signing of the written consent form, ability to attend the scheduled intervention sessions and participate in all research assessments, and absence of concurrent participation in comparable psychological interventions during the study period. Participants were excluded if they voluntarily withdrew from the study at any stage, exceeded the permitted number of absences from intervention sessions, developed a medical or psychological condition that made continued participation inappropriate or impracticable, initiated another psychological treatment or a similar intervention outside the study protocol during the intervention period, or failed to complete the required questionnaires or assessments at the pretest, posttest, or follow-up stage. For participants receiving rTMS, additional safety screening was conducted before treatment to identify established contraindications, including a history of seizure, uncontrolled neurological conditions that could compromise treatment safety, metallic implants in the head or neck region, cardiac pacemakers, or other implanted electronic devices.

2.2. Data Collection Tools

The Cognitive Emotion Regulation Questionnaire–Short Form (CERQ-Short) was used to assess cognitive strategies employed by participants in regulating their emotions following negative or stressful experiences. The short form was developed by Garnefski and Kraaij (2006) to facilitate the use of the instrument in clinical research and studies in which several psychological measures must be administered simultaneously. The original 36-item Cognitive Emotion Regulation Questionnaire was reduced to 18 items while preserving its nine-factor conceptual structure, with each cognitive emotion regulation strategy represented by two items. The CERQ-Short assesses nine theoretically distinct strategies: self-blame, acceptance, rumination, positive refocusing, refocus on planning, positive reappraisal, putting into perspective, catastrophizing, and blaming others. Self-blame reflects the tendency to attribute responsibility for a negative experience to oneself, whereas acceptance concerns cognitively acknowledging and accommodating the reality of what has occurred. Rumination represents repetitive thinking about thoughts and emotions associated with the negative event. Positive refocusing refers to redirecting attention toward pleasant or positive matters rather than remaining focused on the adverse experience, and refocus on planning reflects thinking about the steps that can be taken to manage or resolve the situation. Positive reappraisal involves assigning constructive or growth-related meaning to an adverse experience, whereas putting into perspective involves reducing the perceived severity of an event by comparing it with other experiences or viewing it within a broader context. Catastrophizing reflects an exaggerated emphasis on the negative or disastrous aspects of an experience, and blaming others refers to attributing responsibility for the event to other individuals (Garnefski & Kraaij, 2006).

The version of the CERQ-Short administered in the present study consisted of 18 items scored on a five-point Likert-type scale ranging from 1 (almost never) to 5 (almost always). Respondents indicated how frequently they used each cognitive strategy when confronted with negative or stressful experiences. Each of the nine subscale scores was

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obtained by summing the scores of its two constituent items, with higher scores indicating greater use of the corresponding cognitive emotion regulation strategy. For the purposes of the present study, the strategies were also considered within the broader domains of adaptive and maladaptive cognitive emotion regulation. Adaptive cognitive emotion regulation generally encompasses acceptance, positive refocusing, refocus on planning, positive reappraisal, and putting into perspective, whereas maladaptive cognitive emotion regulation includes self-blame, rumination, catastrophizing, and blaming others. Accordingly, higher scores on the adaptive dimension indicate greater reliance on constructive cognitive approaches to regulating emotional responses, while higher scores on the maladaptive dimension reflect greater reliance on dysfunctional cognitive responses to stressful or negative experiences. Garnefski and Kraaij (2006) reported satisfactory psychometric properties for the short form and demonstrated that the reduction in the number of items did not substantially compromise the theoretical structure or utility of the original questionnaire. The psychometric properties of the Persian version of the CERQ have also been investigated in Iranian samples. Salehi et al. (2015) reported acceptable internal consistency across the questionnaire subscales, with Cronbach's alpha coefficients for the examined dimensions ranging approximately from .49 to .79, supporting the applicability of the instrument in Iranian populations.

2.3. Intervention Protocols

The cognitive behavioral therapy intervention consisted of twelve 90-minute group sessions conducted once weekly at Javaneh Clinic in Kerman. The intervention content was developed primarily on the basis of established cognitive therapy principles and techniques derived from the cognitive therapy literature, including the work of Leahy (2003) and Beck's cognitive therapy framework. The first session was devoted to establishing therapeutic rapport, introducing participants and the therapist, explaining group rules and expectations, familiarizing participants with the principles of group-based CBT, facilitating initial self-expression, and completing baseline procedures where necessary. The second session reviewed the previous material and addressed factors contributing to healthy functioning, present-focused living, acceptance of current life circumstances, and the role of beliefs in emotional and behavioral consequences. Participants were introduced to a three-column cognitive monitoring framework involving thoughts, emotions, and behaviors, and the CBT model was explained with particular emphasis on the relationships among cognitive patterns, behavioral responses, emotion regulation, sleep quality, and cognitive fatigue. The third session focused on identifying cognitive distortions, understanding their influence across different levels of cognition, and recognizing dysfunctional thoughts and behaviors. The fourth session introduced stress-reduction techniques, particularly progressive muscle relaxation, to reduce physiological arousal and enhance emotional self-regulation. The fifth session taught strategies for identifying and challenging negative automatic thoughts through tracing the origins of thoughts, examining their validity, cognitively disputing maladaptive interpretations, and applying thought-stopping techniques when appropriate. Participants also examined recurring behavioral patterns and their relationships with interpersonal experiences and emotional responses, with an emphasis on improving recognition of dysfunctional cognitions and behaviors.

During the sixth CBT session, participants analyzed the relationships among adverse events, beliefs, and subsequent changes in mood and learned to identify and cope with situational triggers associated with maladaptive cognitive and behavioral patterns. The seventh session focused on attributional retraining, particularly modifying pessimistic explanatory styles and developing more balanced and optimistic interpretations, while reinforcing positive behavioral changes. The eighth session involved cognitive self-disputation through examination of evidence for personal interpretations, generation of alternative explanations, evaluation of the usefulness and functional consequences of specific beliefs, and future planning. The ninth session introduced self-acceptance, self-confidence, recognition and strengthening of personal capabilities, assertiveness, and the development of a more circumscribed and realistic perception of limitations. The final phase of treatment emphasized consolidation and relapse prevention. The tenth session integrated the previously learned cognitive and behavioral techniques and taught participants how to maintain newly acquired adaptive habits during the interval before follow-up. The eleventh session reinforced

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maintenance strategies and provided further opportunities to identify difficulties associated with implementing new behavioral and cognitive patterns. The twelfth session reviewed treatment gains, reinforced strategies for maintaining newly established habits, addressed potential future difficulties, formally concluded the intervention, and was followed by post-intervention assessment. The greater emphasis on consolidation during the later sessions was intentionally incorporated to facilitate maintenance of cognitive and behavioral changes throughout the two-month follow-up period.

The repetitive transcranial magnetic stimulation protocol was administered using a standard rTMS device by a trained operator under appropriate professional and medical supervision. Before the first treatment session, participants underwent safety screening for contraindications to rTMS, including seizure history, uncontrolled neurological conditions, metallic implants in the head or neck, cardiac pacemakers, and other implanted electronic devices. Resting motor threshold (RMT) was individually established for each participant before treatment. To determine RMT, the stimulation coil was positioned over the primary motor cortex, and stimulation intensity was progressively adjusted to identify the minimum intensity capable of eliciting an observable motor response in the abductor pollicis brevis muscle in at least five of ten consecutive stimulation trials. Following determination of RMT, the stimulation site over the left dorsolateral prefrontal cortex (left DLPFC) was identified. The location was determined using the conventional 5-cm method by moving the coil approximately 5 cm anteriorly from the motor cortical area identified for the thumb representation along the left hemisphere. When neuronavigation was available, standardized anatomical coordinates and neuronavigation procedures were used to improve localization of the stimulation target. High-frequency rTMS was then delivered to the left DLPFC at a frequency of 10 Hz and an intensity corresponding to 120% of the participant's RMT. Each stimulation train lasted 4 seconds and was followed by a 26-second intertrain interval. A total of 75 stimulation trains were administered per session, corresponding to 3,000 pulses per treatment session. Each rTMS session lasted approximately 37 minutes. Sessions were conducted five days per week for six consecutive weeks, resulting in a total of 30 rTMS sessions for each participant assigned to the combined intervention condition.

Throughout each rTMS session, participants remained comfortably seated and used hearing protection to minimize discomfort associated with the acoustic output of the stimulation device. Physical and psychological status was monitored continuously during treatment, and possible adverse effects, including headache, localized scalp discomfort, dizziness, or other complaints, were documented. Participants were informed that they could discontinue the intervention or withdraw from the study at any time, particularly in the event of clinically significant adverse effects or unwillingness to continue treatment. To maximize treatment fidelity and standardization, all rTMS sessions were administered by the same trained operator whenever possible and followed the same device-specific operating procedures. Stimulation parameters, including stimulation location, intensity, frequency, train duration, number of trains, intertrain interval, and total number of pulses, were kept constant across participants. Posttest assessments were conducted after completion of the full treatment course in accordance with the study protocol.

The combined CBT and rTMS intervention incorporated both neuromodulatory stimulation and the structured psychological treatment described above. Participants allocated to this condition received the full 30-session rTMS protocol in combination with the complete 12-session CBT program. On days when both treatment modalities were scheduled, rTMS was administered first, followed by a short interval of approximately 20–40 minutes before commencement of the CBT session. This sequencing was adopted to ensure consistent intervention delivery and to provide an appropriate transition between neuromodulatory stimulation and active psychological treatment. The rTMS component consisted of 10-Hz stimulation over the left DLPFC at 120% of the individually determined RMT, with 4-second trains, 26-second intertrain intervals, 75 trains, and 3,000 pulses per session. The CBT component retained the same duration, structure, therapeutic content, and therapist-guided procedures as those used in the CBT intervention described above. The combination was designed to integrate a neurostimulation-based approach targeting prefrontal cortical functioning with a psychological intervention targeting maladaptive cognitive appraisals, emotional

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responses, and behavioral patterns. Participants assigned to the control condition did not receive CBT or rTMS during the active intervention period but completed the same pretest, posttest, and follow-up assessments as the intervention groups.

2.4. Data Analysis

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics, including means and standard deviations, were calculated for the principal study variables at the pretest, posttest, and two-month follow-up assessments. Because the study included three groups assessed repeatedly across three measurement occasions, the primary inferential analysis was conducted using mixed-design analysis of variance with repeated measures. In this model, time, comprising pretest, posttest, and follow-up assessments, was treated as the within-subject factor, whereas intervention condition, comprising CBT, CBT combined with rTMS, and control, was treated as the between-subject factor. The analysis examined the main effect of time, the main effect of group, and particularly the group × time interaction to determine whether changes in adaptive and maladaptive cognitive emotion regulation strategies differed across intervention conditions over the course of the study. Prior to conducting the primary analyses, the relevant assumptions of repeated-measures analysis were evaluated, including the distribution of scores, homogeneity of variances, and sphericity of the repeated measurements. When the assumption of sphericity was violated, an appropriate correction such as the Greenhouse–Geisser adjustment was applied. Where significant omnibus effects were identified, pairwise comparisons with an appropriate adjustment for multiple comparisons were conducted to determine the specific differences between measurement occasions and study groups. Statistical significance was evaluated at an alpha level of .05, with more stringent probability values reported where applicable.

3. Findings and Results

The final sample consisted of 45 patients with multiple sclerosis, including 30 women (66.7%) and 15 men (33.3%). The predominance of women in the sample was consistent with the well-established higher prevalence of multiple sclerosis among women. The mean age of the participants was 36.03 years (SD = 6.60), and the mean duration of illness was 5.62 years (SD = 3.54). With respect to educational attainment, the largest proportion of participants had associate or bachelor's degrees, followed by those with high school diplomas. Examination of the demographic characteristics across the three study groups indicated generally comparable distributions, with no marked differences in age or sex composition among the CBT, CBT + rTMS, and control groups.

Table 1

Descriptive Statistics for Adaptive and Maladaptive Cognitive Emotion Regulation Strategies Across the Three Assessment Stages

Variable	Stage	CBT, *M* (*SD*)	CBT + rTMS, *M* (*SD*)	Control, *M* (*SD*)
Acceptance	Pretest	5.33 (1.76)	5.33 (1.11)	5.47 (1.19)
	Posttest	5.73 (1.49)	6.53 (0.83)	5.53 (0.99)
	Follow-up	5.60 (1.59)	6.27 (0.88)	5.53 (0.92)
Positive refocusing	Pretest	4.80 (1.37)	4.80 (1.21)	4.80 (1.37)
	Posttest	6.33 (1.35)	6.33 (1.05)	5.00 (1.25)
	Follow-up	5.93 (1.10)	6.27 (1.67)	5.00 (1.51)
Refocus on planning	Pretest	5.53 (1.51)	5.53 (1.46)	4.93 (1.22)
	Posttest	7.87 (1.51)	8.13 (1.64)	5.20 (1.61)
	Follow-up	7.73 (1.71)	7.93 (1.33)	5.40 (1.24)
Positive reappraisal	Pretest	5.13 (1.36)	5.20 (1.26)	5.33 (1.45)
	Posttest	6.27 (1.62)	6.60 (1.24)	5.33 (1.72)
	Follow-up	6.13 (1.77)	6.47 (1.25)	5.40 (1.68)
Putting into perspective	Pretest	5.13 (1.88)	5.00 (1.31)	4.80 (1.21)
	Posttest	6.40 (1.40)	6.47 (1.46)	5.13 (1.64)
	Follow-up	6.60 (1.76)	6.20 (1.70)	5.07 (1.28)
Adaptive strategies, total	Pretest	25.93 (3.71)	25.87 (2.45)	25.33 (2.66)
	Posttest	32.60 (3.72)	34.07 (2.31)	26.20 (3.17)

	Follow-up	32.00 (4.00)	33.13 (3.02)	26.40 (2.61)
Self-blame	Pretest	6.60 (1.35)	6.53 (1.77)	6.53 (1.55)
	Posttest	5.33 (1.54)	5.00 (1.41)	6.40 (1.55)
	Follow-up	5.53 (1.64)	5.20 (1.66)	6.40 (1.50)
Rumination	Pretest	6.93 (1.58)	7.13 (1.30)	7.13 (1.60)
	Posttest	4.60 (1.55)	4.40 (0.99)	7.00 (1.36)
	Follow-up	4.73 (1.44)	4.67 (1.40)	7.13 (1.41)
Catastrophizing	Pretest	7.13 (1.68)	7.13 (1.13)	6.87 (1.55)
	Posttest	4.67 (1.40)	4.53 (1.64)	6.60 (1.88)
	Follow-up	4.73 (1.94)	4.87 (1.25)	6.53 (1.36)
Blaming others	Pretest	5.60 (1.59)	5.27 (1.44)	5.53 (1.88)
	Posttest	5.20 (1.52)	5.13 (1.51)	5.20 (1.82)
	Follow-up	5.27 (1.22)	5.07 (1.39)	5.20 (1.42)
Maladaptive strategies, total	Pretest	26.27 (3.39)	26.07 (3.22)	26.07 (4.33)
	Posttest	19.80 (3.23)	19.07 (2.89)	25.20 (4.36)
	Follow-up	20.27 (3.33)	19.80 (3.75)	25.27 (3.33)

As shown in Table 1, the three groups demonstrated highly similar baseline scores for both adaptive and maladaptive cognitive emotion regulation strategies. The mean total adaptive strategy score at pretest was 25.93 (SD = 3.71) in the CBT group, 25.87 (SD = 2.45) in the CBT + rTMS group, and 25.33 (SD = 2.66) in the control group. Following treatment, adaptive strategy scores increased to 32.60 (SD = 3.72) in the CBT group and 34.07 (SD = 2.31) in the CBT + rTMS group, whereas only a small increase to 26.20 (SD = 3.17) was observed in the control group. These improvements remained evident at follow-up, with means of 32.00 (SD = 4.00), 33.13 (SD = 3.02), and 26.40 (SD = 2.61), respectively. Among the adaptive subscales, refocus on planning showed one of the clearest improvements in both intervention groups. A corresponding but inverse pattern was observed for maladaptive strategies. The total maladaptive score decreased from 26.27 (SD = 3.39) to 19.80 (SD = 3.23) in the CBT group and from 26.07 (SD = 3.22) to 19.07 (SD = 2.89) in the CBT + rTMS group, while the control group showed only a modest change from 26.07 (SD = 4.33) to 25.20 (SD = 4.36). The reductions were largely maintained at follow-up. The most pronounced decreases were observed for rumination and catastrophizing, whereas blaming others showed relatively little change across the assessment periods.

Prior to inferential analysis, the distributional assumptions of the repeated-measures model were examined. Shapiro–Wilk testing showed that the most restrictive observed values for the total adaptive strategy score included $W = .931$ at pretest, $W = .898$ at posttest, and $W = .793$ at follow-up, with a minimum significance level of $p = .003$. For maladaptive strategies, the corresponding values were $W = .914$, $W = .915$, and $W = .843$, with a minimum significance level of $p = .014$. Thus, some departures from strict univariate normality were observed. However, the distributions were considered sufficiently suitable for mixed repeated-measures analysis given the balanced group sizes and the relative robustness of analysis of variance to moderate deviations from normality. Because the repeated-measures assumption of sphericity was not fully satisfied, Greenhouse–Geisser corrections were applied where appropriate. Consequently, corrected degrees of freedom were used for interpretation of the within-subject and group × time effects.

Table 2

Mixed-Design Analysis of Variance for Adaptive and Maladaptive Cognitive Emotion Regulation Strategies

Variable	Effect	Statistical Result	*p*	Interpretation
Adaptive strategies, total	Time	Significant	< .001	Scores changed significantly across assessment stages
	Group	Significant	< .001	Overall scores differed across study groups
	Group × Time	Significant	< .001	Patterns of change differed significantly among groups
Maladaptive strategies, total	Time	Significant	< .001	Scores changed significantly across assessment stages
	Group	Significant	.005	Overall scores differed across study groups
	Group × Time	Significant	< .001	Patterns of change differed significantly among groups

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The mixed-design analysis of variance revealed significant changes over time for both adaptive and maladaptive cognitive emotion regulation strategies. More importantly, the group × time interaction was statistically significant for both outcome variables ($p < .001$), demonstrating that the pattern of change from pretest to posttest and follow-up differed significantly across the CBT, CBT + rTMS, and control conditions. The descriptive pattern showed that adaptive strategy scores increased substantially after treatment in both intervention groups but remained relatively stable in the control group. Conversely, maladaptive cognitive emotion regulation scores declined markedly in the two intervention groups, whereas only minor changes occurred in the control group. These changes were largely maintained at the follow-up assessment, indicating persistence of the treatment effects after completion of the interventions. Although significant overall group differences were also observed, the group × time interaction constituted the more theoretically relevant effect because the groups showed comparable scores at baseline and diverged primarily after exposure to the interventions. Overall, the findings supported the effectiveness of both CBT and CBT combined with rTMS in improving cognitive emotion regulation among patients with multiple sclerosis.

Table 3

Post Hoc Pairwise Comparisons of the Study Groups at Posttest and Follow-up

Outcome	Stage	Comparison	Mean Difference	Significance
Adaptive strategies	Posttest	CBT − Control	6.40	$p < .001$
		CBT + rTMS − Control	7.87	$p < .001$
		CBT − CBT + rTMS	−1.47	$p > .05$
Adaptive strategies	Follow-up	CBT − Control	5.60	$p < .001$
		CBT + rTMS − Control	6.73	$p < .001$
		CBT − CBT + rTMS	−1.13	$p > .05$
Maladaptive strategies	Posttest	CBT − Control	−5.40	$p < .001$
		CBT + rTMS − Control	−6.13	$p < .001$
		CBT − CBT + rTMS	0.73	$p > .05$
Maladaptive strategies	Follow-up	CBT − Control	−5.00	$p < .001$
		CBT + rTMS − Control	−5.47	$p < .001$
		CBT − CBT + rTMS	0.47	$p > .05$

Post hoc comparisons further clarified the significant interaction effects. At posttest, both the CBT and CBT + rTMS groups had significantly higher adaptive cognitive emotion regulation scores than the control group ($p < .001$), with mean differences of 6.40 and 7.87 points, respectively. These differences remained significant at follow-up, when the CBT and CBT + rTMS groups exceeded the control group by 5.60 and 6.73 points, respectively. However, the difference between CBT and CBT + rTMS was not statistically significant at either posttest or follow-up ($p > .05$), indicating that the addition of rTMS did not produce a statistically detectable advantage in the total adaptive strategy score. A similar pattern was observed for maladaptive strategies. Both treatment groups demonstrated significantly lower maladaptive strategy scores than the control group at posttest and follow-up ($p < .001$). At posttest, the CBT and CBT + rTMS groups scored 5.40 and 6.13 points lower than the control group, respectively, while the corresponding differences at follow-up were 5.00 and 5.47 points. Again, no significant difference emerged between the two active treatment conditions ($p > .05$). Collectively, these findings indicate that both CBT alone and CBT combined with rTMS produced substantial and sustained improvements in cognitive emotion regulation, whereas the combined intervention did not demonstrate a statistically significant superiority over CBT alone at the level of the total adaptive or maladaptive strategy scores.

4. Discussion and Conclusion

The present study aimed to compare the effectiveness of cognitive behavioral therapy (CBT) and CBT combined with repetitive transcranial magnetic stimulation (rTMS) on adaptive and maladaptive cognitive emotion regulation strategies in patients with multiple sclerosis (MS). The findings demonstrated that both active interventions produced significant improvements in cognitive emotion

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regulation compared with the control condition. Specifically, participants in both the CBT and CBT + rTMS groups showed substantial increases in adaptive cognitive emotion regulation strategies from pretest to posttest, and these improvements were largely maintained at the follow-up assessment. In parallel, maladaptive cognitive emotion regulation strategies decreased significantly in both intervention groups, whereas the control group showed only minor changes across the same period. The significant group × time interactions indicated that these changes were attributable to differential treatment effects rather than to the passage of time alone. However, direct comparisons between the two active interventions showed no statistically significant superiority of CBT + rTMS over CBT alone in the total scores of either adaptive or maladaptive cognitive emotion regulation. Thus, the central finding of the study was that both interventions were effective, but the addition of rTMS did not produce a clearly greater overall therapeutic effect on cognitive emotion regulation.

The improvement observed in the CBT group is consistent with previous evidence indicating that cognitive-behavioral interventions can modify maladaptive cognitive processes and improve emotional functioning in patients with MS. Earlier studies have shown that CBT can reduce negative emotions, improve anxiety-related outcomes, and enhance cognitive emotion regulation in this population (5, 7, 8). The current findings extend this literature by demonstrating that CBT was associated not only with a reduction in maladaptive cognitive responses but also with an increase in adaptive regulatory strategies. This distinction is important because improvement in emotion regulation is not limited to decreasing dysfunctional responses such as rumination or catastrophizing; it also involves developing more constructive approaches, including positive reappraisal, planning, acceptance, and putting adverse experiences into perspective. The pattern observed in the present study therefore suggests that CBT may produce a broad restructuring of cognitive responses to stressful experiences in patients with MS.

The present results are also consistent with findings reported by Fakhrmand et al., who found that a cognitive-behavioral intervention integrated with mindfulness reduced negative affect and improved cognitive emotion regulation in patients with MS (4). Although the intervention in that study included a mindfulness component, both studies emphasize the modifiability of cognitive-emotional processes in MS through structured psychological intervention. CBT techniques such as identifying automatic thoughts, challenging cognitive distortions, examining alternative interpretations, and developing problem-solving skills may help patients reduce rigid or catastrophic appraisals of disease-related experiences. Patients with MS frequently face uncertain disease trajectories, episodic symptom exacerbations, functional limitations, and concerns about future independence. In such circumstances, maladaptive patterns such as rumination and catastrophizing can intensify emotional distress, whereas cognitive restructuring can enable patients to adopt more balanced and functional interpretations of their experiences.

The reduction in maladaptive strategies, particularly rumination and catastrophizing, can also be understood within the established cognitive-behavioral model of emotional disorders. Rumination involves repetitive and passive attention to distressing thoughts and emotions, while catastrophizing reflects an exaggerated perception of the severity and consequences of negative events. Both processes tend to maintain emotional arousal and interfere with flexible problem solving. CBT directly targets these processes by teaching patients to identify repetitive negative thoughts, evaluate evidence, generate alternative appraisals, and distinguish between realistic concerns and cognitively amplified interpretations. The reduction in these strategies observed in the present study is therefore theoretically compatible with the mechanisms of CBT. Similar improvements in negative emotional states following CBT have been documented among women with MS, supporting the proposition that modification of dysfunctional thinking may contribute substantially to emotional adaptation in this population (7, 8).

The increase in adaptive strategies is likewise consistent with the structure of the CBT protocol used in the present study. Several sessions emphasized positive reinterpretation, realistic appraisal, planning, self-acceptance, recognition of strengths, and maintenance of newly acquired cognitive and behavioral habits. Such components are conceptually related to positive reappraisal, refocusing on planning, and putting stressful experiences into perspective. Through repeated practice, patients may become more capable of shifting from passive negative thinking toward active cognitive coping. This interpretation is supported by previous evidence showing that CBT can improve cognitive emotion regulation and reduce anxiety in women with MS (5). The present study therefore reinforces the view that CBT can function not merely as a symptom-reduction intervention, but also as a means of strengthening adaptive regulatory capacities.

The persistence of treatment effects at follow-up is another important finding. Both intervention groups retained much of their improvement in adaptive strategies and reductions in maladaptive strategies after the active treatment period. This maintenance effect may reflect the skills-based nature of CBT, in which participants learn cognitive and behavioral techniques that can continue to be applied independently after therapy sessions end. The later sessions of the present CBT protocol specifically emphasized consolidation, maintenance of new habits, and prevention of return to dysfunctional cognitive patterns. These components may have contributed to the stability of treatment gains. Evidence from previous studies also supports the feasibility and therapeutic value of structured cognitive-behavioral approaches in MS, including brief and alternative delivery formats (2, 9). Furthermore, systematic review evidence indicates that CBT can produce meaningful improvements in depressive symptoms among patients with MS, supporting the broader durability and clinical relevance of cognitive-behavioral treatment in this population (3).

The significant effects observed in the CBT + rTMS group also support the potential role of neuromodulation in psychological and cognitive regulation. rTMS, particularly when applied to the left dorsolateral prefrontal cortex, is believed to influence neural systems involved in executive control, cognitive flexibility, affective processing, and top-down regulation of emotional responses. Research in other clinical populations has shown that rTMS can improve emotion regulation and reduce maladaptive repetitive thinking. For example, rTMS has been associated with improved emotion regulation in adults with obsessive-compulsive disorder (13), while other research has demonstrated reductions in depression and ruminative responding following repeated transcranial magnetic stimulation (14). These findings are consistent with the present observation that the combined intervention produced substantial reductions in maladaptive cognitive emotion regulation.

The effect of rTMS may be partly explained through modulation of prefrontal cortical networks that support attentional control and cognitive inhibition. Effective emotion regulation requires the capacity to disengage from negative information, inhibit repetitive maladaptive thoughts, and redirect attention toward more constructive interpretations or goals. The importance of attentional control in emotion regulation has also been emphasized in research on mindfulness and neurocognitive mechanisms, suggesting that improved attentional regulation can reduce emotional dysregulation and repetitive negative processing (6). High-frequency stimulation of the left DLPFC may enhance neural excitability in regions associated with these functions, potentially making it easier for individuals to disengage from rumination and catastrophizing and to employ more adaptive strategies.

This explanation is also compatible with broader evidence concerning the effects of rTMS on cognition and neurological functioning. Studies have reported that rTMS may improve continuous attention and decision-making processes in clinical populations (15), as well as cognitive and neurological functioning in patients with neurological disorders such as acute ischemic stroke (16). Although the patient populations and underlying pathophysiological mechanisms differ from MS, these findings suggest that rTMS can influence cognitive control systems that are relevant across diagnostic groups. Because adaptive emotion regulation depends partly on executive functioning, attentional shifting, inhibition of maladaptive responses, and flexible appraisal, improvement in these neural processes could contribute to better cognitive emotion regulation.

The rationale for combining CBT with rTMS is therefore theoretically strong. CBT operates primarily through explicit learning, cognitive restructuring, behavioral change, and repeated practice of adaptive coping strategies, whereas rTMS directly modulates neural activity in cortical networks involved in cognitive and emotional control. It is plausible that stimulation of the left DLPFC could enhance the neurocognitive conditions required for patients to engage more effectively with CBT techniques. In other words, rTMS may increase cortical readiness for cognitive control, while CBT provides the structured psychological content

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through which this capacity is directed toward meaningful changes in appraisal, coping, and behavior. Contemporary work on TMS increasingly emphasizes its capacity to modulate distributed neurobehavioral systems rather than only localized cortical activity (10, 11). Similarly, studies combining rTMS with other interventions have suggested that multimodal treatment may be valuable when affective symptoms are persistent or complex (12).

Nevertheless, the lack of statistically significant differences between CBT alone and CBT + rTMS requires careful interpretation. Although the combined group often showed numerically greater improvements, these differences were not sufficiently large to establish superiority at the level of total adaptive or maladaptive strategy scores. Several explanations are possible. First, CBT itself may have produced a strong therapeutic effect, leaving limited room for additional improvement from rTMS. When an established psychological intervention already produces substantial change, an adjunctive treatment must generate a relatively large incremental effect to reach statistical significance. Second, the sample size of 15 participants per group may have limited statistical power to detect modest differences between the two active conditions. The study was sufficiently sensitive to distinguish both treatments from the control group, but potentially smaller differences between two effective interventions may require substantially larger samples.

A further possibility is that rTMS may influence some cognitive-emotional processes more strongly than others, and these effects may not be fully captured by broad total scores. For example, previous research suggests that rTMS may be particularly relevant to rumination, attentional control, depression, and certain dimensions of emotion regulation (13, 14). In the present study, reductions in rumination and catastrophizing were prominent in both active groups, whereas blaming others changed relatively little. It is therefore possible that neuromodulatory augmentation produces more selective effects at the level of individual cognitive processes or specific symptom profiles rather than a generalized enhancement across all cognitive emotion regulation domains. Future studies with larger samples and subscale-focused analyses may be able to identify such differential effects more precisely.

The absence of clear superiority of the combined intervention may also reflect the temporal characteristics of psychological and neurostimulatory treatment. CBT involves progressive acquisition and consolidation of skills over repeated sessions, while rTMS effects may depend on stimulation parameters, treatment duration, individual neurophysiological responsiveness, and precision of cortical targeting. Contemporary literature emphasizes that response to TMS can vary substantially between individuals and may be influenced by personalized neuroanatomical and clinical factors (11). Thus, a fixed protocol may not maximize benefit for every patient. Individual variation in resting motor threshold, disease severity, lesion burden, medication use, cognitive impairment, or baseline emotional symptoms could influence response to stimulation. This variability may partly explain why the combined intervention did not significantly outperform CBT alone at the group level.

The findings should also be considered in the specific context of MS. Emotional difficulties in MS are likely to emerge through interactions among disease-related uncertainty, neurological dysfunction, cognitive burden, fatigue, behavioral patterns, and psychological appraisals. Research has shown that anxiety in patients with MS can be related to behavioral brain systems, cognitive avoidance, and intolerance of ambiguity (1). This supports a multifactorial conceptualization in which neither psychological cognition nor neural functioning alone fully explains emotional adaptation. The effectiveness of both CBT and CBT + rTMS in the present study is therefore consistent with the idea that emotion regulation can be improved through multiple pathways. CBT may act primarily through conscious cognitive and behavioral learning, whereas rTMS may influence neural regulatory processes that support these changes.

The current results also fit within the broader literature showing that interventions targeting cognitive and emotional processes can improve psychological functioning in MS. CBT has demonstrated benefits for depression, anxiety, negative affect, and cognitive emotion regulation (2-5). At the same time, research on rTMS in other clinical populations suggests that neuromodulation can influence depression, rumination, emotion regulation, attention, decision-making, and neurological functioning (13-16). The present study brings these two lines of evidence together by

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examining them within a common comparative design. Its findings indicate that both approaches are clinically promising, but they do not support the conclusion that rTMS necessarily adds a substantial overall benefit to CBT for cognitive emotion regulation in every patient with MS.

Another important finding concerns the relatively small change in blaming others compared with other maladaptive strategies. This may indicate that attribution of responsibility to others is less responsive to short-term cognitive-behavioral or neuromodulatory intervention than rumination and catastrophizing. Blaming others can be embedded within interpersonal patterns, longstanding attributional styles, and relational experiences that may require more targeted interpersonal or schema-focused work. By contrast, rumination and catastrophizing are more directly addressed through standard CBT techniques such as cognitive restructuring, attentional redirection, evidence evaluation, and behavioral activation. This differential pattern highlights the value of examining subscale-level responses rather than relying exclusively on overall adaptive and maladaptive scores.

Overall, the findings suggest that cognitive emotion regulation in patients with MS is modifiable and that structured psychological intervention can substantially improve both adaptive and maladaptive regulatory patterns. The maintenance of gains at follow-up strengthens the clinical significance of these changes and suggests that participants were able to retain at least part of the cognitive and behavioral skills acquired during treatment. The combined CBT + rTMS condition also produced strong improvements, supporting the feasibility of integrating neurostimulation with psychotherapy. However, because it did not significantly outperform CBT alone on the total outcome measures, the present findings support a cautious interpretation in which rTMS may be considered an adjunctive rather than universally necessary component of treatment. Decisions about combined treatment may therefore need to consider symptom severity, previous treatment response, access to specialized equipment, patient preference, and individualized clinical characteristics.

A number of limitations should be considered when interpreting these findings. The sample was relatively small and was recruited through convenience sampling from a single specialized clinic, which limits the generalizability of the results to the broader population of individuals with MS. The small number of participants in each group may also have reduced the statistical power to detect modest differences between CBT and CBT combined with rTMS. The study relied primarily on self-report assessment of cognitive emotion regulation, and responses may therefore have been influenced by recall bias, social desirability, or participants' subjective perceptions of treatment effects. In addition, the follow-up period was limited, preventing conclusions regarding long-term maintenance of treatment gains. The study did not stratify participants according to MS subtype, neurological disability, lesion burden, pharmacological treatment, baseline depression or anxiety severity, or cognitive impairment, all of which may influence psychological functioning and responsiveness to CBT or rTMS. Finally, the absence of an rTMS-only condition makes it impossible to isolate the independent contribution of neuromodulation from the combined treatment effect.

Future research should replicate these findings using larger, multicenter samples and randomized controlled designs with sufficient statistical power to detect differences between active treatments. Including separate CBT-only, rTMS-only, combined-treatment, and control conditions would allow clearer identification of additive or synergistic effects. Longer follow-up periods would help determine whether changes in adaptive and maladaptive cognitive emotion regulation persist over six months or one year. Future studies should also examine moderators of treatment response, including disease duration, MS subtype, neurological disability, medication use, baseline emotion dysregulation, depressive symptoms, cognitive impairment, and individual differences in cortical responsiveness. Neuropsychological testing, clinician-rated outcomes, and neurophysiological or neuroimaging measures could complement self-report questionnaires and provide stronger evidence regarding mechanisms of change. Research may also benefit from examining individual CERQ subscales separately to determine whether rTMS preferentially influences specific processes such as rumination, catastrophizing, positive reappraisal, or attentional refocusing.

From a clinical perspective, the findings support the inclusion of structured CBT within comprehensive

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psychological care for patients with MS who experience difficulties in regulating emotion. Clinicians may particularly emphasize cognitive restructuring, reduction of rumination and catastrophizing, development of positive reappraisal, planning, acceptance, and relapse-prevention strategies. The combined use of rTMS and CBT may be considered for patients with more persistent or complex psychological symptoms, especially when access to specialized neuromodulation services is available and appropriate medical screening has been completed. However, because the combined intervention did not clearly outperform CBT alone in the present study, treatment selection should remain individualized rather than assuming that adding rTMS will necessarily produce superior outcomes. Integrating psychological assessment into neurological care and providing patients with practical emotion-regulation training may help improve adaptation to the continuing cognitive, emotional, and functional challenges associated with multiple sclerosis.

Authors' Contributions

All authors contributed substantially to the study and to manuscript development, and all approved the final version.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study placed a high emphasis on ethical considerations. Informed consent obtained from all participants, ensuring they are fully aware of the nature of the study and their role in it. Confidentiality strictly maintained, with data anonymized to protect individual privacy. The study adhered to the ethical guidelines for research with human subjects as outlined in the Declaration of Helsinki.

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