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rTMS Therapy for Eating Disorders: Scoping Review on Efficacy, Safety, Stimulation Parameters and Study Subjects

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ABSTRACT

Objective: Repetitive transcranial magnetic stimulation (rTMS) has potential as a therapeutic tool for eating disorders. In this scoping review, we examine the efficacy and safety of rTMS therapy for eating disorders besides stimulation parameters and the clinical statuses of participants.

Method: Following PRISMA-ScR framework, we searched four databases (PubMed, Scopus, Web of Science and PsycInfo) to review clinical interventional studies using rTMS for patients with eating disorders.

Results: Thirty-two studies were included. Benefits of rTMS on mood or eating disorder symptoms were reported for patients with anorexia nervosa. Meanwhile, there was improvement in binge eating and impulsivity in patients with bulimia nervosa, but without statistical significance in randomised controlled studies. There were no serious adverse events in relation to rTMS therapy. Stimulation of the left dorsolateral prefrontal cortex at high frequency with 20,000 stimulations was shown to be widely adopted in research on rTMS therapy for eating disorders.

Conclusion: The number of pulses to the left dorsolateral prefrontal cortex may have been insufficient. The dorsomedial prefrontal cortex is suggested to be an effective stimulation site for patients with binge-purge symptoms. Future research should focus on optimising stimulation parameters including the frequency, the intensity, the session number, and the stimulation site.

1 | Introduction

Eating disorders have many unresolved clinical problems, with low rates of remission and high risk of mortality still being reported (Miskovic-Wheatley et al. 2023). The lifetime prevalence rates in patients with anorexia nervosa (AN) and bulimia nervosa (BN) are around 4% and 3% in women, respectively, and 0.3% and1% in men, respectively (van Eeden et al. 2021). AN has the highest mortality rate of any psychiatric disorder, with approximately 5% of patients dying within 4 years of the diagnosis (Meczekalski et al. 2013). The severity may be increasing over time (Harada et al. 2021). In addition, eating disorders are often seen with comorbid mental issues. The criteria for at least one of the core DSM-IV disorders were reportedly met by 56.2% of patients with AN and 94.5% of patients with BN (https://www.nimh.nih.gov/health/statistics/eating-disorders, accessed September 28, 2025). Besides mortality by poorer physical condition, suicide is the second leading cause of death among

Highlights

- Preferable effects of rTMS therapy on mood or eating disorder symptoms have been reported in various papers, but few effects were seen on weight gain in patients with anorexia nervosa.
- The dorsomedial prefrontal cortex is expected to be an effective stimulation site for binge-purge symptoms in patients with eating disorders.
- Future research should focus on optimising stimulation parameters tailored to the specific symptom domains and subtypes of eating disorders.

patients with AN, and suicidal behaviour is elevated in patients with BN relative to the general population (Smith et al. 2018). Relative to sex and age matched comparison groups, patients with AN are 18 times more likely and patients with BN are seven times more likely to die by suicide than the general population (Smith et al. 2018). In addition to conventional psychotherapy and pharmacological treatments, new interventions are desired as a means to improve the clinical outcomes of patients with eating disorders (Himmerich et al. 2024).

Based on neurobiological etiological hypotheses on eating disorders (Bulik et al. 2022; Stover et al. 2023), several research groups are working on developing pertinent brain stimulation therapies (Dalton, Bartholdy, Campbell, and Schmidt 2018; Gallop et al. 2022; Murray et al. 2022; Rodan et al. 2023; K. Wu et al. 2024). Among non-surgical brain stimulation techniques, electroconvulsive therapy (ECT) requires general anaesthesia and there is acute fluctuation of autonomic function (i.e., heat rate, blood pressure) during implementation. These treatment procedures could be clinical risks for patients with eating disorders in an unstable physical condition (Satogami et al. 2019). After ECT, repetitive transcranial magnetic stimulation (rTMS) therapy is the second most widely used non-surgical brain stimulation technique in the neuropsychiatric clinical field (Imazu et al. 2024; Matsuda et al. 2024; Tseng et al. 2022). It was approved in 2008 by the Food and Drug Administration (FDA) in the United States for the treatment of depression. Subsequently, the FDA announced regulatory approval for obsessive-compulsive disorder in 2017, for smoking cessation in 2020, and for anxiety disorders comorbid with depression in 2021 (Cohen et al. 2022). Based on associations between eating disorders and depression and anxiety (Ernst et al. 2021), obsessive-compulsive disorder (Altman and Shankman 2009) and smoking (Mason et al. 2022), rTMS therapy is expected to become a novel therapeutic tool in the treatment of eating disorders.

Among the increasing number of publications of clinical research on rTMS for eating disorders, there have been several reviews published in the 2020s (Bahadori et al. 2025; Cavicchioli et al. 2022; Gallop et al. 2022; Longo et al. 2025; Marcolini et al. 2024; Muratore and Attia 2021; Murray et al. 2022; Ramanathan et al. 2025; Rodan et al. 2023; K. Wu et al. 2024). Some of them are narrative (Gallop et al. 2022; Muratore and Attia 2021; Rodan et al. 2023), and some include literature with searching strategy but they were not conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Marcolini et al. 2024; K. Wu et al. 2024). Some previous systematic reviews were conducted in accordance with PRISMA guidelines, but they focused only upon AN (Bahadori et al. 2025; Murray et al. 2022; Ramanathan et al. 2025). Furthermore, the number of articles in these reviews have been comparatively small, ranging between seven (Cavicchioli et al. 2022; Marcolini et al. 2024; Murray et al. 2022; Rodan et al. 2023) and sixteen (Ramanathan et al. 2025) for AN, and between four (Cavicchioli et al. 2022) and eight (Rodan et al. 2023) for BN. To address the various limitations of the previous review papers, and to provide a more definitive review of rTMS for eating disorders, we therefore undertook the current review.

rTMS therapy for eating disorders is still in the developmental stage, so in addition to verifying the clinical outcome of rTMS therapy from previous interventional research, we suggest that it is necessary to consider appropriate stimulation protocols and the patients that are most suited to the therapy. This scoping review therefore also aims to address these clinical issues, to provide a reliable summary of the efficacy and safety of rTMS therapy for eating disorders, and to provide information of stimulation parameters and the clinical status of participants.

2 | Methods

To classify and review clinical interventional studies of rTMS in patients with eating disorders, we applied the Preferred Reporting Systems for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) framework (Tricco et al. 2018).

2.1 | Search Strategy

The inclusion criterion of this scoping review was articles of clinical research in which rTMS was used in the treatment of patients with eating disorders. Exclusion criteria were articles written in languages other than English, review articles, meta-analyses, protocol papers, meeting abstracts, book chapters, and proceedings papers. For the literature search, the search criteria were jointly developed by authors who are rTMS experts (ST and SI) and an eating disorder expert (TH). The specific search terms for PubMed, Scopus, Web of Science and PsycInfo are each listed in the Supplemental File. The searches were conducted on September 5, 2025.

2.2 | Participants

We include studies on patients with eating disorders (AN, BN, binge eating disorder, and avoidant restrictive food intake disorder (ARFID)).

2.3 | Concept

We aimed to search, identify, and synthesise the research in the literature to elucidate treatment outcomes, stimulation

parameters, study subjects, and the safety of rTMS therapy in the treatment of patients with eating disorders.

2.4 | Context

In this review, we consider studies in which at least one session of rTMS was conducted, with the aim of improving clinical symptoms in patients with eating disorders.

2.5 | Types of Study

Prospective longitudinal and cross-sectional studies were included in this review.

2.6 | Data Items

The study design, subject's age and body mass index (BMI) at baseline, subtypes in AN and comorbidity in BN, the type of rTMS apparatus, the stimulation parameters, and the clinical outcomes were extracted from the literature.

2.7 | Study Selection

All search result details were imported into Microsoft Excel spreadsheets. Two independent reviewers (ST and SI) screened all of the titles and abstracts, and then independently reviewed articles that met the inclusion criteria. Any discrepancies in the selection were resolved through discussion. In case of uncertainty, they consulted an experts on eating disorders (TH) and on scoping review (MU).

3 | Results

3.1 | Description of Studies

A PRISMA diagram describing the decision flow for study inclusion is shown in Figure 1. Included were 15 articles on patients with AN, consisting of three case reports (Choudhary et al. 2017; Jaššová et al. 2018; McClelland et al. 2013), one case series (McClelland, Kekic, Campbell, and Schmidt 2016), five papers (Dalton, Bartholdy, McClelland, et al. 2018; Dalton, Lewis, et al. 2020; Dalton, Foerde, et al. 2020; Dalton, McClelland, et al. 2021; Dalton, Maloney, et al. 2021) from one randomised controlled trial (RCT) (Bartholdy et al. 2015), one paper from another RCT (Chastan et al. 2024), two single arm open label studies (Knyahnytska et al. 2019; Woodside et al. 2021), and three studies of one-session rTMS (McClelland, Kekic, Bozhilova, et al. 2016; Muratore et al. 2021; Van den Eynde et al. 2013) (Table 1). Twelve papers on patients with BN consisted of two case reports (Downar et al. 2012; Hausmann et al. 2004), two papers from one RCT (Gay et al. 2016; Guillaume et al. 2018), one paper from the other RCT (Walpoth et al. 2008), one single arm open label study (Dunlop et al. 2015), four papers from one study of one session rTMS (Claudino et al. 2011; Van den Eynde et al. 2010; Van den Eynde, Claudino, Campbell, et al. 2011; Van den Eynde, Claudino, Campbell, and Schmidt 2011) and the other two studies of one session rTMS (Van den Eynde et al. 2012; Sutoh et al. 2016) (Table 2). There were two case report articles (Baczynski et al. 2014; Sciortino et al. 2021) and one RCT (Maranhão et al. 2025) on patients with binge eating disorder; one case series included patients with AN, BN, and eating disorder not otherwise specified, and all had post-traumatic stress disorder (PTSD) (Woodside et al. 2017); one case report article on a patient with paediatric ARFID (Wang et al. 2025).

3.2 | Review Findings in Patients With AN

3.2.1 | Clinical Outcome in Study on Patients With AN

The TIARA study is a core clinical study in this field (Dalton, Bartholdy, McClelland, et al. 2018). Although a feasibility trial, it is a relatively large-scale randomised placebo-controlled double-blind parallel-group study. Its primary objectives were recruitment, attendance and retention rates. Secondary objectives were to estimate the treatment effect sizes and the standard deviations for outcome measures to inform future sample size calculations and to determine safety and tolerability of rTMS in patients with severe enduring AN (SE-AN). rTMS was reportedly safe and well tolerated in SE-AN, and the effect sizes of the change scores between groups were small for BMI and eating disorder symptoms, medium for quality of life, and medium to large for mood outcomes, with real stimulation being superior to sham stimulation in all cases. Statistical significance was reached for the improvement in depression, anxiety and stress scale-21 (DASS-21) at the 4-month follow-up.

Several subsequent analyses have been published following the TIARA study. In one of them, 30 patients who received the original study protocol proceeded to an 18-month open follow-up, and 24 of them completed the follow-up period (Dalton, Lewis, et al. 2020). Of the 12 patients who initially received sham treatment, 10 received active treatment during follow-up. The significant improvements in DASS-21 scores with rTMS therapy observed at the 4-month follow-up were shown to be maintained at the 18-month follow-up.

Another secondary analysis examined the effect of antidepressant use on response to rTMS treatment (Dalton, McClelland, et al. 2021). Patients who received antidepressants during rTMS treatment ($n = 16$) showed a significant improvement in eating disorder symptoms at the 4-month follow-up compared with patients who did not ($n = 10$). However, antidepressant use was not associated with significant changes in mood outcomes. Another study analysed the results of a food choice task before and after rTMS treatment and after a 4-month follow-up, but no significant results were obtained regarding the effect of rTMS therapy (Dalton, Foerde, et al. 2020). Finally, the effect of rTMS treatment on cerebral blood flow was examined using fMRI (Dalton, Maloney, et al. 2021). A significant interaction between rTMS treatment and time was found in the right amygdala, which suggests that the reduction in amygdala cerebral blood flow was greater after actual rTMS treatment than after sham treatment.

Among multiple-session treatment studies other than the TIARA study, a single-arm open-label trial (Woodside et al. 2021) with the

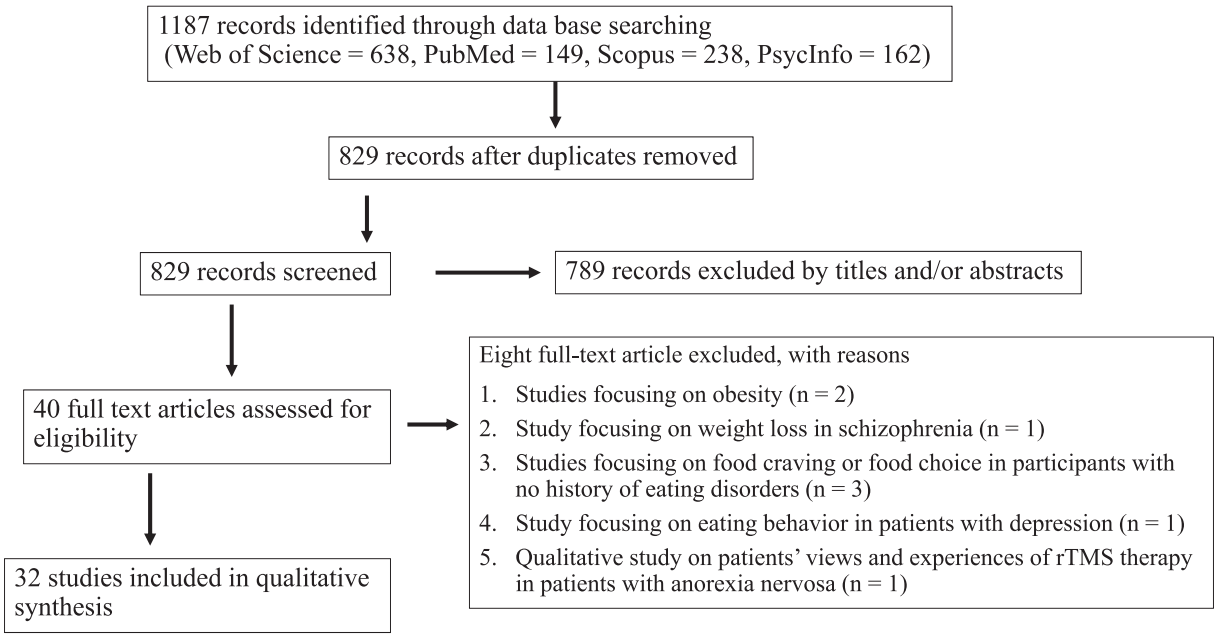

FIGURE 1 | PRISMA diagram describing the flow of decision.

bilateral dorsomedial prefrontal cortex (DMPFC) as the stimulation site showed significant improvements in the eating disorder examination global score, shape concern, and weight concern scores before and after rTMS therapy. In the same study, depressive and anxiety symptoms also significantly improved after treatment. In studies in which the right inferior parietal lobe was stimulated (Chastan et al. 2024) and in which the bilateral insula was stimulated (Knyahnytska et al. 2019), no significant effects were observed in BMI, eating disorder symptoms, or mood symptoms.

In studies in which there was one session of rTMS, the research group that conducted the TIARA study (Van den Eynde et al. 2013) reported significant improvements in the VAS assessments of feeling full and feeling fat in real stimulation compared with sham stimulation. The same group investigated the effects of one session of rTMS in a large-scale RCT involving 60 patients. There were no significant difference of changes in eating disorder symptoms or mood symptoms between sham stimulation and real stimulation groups (McClelland, Kekic, Bozhilova, et al. 2016). Elsewhere, another research group found a significant reduction in fat avoidance on a food choice task after one session of rTMS to right dorsolateral prefrontal cortex (DLPFC) (Muratore et al. 2021).

As for case reports and case series, improvement in BMI was only reported in one of them (Choudhary et al. 2017), which also reported improvements in attitude toward body shape, weight and food, laxative abuse and diuretic abuse. Elsewhere, improvements in eating disorder symptoms and depressive symptoms, with further improvements observed at 6-month follow-up, were reported in a case report (McClelland et al. 2013) and in a case series (McClelland, Kekic, Campbell, and Schmidt 2016) from the same research group that conducted the TIARA study. Meanwhile, case report from the Czech Republic showed no improvement in BMI, eating disorder symptoms, or mood symptoms (Jaššová et al. 2018).

3.2.2 | Stimulation Parameters

The stimulation parameters of the included studies are detailed in Table 1. Seven articles published from the research group that conducted the TIARA study used the same stimulation parameters (Dalton, Bartholdy, McClelland, et al. 2018; Dalton, Lewis, et al. 2020; Dalton, Foerde, et al. 2020; Dalton, McClelland, et al. 2021; Dalton, Maloney, et al. 2021; McClelland et al. 2013; McClelland, Kekic, Campbell, and Schmidt 2016). One open-label study set the insula as the stimulation site (Knyahnytska et al. 2019) and one RCT set the right inferior parietal lobe as the stimulation site (Chastan et al. 2024). An open-label study which set the DMPFC as the stimulation site conducted 3000 stimulations on both sides per session, and a total stimulation number of 120,000 to 180,000 (Woodside et al. 2021).

3.2.3 | Study Subjects

The age, BMI at baseline and subtypes of the subjects in included studies are also listed in Table 1.

3.2.4 | Tolerability and Adverse Events

Dropout rates in included studies are listed in Table 1. Elucidation of the safety and tolerability of rTMS therapy for patients with AN was a secondary objective of the TIARA study (Dalton, Bartholdy, McClelland, et al. 2018) and headache was the most common side effect. In another RCT, no side effects related to rTMS were reported in the active stimulation group (Chastan et al. 2024). Meanwhile, in a study of deep TMS, no side effects other than headache were reported (Knyahnytska et al. 2019). In a treatment study using the DMPFC as the stimulation site, all 19 patients completed the 20 sessions of treatment (Woodside

TABLE 1 | Review findings in patients with AN.

Author	Study design	Number of subjects	Age	BMI at baseline	Subtype	rTMS machine	Stimulation site	Frequency (Hz)	Intensity (%RMT)	Train duration (second)	Inter-train interval (second)	No. of pulses (/session)	No. of sessions	Clinical outcome			Dropout rate
														Body weight	Eating disorder symptoms	Psychological symptom	
McClelland et al. (2013)	Case report	2	Patient A: 23 Patient B: 52	Patient A: 15.7 Patient B: 16.4	Patient A; restrictive Patient B; binge-purge	Magstim rapid	Left DLPFC	10	110%	5	55	1000	20	Unchanged	Improved	Improved	0/2
Choudhary et al. (2017)	Case report	1	23	14.74	Not specified	Unknown	Left DLPFC	10	110%	Unknown	Unknown	1000	21	Improved	Improved	NA	0/1
Jaššová et al. (2018)	Case report	1	29	11.98	Not specified	Magstim super rapid 2	Left DLPFC	10	100%	10	107	1500	10	Unchanged	Unchanged	Unchanged	0/1
McClelland, Kekic, Campbell, and Schmidt (2016)	Case series	5	Mean [SD] 35.6 [11.19]	Mean [SD] 16.06 [1.90]	Restrictive: 3 Binge-purging: 2	Magstim rapid	Left DLPFC	10	110%	5	55	1000	19–20	Unchanged	Improved	Improved	0/5
Dalton, Bartholdy, McClelland, et al. (2018)	Double-blind sham controlled trial (TIARA study)	34	Mean [SD] 29.74 [10.35]	Mean [SD] 16.00 [1.44]	Restrictive: 22 Binge-purging: 12	Magstim rapid	Left DLPFC	10	110%	5	55	1000	20	Favouring real rTMS with small effect size	Favouring real rTMS with small effect size	Favouring real rTMS with large effect size	Real 1/17 Sham 3/17
Chastan et al. (2024)	Double-blind sham controlled trial	17	Median (range) 35 (27–39)	Median (range) 16 (14–17)	Restrictive: 17	Magstim rapid	Right IPL	10	90%	10	50	2000	10	No statistically significant difference between real and sham rTMS	No statistically significant difference between real and sham rTMS	No statistically significant difference between real and sham rTMS	None
Woodside et al. (2021)	Single arm open label	19	Mean [SD] (range) 31.2 [9.8] (21–56)	Mean [SD] (range) 16.4 [1.3] (14.5–18.5)	Not specified	MagPro R30	Bilateral DMPFC	10	120%	5	10	6000 (3000/ hemisphere)	20–30	No statistically significant change	Statistically significant improvement	Statistically significant improvement	None
Knyahnytska et al. (2019)	Single arm open label	8	Mean [SD] 33 [11.56]	Mean [SD] 16.6 [0.9]	Restrictive: 6 Binge-purging: 2	Brainsway H-Coil device	Bilateral insula	18	Unknown	2	20	2880	Acute 30 + maintenance 12	No statistically significant change	No statistically significant change	No statistically significant change	None
Van den Eynde et al. (2013)	Single arm open label	10	Median (range) 25 (18–44)	Median (range) 15.7 (13.8–17.8)	Restrictive: 7 Binge-purging: 2 other was not documented	Magstim rapid	Left DLPFC	10	110%	5	55	1000	1	NA	Statistically significant improvement	Statistically significant improvement	1/10
Muratore et al. (2021)	Double blinded cross-over trial	11	Mean [SD] (range) 30.7 [7.4] (18–37)	Mean [SD] (range) 17.1 [1.8] (14.6–20.9)	Restrictive: 7 Others were not documented	Neurostar	Right DLPFC	10	120%	4	Unknown	3000	1	NA	Statistically significant improvement	NA	1/11
McClelland, Kekic, Bozhilova, et al. (2016)	Double-blind sham controlled trial	51	Mean [SD] Real: 25.29 [6.88] Sham: 27.68 [9.89]	Mean [SD] Real: 16.73 [1.59] Sham: 16.38 [1.76]	Restrictive: 28 Binge-purging: 23	Magstim rapid	Left DLPFC	10	110%	5	55	1000	1	NA	No statistically significant difference between real and sham rTMS	No statistically significant difference between real and sham rTMS	2/51

Abbreviations: AN, anorexia nervosa; DLPFC, dorsolateral prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; IPL, inferior parietal lobe; rTMS, repetitive transcranial magnetic stimulation; SD, standard deviation.

et al. 2021). The study with the largest number of subjects reported that 2 out of 51 subjects dropped out due to discomfort from rTMS during the first few trains (McClelland, Kekic, Bozhilova, et al. 2016). No serious adverse events such as fainting or convulsions were reported in any of the studies included in this current scoping review.

3.3 | Review Findings in Patients With BN

3.3.1 | Clinical Outcomes of Patients With BN

Multiple sessions of rTMS for patients with BN were reported in two RCTs, but neither of them showed a significant difference in binge eating symptoms between real and sham stimulation. In one of them, the number of binge eating episodes per day decreased before and after treatment in both the real and sham stimulation groups (Walpoth et al. 2008). However, in the other, the number of binge eating episodes and vomiting episodes did not change after treatment in either the real or the sham stimulation groups (Gay et al. 2016). In sub-analyses, no significant effect on impulsivity was confirmed in the between-group analysis. A significant improvement in impulsivity was observed after treatment in the real stimulation group, but not in the sham stimulation group (Guillaume et al. 2018). A single-arm open-label study recruited 11 patients with AN with binge eating and purging type and 17 patients with BN. The criteria for treatment response (50% reduction of binge eating and vomit symptoms) was met by 16 out of 28 patients (Dunlop et al. 2015). rTMS was administered to the DMPFC, and fronto-striatal connectivity increased in the treatment responder group and decreased in the non-responder group (Dunlop et al. 2015).

The research group that carried out the TIARA study conducted an RCT (Van den Eynde et al. 2010) and an open-label study (Van den Eynde et al. 2012) using a one-session stimulation protocol in patients with BN. The RCT included more than 15 patients in each of the real and sham stimulation groups, and the real stimulation group showed a significant reduction in self-reported food cravings and the number of binge eating episodes 24 h after stimulation compared with the sham stimulation group (Van den Eynde et al. 2010). Sub-analyses of that RCT reported that there was no significant difference between the real and sham stimulation groups in changes in cognitive function before and after rTMS (Van den Eynde, Claudino, Campbell, and Schmidt 2011). Salivary cortisol was significantly lower after rTMS in the real stimulation group than in the sham stimulation group (Claudino et al. 2011). Changes in blood pressure or heart rate due to rTMS were not significantly different between the real and sham groups (Van den Eynde, Claudino, Campbell, et al. 2011). In an open label study, the same group investigated the effect of handedness and rTMS, comparing seven left-handed and 14 right-handed patients (Van den Eynde et al. 2012). Food craving (FCQ-S score) was significantly reduced in the left-handed patients but not in the right-handed patients. There was also a significant difference in the change in mood caused by rTMS between the two groups: left-handed patients experienced worsening of mood after rTMS, whereas right-handed patients had an improvement. Another one-session, single-arm, open-label study based in Japan showed that in eight subjects, food craving for high-calorie foods was significantly reduced after rTMS (Sutoh et al. 2016).

Finally, in a case report, a 43-year-old woman with BN with major depressive disorder underwent 20 sessions of rTMS to the bilateral DMPFC, resulting in complete remission of binge eating and vomiting behaviour and depressive symptoms, with no relapses for 2 months after treatment (Downar et al. 2012). Elsewhere, a 20-year-old woman also responded to treatment with 10 sessions of rTMS therapy stimulating the left DLPFC, resulting in remission of binge eating and vomiting behaviour and reduction of half of her depressive symptoms (Hausmann et al. 2004).

3.3.2 | Stimulation Parameters

The detail stimulation parameters of the included studies are listed in Table 2. The research group that conducted the TIARA study used a similar stimulation protocol for patients with BN (Claudino et al. 2011; Van den Eynde et al. 2010; Van den Eynde, Claudino, Campbell, et al. 2011; Van den Eynde, Claudino, Campbell, and Schmidt 2011; Van den Eynde et al. 2012). Research groups in Japan and France have also used the same stimulation parameters (Gay et al. 2016; Guillaume et al. 2018; Sutoh et al. 2016). One case report (Downar et al. 2012) and one single-arm open-label study (Dunlop et al. 2015) used the DMPFC as the stimulation site.

3.3.3 | Study Subjects

The age, BMI at baseline, and comorbidity of the subjects in included studies are listed in Table 2.

3.3.4 | Tolerability and Adverse Events

Dropout rates in included studies are also listed in Table 2. In the largest RCTs with multiple-session rTMS protocol, all withdrawals (4/51) were due to cancelation of consent or to technical problems, and not due to adverse events (Gay et al. 2016). Another RCT with multiple-session rTMS recruited 16 patients, among whom one patient in the sham group ended the intervention because his binge eating and vomiting symptoms had been reduced by half, and another patient discontinued because of worsening of hidden depression symptoms during the placebo-wash-out period (Walpoth et al. 2008). An RCT with single-session rTMS recruited 38 patients (Van den Eynde et al. 2010), one of whom in the real stimulation group dropped out due to discomfort during the fourth TMS train (Van den Eynde et al. 2010). No patients dropped out of the other studies, and no serious adverse events such as syncope or convulsions were reported in any of the papers included in this scoping review.

TABLE 2 | Review findings in patients with BN.

Author	Study design	No. of subjects	Age	BMI at baseline	Comorbidity	rTMS machine	Stimulation site	Frequency (Hz)	Intensity (%RMT)	Train duration (second)	Inter-train interval (second)	No. of pulses (/session)	No. of sessions	Clinical outcome		Dropout rate
														Binge-purge behaviour	Psychological symptom	
Downar et al. (2012)	Case report	1	43	20.3	Depression	Magpro R30	Bilateral DMPFC	10	120%	5	10	6000 (3000/ hemisphere)	20	Improved	Improved	0/1
Hausmann et al. (2004)	Case report	1	28	18	Depression	Magstim rapid	Left DLPFC	20	80%	10	60	2000	10	Improved	Improved	0/1
Walpoth et al. (2008)	Double-blind sham controlled trial	16	Mean [SD] Real: 27.4 [4.8] Sham: 22.6 [2.6]	Mean [SD] Real: 19.6 [2.4] Sham: 19.7 [1.7]	Depression (5/14)	Magstim rapid	Left DLPFC	20	120%	10	60	2000	15	No statistically significant difference between real and sham rTMS	No statistically significant difference between real and sham rTMS	2/16
Gay et al. (2016)	Double-blind sham controlled trial	51	Median (range) Real: 27 (19–38) Sham: 29.50 (19–40)	NA	Depression (31/47) Anxeity (11/47) Alcohol/ substance Dependance/ abuse (4/47)	Magstim rapid	Left DLPFC	10	110%	5	55	1000	10	No statistically significant difference between real and sham rTMS	No statistically significant difference between real and sham rTMS	4/51
Dunlop et al. (2015)	Single arm open label	28	Mean [SD] 31.0 [9.5]	Range 14.5–28.8	Depression (16/28) OCD (6/28) PTSD (8/28) bipolar disorder (6/28)	Magpro R30	Bilateral DMPFC	10	120%	5	10	6000 (3000/ hemisphere)	20–30	Statistically significant improvement	NA	0/28
Van den Eynde et al. (2010)	Double-blind sham controlled trial	38	Mean [SD] Real: 30.5 [11.2] Sham: 29.5 [8.4]	Mean [SD] Real: 25.8 [11.5] Sham: 25.0 [8.5]	No described	Magstim rapid	Left DLPFC	10	110%	5	55	1000	1	Statistically significant improvement in real rTMS compared to sham	No statistically significant difference between real and sham rTMS	1/38
Van den Eynde et al. (2012)	Single arm open label	21	Mean [SD] Left-handed: 22.9 [2.9] Right-handed: 28.5 [9.8]	Mean [SD] Left-handed: 22.2 [2.7] Right-handed: 25.4 [11.9]	No described	Magstim rapid	Left DLPFC	10	110%	5	55	1000	1	Statistically significant improvement between pre-post rTMS in left-handed group	Statistically significant difference between left and right handed (worsen in left-handed, improve in right-handed)	0/7[a]
Sutoh et al. (2016)	Single arm open label	8	Mean [SEM] 24.80 [2.54]	Mean [SEM] 19.54 [1.54]	No comorbidities	Magstim rapid	Left DLPFC	10	110%	5	55	1000	1	Statistically significant improvement	NA	0/8

Abbreviations: BN, bulimia nervosa; DLPFC, dorsolateral prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; OCD, obsessive compulsive disorder; PTSD, post traumatic stress disorder; SD, standard deviation; SEM, standard error of mean; TMS, repetitive transcranial magnetic stimulation.

[a]Subjects with right-handed (n = 14) was adopted from the previous study (Van den Eynde et al. 2010).

3.4 | Review Findings in Patients With Binge Eating Disorder, Eating Disorders With PTSD, and ARFID

Two case reports on binge eating disorder were included in this current review (Baczynski et al. 2014; Sciortino et al. 2021). In one, a 19-year-old woman who did not respond to pharmacotherapy for 2 years or to psychotherapy for more than 5 years received 20 sessions of stimulation at 10 Hz, 120%, and 2400 pulses/session, with the left DLPFC as the stimulation site (Baczynski et al. 2014). After the rTMS therapy, her binge eating score improved from 38 to 27. The other case report featured a 45-year-old woman with a history of eating disorders since the age of 13 years and a 28-year-old woman with binge eating symptoms since being first diagnosed with a mood disorder at 18 years (Sciortino et al. 2021). They received accelerated intermittent theta burst stimulation (iTBS) therapy for depressive symptoms of bipolar II disorder for three weeks (total of 18 sessions), with the left DLPFC as the stimulation site. Their depressive symptoms remained moderate with iTBS therapy, but binge eating symptoms were completely remitted (Sciortino et al. 2021). In a recent RCT, 60 patients with binge eating disorder associated with obesity were allocated to real or sham rTMS groups. The real rTMS group showed statistically significant decrease in the number of binge eating episode compared with the sham treatment group (Maranhão et al. 2025). Twenty sessions of 10 Hz rTMS to the left DLPFC were delivered in that study. Elsewhere, a case series reported rTMS therapy for eating disorders (AN restrictive type; $n = 2$, binge eating and purging type; $n = 4$, BN; $n = 5$, eating disorder not otherwise specified; $n = 3$) concomitant with PTSD (Woodside et al. 2017). Ten patients received 10 Hz, 120% RMT, 3000 pulses/bilateral stimulation on one side, three received iTBS (120% RMT, 50 Hz triplet bursts, 5 bursts/sec, 600 pulses/bilateral stimulation on one side), and one received 20 Hz, 120% RMT, 1500 pulses/bilateral stimulation on one side with the DMPFC as the stimulation site. Treatment was performed for 20-30 sessions, and significant improvement in PTSD symptoms was observed. A case report on a 5-year-old boy with ARFID showed improvement in emotional status and eating behaviour after 11 sessions of 1 Hz rTMS for 1200 pulses to the right DLPFC (Wang et al. 2025).

4 | Discussion

Based on a search strategy that was jointly developed by brain stimulation and eating disorder specialists, this current review is thought to include the largest number of published articles (Bahadori et al. 2025; Cavicchioli et al. 2022; Gallop et al. 2022; Longo et al. 2025; Marcolini et al. 2024; Muratore and Attia 2021; Murray et al. 2022; Ramanathan et al. 2025; Rodan et al. 2023; K. Wu et al. 2024). Since the early 2010s, a research team from King's College London has been developing TMS treatment for patients with AN (McClelland et al. 2013; McClelland, Kekic, Campbell, and Schmidt 2016; McClelland, Kekic, Bozhilova, et al. 2016; Van den Eynde et al. 2013). The TIARA study was conducted between 2014 and 2017 (Bartholdy et al. 2015), its main outcomes were reported in Dalton, Bartholdy, McClelland, et al. (2018), before being followed by several sub-analyses (Dalton, Lewis, et al. 2020; Dalton, Foerde, et al. 2020; Dalton, McClelland, et al. 2021; Dalton, Maloney, et al. 2021). As for patients with AN, another RCT included 17 subjects in both the real and sham groups (Chastan et al. 2024). For patients with BN, an RCT was conducted with a small number of subjects in real and sham stimulation groups (Walpoth et al. 2008). Another larger RCT for patients with BN was conducted with real and sham stimulation subjects (Gay et al. 2016). In addition to these RCTs, there are two single-arm open-label studies with multi-session protocols for patients with AN (Knyahnytska et al. 2019; Woodside et al. 2021) and one for patients with BN (Dunlop et al. 2015). In summary, interventional clinical studies are still limited in number, so we suggest that rTMS therapy for eating disorders should be considered to be in the development stage.

Just one case report has reported an increase in BMI by rTMS therapy (Choudhary et al. 2017), but significant preferable effects of rTMS therapy have been reported in several studies on mood or eating disorder symptoms in patients with AN (Dalton, Bartholdy, McClelland, et al. 2018; Dalton, Lewis, et al. 2020; Dalton, McClelland, et al. 2021; McClelland et al. 2013; McClelland, Kekic, Campbell, and Schmidt 2016; Woodside et al. 2021). This suggests that rTMS therapy may improve quality of life by improving the patients' depressive mood or obsessive fear of gaining weight. Many favourable results have been reported from the TIARA study (Dalton, Bartholdy, McClelland, et al. 2018; Dalton, Lewis, et al. 2020; Dalton, Foerde, et al. 2020; Dalton, McClelland, et al. 2021; Dalton, Maloney, et al. 2021). However, it should be noted that it was designed as a feasibility trial and further studies are needed with clear hypotheses and appropriate sample size calculation in order to verify the effects of TMS therapy for patients with AN. In the RCT of patients with BN, improvements in binge eating and impulsivity were observed in the real stimulation group, although without significant difference from the sham group (Walpoth et al. 2008). A single-arm open-label study reported that more than half of the participants had a halving of binge-purge symptoms (Dunlop et al. 2015). rTMS therapy has been said to have some therapeutic effectiveness for disorders with craving, with some report of impulse control (Gay et al. 2016; M. K. Wu et al. 2022; Yang et al. 2018; Zhang et al. 2019). Binge eating symptoms may therefore become target for rTMS therapy.

The stimulation parameters developed in the TIARA study have been widely adopted in research on rTMS therapy for eating disorders, which stimulate the left DLPFC at high frequency, with a total of 20,000 stimulations over 20 treatment sessions (Dalton, Bartholdy, McClelland, et al. 2018). In rTMS treatment for depression, which is widely used in clinical settings (O'Reardon et al. 2007), the stimulation site and frequency are the same as in the TIARA study, but the total number of stimulations is 60,000 to 90,000, which is 3–4.5 times that of the TIARA study protocol. When rTMS therapy for eating disorders is performed using the left DLPFC as the stimulation site, the TIARA study parameters that have been verified so far may not provide enough stimulations. In addition to the stimulation protocol used in TIARA study, recent studies have attempted to stimulate alternative regions such as the DMPFC (Woodside et al. 2021), the bilateral insula (Knyahnytska et al. 2019), and the right inferior parietal lobe (Chastan et al. 2024), aiming to target impulsivity, interoceptive awareness, and body image disturbance, respectively. These trials remain exploratory, but

they represent promising directions for tailoring rTMS therapy to specific clinical phenotypes within eating disorders. Studies of rTMS therapy for eating disorders that used the DMPFC as the stimulation site have used protocols with a high number of stimulations, ranging from 120,000 to 180,000 (Dunlop et al. 2015; Downar et al. 2012; Woodside et al. 2021). The DMPFC is the stimulation site for the FDA-approved treatment protocol for obsessive-compulsive disorder (Cotovio et al. 2023). There is also an open-label study of rTMS treatment for eating disorders that has shown effectiveness on binge-purge frequency (Dunlop et al. 2015). Consideration of the stimulation site should depend on which symptoms of eating disorders are targeted by rTMS treatment.

In four studies with multi-session protocol for patients with AN, the mean BMI of study subjects was 13.6 kg/m^2 (Chastan et al. 2024), 16.0 kg/m^2 (Dalton, Bartholdy, McClelland, et al. 2018), 16.4 kg/m^2 (Woodside et al. 2021), and 16.7 kg/m^2 (Knyahnytska et al. 2019). Among them, only one study (Chastan et al. 2024) had a mean BMI < 15 kg/m^2, which is considered to be a severe clinical condition. Further, one study focused on restrictive subtypes (Chastan et al. 2024), while the others included a mixture of restrictive and binge-purging subtypes (Dalton, Bartholdy, McClelland, et al. 2018; Knyahnytska et al. 2019) or unknown subtype (Woodside et al. 2021). Elucidation of the effectiveness and safety of rTMS therapy with consideration of the severity and subtype of AN is required. In patients with BN, the comorbidity of mood disorders and substance abuse is a clinical problem (Bodell et al. 2013; Himmerich et al. 2019). Previous rTMS studies have recruited subjects with comorbid mood disorders, obsessive-compulsive disorders, and stress-related disorders (Dunlop et al. 2015; Gay et al. 2016; Walpoth et al. 2008). rTMS therapy has already been clinically introduced for mood disorders and obsessive-compulsive disorders (Cotovio et al. 2023), and in patients with such comorbid disorders, their improvement may lead to improvement of BN symptoms. We also suggest the need to verify the difference in the effects of rTMS therapy depending on the presence or absence of comorbid disorders in patients with BN.

Other than headaches and pain at the stimulation site, no serious adverse events (such as fainting or convulsions) have been reported in relation to rTMS therapy for eating disorders. This is compatible with previous reports on the safety of rTMS therapy for psychiatric disorders (Taylor et al. 2018). rTMS therapy can perhaps be said to be a safe and tolerable treatment for patients with eating disorders. However, its safety should be cautiously considered in patients with high-risk clinical situations such as severe undernutrition or electrolyte abnormalities, in which the seizure threshold may be lower (Kim and Paik 2021).

Most of the literature included in this scoping review was based on patients with AN or BN, but there were two case reports (Baczynski et al. 2014; Sciortino et al. 2021) and one RCT (Maranhão et al. 2025) on binge eating disorder (Baczynski et al. 2014; Sciortino et al. 2021), a case series that focused upon PTSD associated with eating disorders (Woodside et al. 2017) and a case report on paediatric ARFID (Wang et al. 2025). According to the results from recent well designed RCT (Maranhão et al. 2025), high frequency rTMS to left DLPFC may be promising therapy for binge eating disorder associated with obesity. Along with the development of concept of eating disorders, we suggest rTMS-centred research is required to verify the efficacy and safety of each subtype of eating disorder.

Concerning clinical use of rTMS therapy for eating disorders in near future, there should also be consideration of the development of rTMS therapy in other neuropsychiatric disorders. iTBS to left DLPFC was approved by FDA for depression in 2018 (Cotovio et al. 2023). iTBS was not included in the literature for AN and BN in this scoping review, but an ongoing trial is investigating the effectiveness of this stimulation method for patients with AN (Chen et al. 2025; Hemmings et al. 2024).

5 | Conclusion

This scoping review included the largest number of articles on rTMS therapy for patients with AN and BN to date. For patients with AN, the effects of rTMS therapy on mood or eating disorder symptoms have been reported, but few effects were seen on weight gain. For patients with BN, no RCTs with multiple session rTMS have reported significant differences between real and sham stimulation. In patients with AN and patients with BN who were stimulated at the left DLPFC, we suggest the total number of pulses may have been insufficient. The DMPFC is expected to become an effective stimulation site for binge-purge symptoms in patients with BN. We suggest future research should focus upon optimising stimulation parameters, including frequency, intensity, session number, and stimulation site, tailored to the specific symptom domains and eating disorder subtypes.

Author Contributions

S.T., S.I., M.U., T.H., and R.I. contributed to the design of this study. S.T., S.I., and T.H. created the search criteria. S.T. and S.I. independently screened all titles and abstracts and reviewed the articles that met the inclusion criteria. T.H. and M.U. helped in the decision for inclusion when the case was uncertain. S.T. wrote the manuscript with support from S.I., M.U., T.H., and R.I. R.I. supervised this study. All authors contributed to the article and approved the submitted version.

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Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

S.T. received speaker's honoraria from Teijin Pharma Ltd. Tokyo, Japan. The other authors declare no conflicts of interest in relation to this work.

Data Availability Statement

The datasets used in the current study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Supporting Information S1: erv70046-sup-0001-suppl-data.docx.