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Evaluation of Children and Adolescents Receiving Transcranial Magnetic Stimulation Treatment at a University Hospital

Bir Üniversite Hastanesinde Transkraniyal Manyetik Stimülasyon Tedavisi Alan Çocuk ve Ergenlerin Değerlendirilmesi

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ABSTRACT

Aim: This study presents the first clinical data from Türkiye on the use of transcranial magnetic stimulation (TMS) in treating psychiatric disorders among children and adolescents. This study aimed to evaluate clinical outcomes and the safety of TMS in treatment-resistant child and adolescent psychiatric cases retrospectively.

Materials and Methods: Medical records of 23 patients who received TMS between April 2015 and October 2024 at the Department of Child and Adolescent Psychiatry, Pamukkale University Faculty of Medicine, were reviewed. Demographic and clinical variables-including age, sex, diagnosis, comorbidities, medication use, applied TMS protocol, and Clinical Global Impression-Severity (CGI-S) and Improvement (CGI-I) scores were analyzed.

Results: The mean age was 15.65±1.64 years, and 69.6% were male. The most frequent diagnoses were obsessive-compulsive disorder [(OCD); 39.1%] and depressive disorder (30.4%). Diagnosis-specific protocols targeted distinct brain regions and frequencies. Among patients with available CGI-I data (n=18), marked improvement was observed in 38.9% of cases, mild improvement in 38.9%, and no significant change in 22.2%. Among patients with depression, 60% showed marked improvement, compared with 25% of those with OCD. Mild, transient side effects (headache, visual dimming) occurred in 13% of patients.

Conclusion: TMS appears to be a safe and well-tolerated adjunctive treatment option and was associated with clinical improvement in a proportion of children of children and adolescents with partially or fully treatment-resistant psychiatric disorders. These findings represent the first national data on pediatric TMS use in Türkiye and underscore the need for larger, prospective, and controlled studies to confirm its efficacy and optimize treatment protocols.

Keywords: Transcranial magnetic stimulation, adolescent, depressive disorder, obsessive-compulsive disorder, treatment resistance

ÖZ

Amaç: Bu çalışma, çocuk ve ergen psikiyatrik bozukluklarının tedavisinde transkraniyal manyetik stimülasyon (TMS) kullanımına ilişkin Türkiye'de bildirilen ilk klinik verileri sunmaktadır. Bu araştırmada, tedaviye dirençli çocuk ve ergen psikiyatri olgularında TMS uygulamalarının etkinlik ve güvenilirliğinin retrospektif olarak değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Pamukkale Üniversitesi Tıp Fakültesi Çocuk ve Ergen Ruh Sağlığı ve Hastalıkları Anabilim Dalı'nda Nisan 2015-Ekim 2024 tarihleri arasında TMS uygulanan 23 olgunun tıbbi kayıtları incelenmiştir. Yaş, cinsiyet, tanı, ek tanılar, ilaç kullanımı, uygulanan TMS protokolü ile Klinik Global İzlem-Şiddet (KGİ-Ş) ve KGİ- İyileşme (KGİ-İ) puanlarını içeren demografik ve klinik değişkenler değerlendirilmiştir.

Bulgular: Olguların yaş ortalaması 15,65±1,64 yıl olup, %69,6'sı erkeklerden oluşmaktaydı. En sık görülen tanılar obsesif-kompulsif bozukluk [(OKB); %39,1] ve depresif bozukluk (%30,4) idi. Tanıya özgü protokoller, farklı beyin bölgelerini ve frekanslarını hedef almıştır. CGI-I verileri mevcut olan hastalar arasında (n=18), olguların %38,9'unda belirgin iyileşme, %38,9'unda hafif düzeyde iyileşme gözlenmiş, %22,2'sinde ise anlamlı bir değişiklik gözlenmemiştir. Depresyon tanılı olguların %60'ında belirgin iyileşme saptanırken, OKB olgularında bu oran %25 olarak bulunmuştur. Yan etki oranı %13 olup, gözlenen yan etkiler hafif ve geçici nitelikte (baş ağrısı, geçici görme kararması) seyretmiştir.

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Sonuç: TMS, çocuk ve ergenlerde kısmen veya tamamen tedaviye dirençli psikiyatrik bozukluklarda güvenilir, iyi tolere edilen ve potansiyel olarak etkili tamamlayıcı bir tedavi seçeneği olarak görünmektedir. Bu çalışma, Türkiye'de pediatrik TMS uygulamalarına ilişkin bildirilen ilk ulusal verileri sunmakta olup, etkinliğin doğrulanması ve tedavi protokollerinin optimize edilmesi amacıyla geniş örneklemli, prospektif ve kontrollü araştırmalara ihtiyaç olduğunu göstermektedir.

Anahtar Kelimeler: Transkraniyal manyetik stimülasyon, ergen, depresif bozukluk, obsesif-kompulsif bozukluk, tedavi direnci

INTRODUCTION

The global prevalence rate of mental disorders in children and adolescents increases with age, reaching 6.8% for ages 5-9, 12.4% for ages 10-14, and 13.96% for ages 15-19[1]. These disorders not only impair individual and familial functioning but are also associated with serious social consequences such as high school dropout rates, reduced economic productivity, legal problems, suicide, and homelessness[2,3]. In recent decades, significant advances have been made in the field of psychopharmacology for the treatment of these disorders. However, pharmacological monotherapy fails to achieve adequate therapeutic effects in some cases, and concerns regarding side-effect profiles and long-term safety have increased the demand for alternative and integrative treatment modalities[4].

Transcranial magnetic stimulation (TMS) is a non-invasive neurostimulation technique that modulates brain tissue activity through the application of magnetic fields[5]. Its repetitive form, known as repetitive TMS (rTMS), has the capacity to induce neural changes that persist beyond the stimulation period[6]. The therapeutic effects are generally achieved through cumulative sessions, during which neuroplasticity-based lasting alterations are induced within cortical networks[7,8]. Depending on the applied frequency, high-frequency (>5 Hz) protocols exert excitatory effects, whereas low-frequency (≤1 Hz) protocols produce inhibitory effects[9,10].

In adult populations, the therapeutic efficacy of TMS has been extensively investigated across various psychiatric disorders, including major depressive disorder (MDD), obsessive-compulsive disorder (OCD), bipolar disorder, and schizophrenia. Randomized controlled trials have demonstrated the efficacy of TMS, particularly in treatment-resistant MDD and OCD, leading to its approval by the US Food and Drug Administration (FDA) for these indications[11,12].

In contrast, studies investigating the use of TMS in child and adolescent psychiatry remain limited. This scarcity can be attributed to factors such as developmental differences in neuroplasticity, uncertainties regarding safety and tolerability, ethical constraints, and methodological challenges in achieving adequate sample sizes[13-15]. Nevertheless, recent research has suggested that TMS may contribute to clinical improvement across a range of diagnoses, including MDD, OCD, autism spectrum disorder (ASD), Tourette's disorder, and attention-deficit/hyperactivity disorder and is generally considered a safe intervention[15-18]. As a result of these advances, the use of specific TMS devices in adolescents aged 15 years and older with depressive disorder has recently been approved by the FDA[19].

TMS protocols vary according to the targeted anatomical region and stimulation frequency, depending on the psychiatric disorder being treated. The left dorsolateral prefrontal cortex (DLPFC) is commonly targeted in depressive and anxiety disorders. In contrast, the right DLPFC or the supplementary motor area (SMA) are preferred in OCD and tic disorders[17]. For ASD interventions, stimulation sites have included not only the DLPFC but also social cognition-related networks such as the medial prefrontal cortex (mPFC) and temporoparietal regions[20]. However, in pediatric populations, the standardization of parameters such as stimulation site, dosage, and session number has not yet been achieved. The existing literature reports substantial heterogeneity among protocols and a lack of consensus regarding standardized procedures[16-18,20].

Systematic data on the use of TMS in the field of child and adolescent psychiatry in Türkiye are minimal, and no studies specifically focusing on this topic have been identified in the national literature. This gap highlights the importance of sharing clinical experiences within the country, both to contribute to the establishment of a national database and to inform international efforts in protocol development. In this context, the present study aims to retrospectively examine pediatric cases that received TMS treatment at the Department of Child and Adolescent Psychiatry, Pamukkale University Faculty of Medicine, and to evaluate the observed patterns of clinical response in light of the existing literature.

MATERIALS AND METHODS

This descriptive study retrospectively examined cases that underwent TMS treatment at the Department of Child and Adolescent Psychiatry, Pamukkale University Faculty of Medicine Hospital, between April 1, 2015, and October 1, 2024.

The study was approved by the Pamukkale University Non-Interventional Clinical Research Ethics Committee (decision number: 17, approval date: 02.10.2024).

Participants

A total of 24 children and adolescents who received TMS treatment during the specified period were identified. One case was excluded from the study because the treatment protocol was discontinued after the first session (this patient, diagnosed with ASD, was unable to adapt to the clinical setting and exhibited marked psychomotor agitation). Consequently, a total of 23 children and adolescents were included in the final analysis.

The study included cases aged between 12 and 18 years who had completed clinical evaluations both before and after TMS treatment and met the diagnostic criteria for at least one psychiatric disorder according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. Five cases for which Clinical Global Impression-Severity, (CGI) data were unavailable were excluded only from the analyses of clinical treatment response. Pharmacological treatment regimens remained stable throughout the TMS intervention period.

Data Collection

Demographic and clinical data, including participants' age, sex, primary diagnosis, comorbid conditions, medication use, TMS treatment protocol, targeted brain region, and scores on the CGI-Severity (CGI-S) and CGI-Improvement (CGI-I) scales, were retrospectively obtained from patient medical records.

Clinical Global Impression Scale

CGI consists of three general measures. The CGI-S illness severity measure is rated on a scale from 1 (normal, not ill at all) to 7 (the most severely ill among patients). If the patient has not been evaluated, a score of "0" is assigned. CGI-S is rated at admission (CGI-S adm) and at discharge (CGI-S dis). The overall CGI improvement measure is rated from 1 (very much improved) to 7 (much worse). Again, "0" means "not evaluated." CGI-I was only rated at discharge. The third measure, called the CGI-efficacy index, was not evaluated in the current study[21,22].

TMS Treatment

rTMS was administered at the rTMS unit of Pamukkale University Psychiatry Hospital by a psychiatric nurse certified in TMS application, using a Neuro-MS/D device (Neurosoft Ltd., Russia) equipped with an angled figure-of-eight coil.

During the first session, the motor threshold was determined. For this purpose, stimuli of gradually increasing intensity were delivered approximately 5 cm lateral to the vertex along the interaural line, and involuntary finger movements were observed on the contralateral side. If no visible muscle contraction was elicited at the coil position used to determine the threshold, the coil was slightly adjusted within negligible distances to optimize the response. rTMS sessions were conducted according to diagnosis-specific target brain regions and frequency parameters. Clinical status and potential adverse effects were evaluated before and after each session. The specific protocols applied are summarized below:

Depression Protocol (Left DLPFC): Stimulation was delivered at 120% of the individual motor threshold with a frequency of 10 Hz. A total of 75 trains, each consisting of 40 pulses, were administered with an inter-train interval of 11 seconds, resulting in 3,000 pulses per session. The average duration of each session was approximately 18.3 minutes.

Tic Disorder Protocol (Bilateral SMA): Stimulation was delivered at 120% of the individual motor threshold with a frequency of 1 Hz. A total of 20 trains, each consisting of 60 pulses, were administered with an inter-train interval of 2 seconds, resulting in a total of 1,200 pulses per session. The average session duration was approximately 20 minutes.

OCD and Auditory Hallucination Protocols [mPFC; Orbitofrontal Cortex (OFC); Left Temporoparietal Junction: stimulation was administered at 110% of the individual motor threshold with a frequency of 1 Hz. Each session consisted of a single train comprising 1,000 pulses, with an inter-train interval of 1 second. The average session duration was approximately 16.4 minutes.

All protocols were planned to include 20 sessions, conducted three times per week. Clinical status and potential adverse effects were evaluated before and after each session.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were reported as mean ± standard deviation for continuous variables and as frequencies and percentages for categorical variables. The distributions of categorical variables, such as sex, diagnostic group, presence of comorbidity, treatment type, and applied TMS protocol, were examined using the chi-square test; when more than 20% of the expected cell frequencies were below five, Fisher's exact test was applied. Clinical severity was assessed using the CGI-S scale, whereas post-TMS clinical improvement was classified according to scores on the CGI-I scale. Comparisons of clinical response rates (marked or very marked improvement) between diagnostic groups were also conducted using the chi-square or Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

Of the participants, 16 were male (69.6%), and 7 were female (30.4%), with ages ranging from 12 to 18 years (mean =

15.65±1.64 years). Nine patients (39.1%) received TMS as outpatients, 10 (43.5%) during inpatient treatment, and 4 (17.4%) received TMS during both inpatient and outpatient treatment periods.

The Diagnostic Distribution of the Sample (n=23) was as Follows: 39.1% OCD (n=9); 30.4% depressive disorder (n=7), 13.0% Tourette's disorder (n=3), 8.7% psychotic disorder (n=2), 4.3% bipolar disorder (n=1), and 4.3% tic disorder (n=1). Comorbid psychiatric diagnoses were present in 13 participants (56.5%).

All cases received rTMS treatment as an adjunct to their ongoing pharmacotherapy. Among the 21 patients for whom medication data were available, all were found to be receiving multiple psychotropic medications. Treatment protocols were determined based on the primary diagnosis and, in some cases, tailored to target specific primary symptoms. The specific protocols applied are detailed in Table 1.

DLPFC (n=8): A total of eight patients (34.7%) received a high-frequency (10 Hz) protocol targeting the left DLPFC. Of these, seven had a primary diagnosis of depressive disorder, while one patient with psychotic disorder received stimulation targeting treatment-resistant negative/depressive symptoms.

OCD Protocol (n=12): Twelve patients (52.2%) underwent a low-frequency (1 Hz) protocol targeting the mPFC (n=6), OFC (n=5), or SMA (n=1). Among these, nine had a primary diagnosis of OCD, one had bipolar disorder (targeting OCD symptoms), and two had Tourette's disorder (targeting OCD symptoms).

Tic Protocol (n=2): Two patients (8.7%) received a low-frequency (1 Hz) bilateral SMA protocol. One of these had Tourette's disorder (targeting tics), and the other was diagnosed with tic disorder.

Auditory Hallucination Protocol (n=1): One patient (4.4%) with psychotic disorder received a low-frequency (1 Hz) protocol targeting the left temporoparietal junction for treatment-resistant auditory hallucinations (Table 1).

Examination of the participants' CGI-S scores revealed that clinical severity levels ranged from 4 to 7. Specifically, 4.4% (n=1) of participants were rated as moderately ill, 30.4% (n=7) as moderately ill, 30.4% (n=7) as markedly ill, and 34.8% (n=8) as severely ill. These findings indicate that, overall, the sample exhibited moderate-to-severe levels of clinical symptomatology (Table 2).

Based on CGI-I scores among patients with available outcome data (n=18), 38.9% (n=7) of participants showed marked improvement, 38.9% (n=7) showed mild improvement, and 22.2% (n=4) demonstrated no clinically significant change. These results indicate that following TMS treatment, a substantial proportion of participants experienced either marked or partial clinical improvement (Table 3). Given the very small sample sizes within certain diagnostic subgroups, these percentages should be interpreted with caution.

Among patients diagnosed with depressive disorder, 60.0% (n=3) showed marked improvement, 20.0% (n=1) showed mild improvement, and 20.0% (n=1) exhibited no change. In the OCD group, 25.0% (n=2) demonstrated marked improvement, 37.5% (n=3) mild improvement, and 37.5% (n=3) no change. Among those diagnosed with Tourette's disorder, 50.0% (n=1) showed marked improvement and 50.0% (n=1) mild improvement. In patients with psychotic disorders (treatment-resistant auditory hallucinations and treatment-resistant negative/depressive symptoms), mild improvement was observed in 100.0% (n=2). The patient diagnosed with tic disorder showed marked improvement (100.0%, n=1).

Overall, adverse effects were reported in three participants (13%). Two participants experienced mild headache and one reported transient visual dimming.

DISCUSSION

In this retrospective study, 23 children and adolescents who received rTMS treatment were evaluated in terms of their clinical characteristics, stimulation protocols, and treatment

Table 1. Target brain regions, stimulation protocols, and clinical indications of rTMS treatment

Target brain region	Stimulation protocol (frequency)	Diagnostic indication	n	%	Number of sessions
Left DLPFC	High-frequency rTMS (10 Hz)	Depressive disorder	8	34.7	20
mPFC	Low-frequency rTMS (1 Hz)	OCD	6	26.1	20
OFC	Low-frequency rTMS (1 Hz)	OCD	5	21.7	20
Bilateral SMA	Low-frequency rTMS (1 Hz)	Tic disorders/Tourette syndrome	2	8.7	20
Bilateral SMA	Low-frequency rTMS (1 Hz)	OCD	1	4.3	20
Left temporoparietal junction	Low-frequency rTMS (1 Hz)	Treatment-resistant auditory hallucinations	1	4.3	20

DLPFC: Dorsolateral prefrontal cortex, mPFC: Medial prefrontal cortex, OFC: Orbitofrontal cortex, SMA: Supplementary motor area, OCD: Obsessive-compulsive disorder, rTMS: Repetitive transcranial magnetic stimulation

Table 2. Distribution of clinical global impression (CGI) scores

	n	%
CGI-S		
4 (moderately ill)	1	4.4
5 (markedly ill)	7	30.4
6 (severely ill)	7	30.4
7 (among the most extremely ill patients)	8	34.8
Total	23	100
CGI-I		
2 (much improved)	7	38.9
3 (minimally improved)	7	38.9
4 (no change)	4	22.2
Total	18	100

CGI-S: Clinical Global Impression-Severity, CGI-I: Clinical Global Impressionimprovement, CGI-I scores were available for 18 patients; percentages were calculated based on these available data; n: Number of cases, %: Percentage

Table 3. CGI-I scores by diagnosis

Diagnosis	CGI-I score	n	%
Depressive disorder	2 (much improved)	3	60.0
	3 (minimally improved)	1	20.0
	4 (no change)	1	20.0
OCD	2 (much improved)	2	25.0
	3 (minimally improved)	3	37.5
	4 (no change)	3	37.5
Tourette syndrome	2 (much improved)	1	50.0
	3 (minimally improved)	1	50.0
Psychotic disorder	3 (minimally improved)	2	100.0
Tic disorder	2 (much improved)	1	100.0

CGI-I: Clinical Global Impression-Severity, OCD: Obsessive-compulsive disorder, n: Number of cases; %: Percentage. Percentages for diagnostic subgroups with very small sample sizes should be interpreted with caution

outcomes. The majority of participants presented with moderate-to-severe psychiatric disorders, with OCD and depressive disorder being the most common diagnoses. TMS protocols were tailored according to diagnosis-specific target brain regions and stimulation frequencies. Following treatment, approximately 39% of cases demonstrated marked clinical improvement, while reported adverse effects were mild and transient in nature.

The literature indicates that rTMS has increasingly been utilized in the treatment of various psychiatric disorders among children and adolescents; however, it is most commonly regarded as an adjunctive therapeutic option for treatment-resistant cases, particularly in depressive disorders where pharmacotherapy has yielded inadequate or only partial responses[15,23,24]. The ability of rTMS to modulate cortical excitability and neuronal plasticity offers a novel therapeutic avenue for treatment-resistant cases in which pharmacological interventions are ineffective. Indeed, recent clinical studies conducted on adolescents diagnosed with treatment-resistant MDD and OCD have consistently demonstrated that TMS administration yields significant clinical improvements in this population despite ongoing pharmacotherapy[23-26]. All cases included in our study consisted of patients who exhibited moderate-to-severe clinical symptoms and had shown insufficient response to ongoing psychopharmacological treatments. The recorded improvements reflected in the CGI scores were consistent with findings reported in the existing literature. This observation supports the potential benefit of TMS as a therapeutic option in treatment-resistant cases.

The TMS protocols applied in our study were designed to target brain regions identified in the literature as disorder-specific. For instance, in cases of depressive disorder, high-frequency (10 Hz) stimulation was directed to the left DLPFC, consistent with the general principle of enhancing cortical excitability in this region, which has been frequently shown to exhibit hypoactivity in treatment-resistant depression[15,16] . Activation of the DLPFC has been shown to produce significant clinical improvement in depressive symptoms through multiple neurobiological mechanisms, primarily by modulating limbic-prefrontal connections associated with emotional regulation, motivation, and executive functioning[27].

In contrast, low-frequency (1 Hz) stimulation was applied to the mPFC and OFC regions in patients diagnosed with OCD. The selection of these regions and stimulation frequency was aimed at reducing the hyperactivity within the cortico-striato-thalamo-cortical circuit, which is known to play a central role in the pathophysiology of OCD[7,15,17]. Given the inhibitory effects of low-frequency (1 Hz) stimulation on cortical activity, the 1 Hz protocol applied to the mPFC and OFC can be considered to target the neurophysiological basis of compulsive behaviors by suppressing excessive activation within this circuit[9]. In one OCD case, low-frequency (1 Hz) stimulation was applied to the bilateral SMA, based on findings reported in previous studies in the literature[28,29]. Considering that standardized stimulation protocols have not yet been established in the child and adolescent population and that stimulation parameters have been reported heterogeneously across studies, the targeting of different brain regions in our study reflects clinicians' ongoing efforts to develop disorder-specific, circuit-based treatment protocols[16,18]. This variability also indicates that a universally accepted "gold standard" protocol with proven efficacy for this age group has yet to be established.

In our study, adverse effects were observed in 13% (n=3) of cases, consisting of mild headache (n=2) and transient visual dimming (n=1). No adverse events requiring discontinuation of treatment were observed. In addition, no serious side effects were detected after the intervention.

Recent meta-analyses have characterized TMS as a generally well-tolerated neuromodulation technique in children and adolescents, with no reports of serious adverse effects. An umbrella review conducted by Santos et al.[18] summarized more than 40 randomized controlled trials on the use of rTMS and Transcranial Direct Current Stimulation in pediatric populations and reported a rate of serious adverse events below 1%. Similarly, Gallop et al.[16], in their systematic review including 19 clinical studies, reported that the most frequently observed adverse effects of rTMS were transient headache, dizziness, and discomfort at the stimulation site, emphasizing that these effects were generally mild and short-lived. Findings summarized by El-Shahawy et al.[17] also indicate that rTMS applications in child and adolescent populations exhibit a safety profile comparable to that observed in adults, with no reports of serious adverse effects such as seizures, syncope, or long-term neurological complications. Our findings are consistent with the general safety profile reported in the literature. Although, in theory, increased neurophysiological sensitivity has been suggested in children and adolescents due to heightened brain plasticity, current evidence indicates that TMS is a safe and well-tolerated intervention when administered under appropriate clinical conditions and stimulation parameters. Nevertheless, given that long-term safety data remain limited, prospective follow-up studies are warranted.

Study Limitations

Several limitations should be considered when interpreting the findings of this study. First, as the study was retrospective and descriptive in design, the observed clinical improvements cannot be directly attributed to TMS treatment. However, the consistency of our results with the meta-analytic evidence discussed above reinforces their clinical relevance. The absence of a control group represents another limitation, as it precludes evaluation of potential placebo effects or the contribution of concurrent psychopharmacological treatments. Nonetheless, the fact that TMS was primarily administered to patients with treatment-resistant and severe clinical presentations supports the clinical significance of the improvements observed.

The relatively small sample size (n=23) and the heterogeneous diagnostic distribution limit the possibility of conducting statistical comparisons and reduce the generalizability of the findings. In addition, clinical response was assessed solely using the CGI scales. Due to the retrospective design, diagnosis-specific standardized rating scales (e.g., Yale-Brown Obsessive Compulsive scale for OCD or Children's Depression Rating Scale-Revised depressive disorders) were not systematically available. Future prospective studies should incorporate disorder-specific measures to allow a more precise evaluation of treatment response. The observational and subjective nature of CGI-based evaluations does not capture corresponding changes at the neuropsychological or neurophysiological level. For these reasons, the current findings should be regarded as preliminary data. Prospective, controlled studies with larger sample sizes conducted in Türkiye will be essential to more clearly delineate the efficacy and safety profile of TMS in children and adolescents.

CONCLUSION

To the best of our knowledge, this study provides the first clinical data from Türkiye regarding the use of TMS in child and adolescent psychiatry. Our findings suggest that TMS may represent a feasible and well-tolerated adjunctive treatment option, particularly for patients showing partial resistance to pharmacotherapy. The observed rates of partial or marked improvement in depressive and obsessive-compulsive symptoms also highlight the potential clinical relevance of circuit-based neuromodulation approaches in this population.

Nevertheless, further well-designed prospective studies conducted in Türkiye are needed to better clarify the efficacy of TMS and to determine optimal stimulation parameters in pediatric populations. Although the high neuroplasticity characteristic of children and adolescents may enhance the therapeutic potential of TMS, the interaction between neuromodulation effects and neurodevelopmental processes remains incompletely understood. Future studies should therefore address efficacy, safety, and ethical considerations in larger pediatric samples.

Ethics

Ethical Committee Approval: The study was approved by the Pamukkale University Non-Interventional Clinical Research Ethics Committee (decision number: 17, approval date: 02.10.2024).

Informed Consent: This descriptive study retrospectively examined.

Footnotes

Authorship Contributions

Concept: Ö.B., B.K.B., A.B., Design: Ö.B., B.K.B., M.A.T., A.B., Data Collection or Processing: A.P., B.K.B., Analysis or Interpretation: Ö.B., M.A.T., A.B., B.K.B., Literature Search: Ö.B., A.P., M.A.T., A.B., Writing: Ö.B., A.P., B.K.B.

Conflict of Interest: No conflict of interest was declared by the authors.

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