ORIGINAL RESEARCH

Effectiveness of rTMS in the Left TPJ on Cognitive Function in Schizophrenia Patients

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ABSTRACT

Background: Cognitive impairment is a core and persistent symptom in schizophrenia, contributing to poor social functioning and reduced quality of life. Antipsychotic treatment often provides limited cognitive improvement, highlighting the need for non-pharmacological adjuvant interventions. Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive neuromodulation technique that may enhance cognitive function through cortical modulation. **Objective:** To evaluate the effectiveness of rTMS targeting the left temporo-parietal junction (TPJ) on cognitive function in patients with schizophrenia at Dr. Arif Zainudin Mental Hospital, Surakarta. **Methods:** A quasi-experimental pre-test–post-test study with a control group was conducted involving 38 inpatients with schizophrenia and cognitive impairment. Participants were divided into a treatment group (n=19) receiving standard antipsychotic therapy plus rTMS and a control group (n=19) receiving standard therapy alone. rTMS was administered in five sessions targeting the left TPJ. Cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina). Statistical analyses included paired and independent t-tests, with $p<0.05$ considered significant. **Results:** The treatment group showed a significant improvement in MoCA-Ina scores from 13.79 ± 9.05 to 19.89 ± 8.48 ($p<0.001$), with a mean increase of 6.1 points. The control group also improved significantly, from 21.94 ± 5.85 to 24.79 ± 4.47 ($p<0.001$), but with a smaller mean increase of 2.85 points. Post-test scores differed significantly between groups ($p=0.005$). **Conclusion:** rTMS targeting the left TPJ significantly improves cognitive function in patients with schizophrenia and may serve as an effective adjuvant therapy.

Keywords: Schizophrenia, Cognitive Impairment, rTMS, Temporo-Parietal Junction, MoCA-Ina

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INTRODUCTION

Schizophrenia is a chronic psychiatric disorder characterized by disturbances in perception, thought, emotion, and behavior, leading to significant functional impairment. It affects approximately 24 million people worldwide, representing a substantial global health burden (Goldsmith and Rapaport, 2020; WHO, 2023). The disorder is multifactorial, involving complex interactions between genetic and environmental factors that influence early brain development and neural functioning (Hany et al., 2024; McCutcheon et al., 2023).

Clinically, schizophrenia is characterized by three main symptom domains: positive symptoms (such as hallucinations and delusions), negative symptoms (including reduced motivation and affect), and cognitive symptoms. Among these, cognitive impairment—encompassing deficits in attention, memory, and executive function—is a core feature of the disorder and is strongly associated with poor functional outcomes and reduced quality of life (Pamela Ruiz-Castañeda et al., 2022). Cognitive deficits are present in up to 80–90% of patients and tend to persist throughout the course of illness, even when other symptoms are controlled.

Current pharmacological treatments, particularly antipsychotic medications, are effective in reducing positive symptoms but have limited impact on cognitive dysfunction (Goff, 2021; Kahn et al., 2020). This limitation highlights the need for adjunctive therapeutic strategies targeting cognitive deficits. In recent years, non-invasive neuromodulation techniques, such as repetitive transcranial magnetic stimulation (rTMS), have gained attention as potential interventions for improving cognitive function in schizophrenia (Sabé et al., 2024; Liu et al., 2024).

rTMS is a non-invasive brain stimulation technique that uses magnetic fields to modulate neuronal activity in specific cortical regions. It has been approved by the U.S. Food and Drug Administration (FDA) for major depressive disorder and has shown potential benefits in various neuropsychiatric conditions, including schizophrenia (Mann and Mahli, 2023). Previous studies have suggested that rTMS may improve cognitive domains such as working memory, attention, and executive function, particularly when applied to key brain regions involved in cognitive processing (Schifani et al., 2024; Yi et al., 2024).

The temporo-parietal junction (TPJ) is an important cortical region involved in auditory processing, attention, and integration of sensory information. Abnormal activity in this region has been implicated in schizophrenia, particularly in relation to cognitive dysfunction and hallucinations. Low-frequency rTMS targeting the left TPJ has been shown to modulate cortical excitability and may contribute to improvements in cognitive performance. Based on these considerations, this study aims to evaluate the effectiveness of rTMS applied to the left TPJ as an adjunctive therapy in improving cognitive function in patients with schizophrenia at RSJD dr. Arif Zainudin Surakarta. It is expected that this intervention may provide a clinically relevant improvement in cognitive outcomes and contribute to better long-term patient functioning.

METHODS

Study Design and Setting

This study employed a quasi-experimental design to evaluate the effectiveness of repetitive transcranial magnetic stimulation (rTMS) applied to the left temporo-parietal junction (TPJ) on cognitive function in patients with schizophrenia. The research was conducted in the inpatient unit of RSJD dr. Arif Zainudin Surakarta between January and March 2025.

Participants

The study population consisted of hospitalized patients diagnosed with schizophrenia who presented with cognitive impairment. Inclusion criteria were patients aged 18–60 years, diagnosed with schizophrenia after the age of 18, and demonstrating cognitive deficits as assessed using the Montreal Cognitive Assessment – Indonesian version (MoCA-Ina). Exclusion criteria included patients who were uncooperative, had a history of epilepsy or seizures, had ferromagnetic implants or metallic devices in the head and neck region, or had a history of substance use.

Sampling and Group Allocation

Sampling was performed using a purposive sampling technique among eligible patients. Subjects who met the inclusion and exclusion criteria were allocated into two groups based on enrollment order: odd-numbered participants were assigned to the intervention group, while even-numbered participants were assigned to the control group. The minimum required sample size was calculated using the Federer formula, resulting in at least 16 subjects per group. To account for potential dropouts, an additional 10% was added, yielding a total of 18 subjects per group.

Intervention

Participants in the intervention group received adjunctive rTMS therapy targeting the left TPJ in addition to standard antipsychotic treatment, whereas the control group received standard therapy alone. The rTMS protocol consisted of low-frequency stimulation at 1 Hz for 20 minutes per session, delivering 1200 pulses per session at 100% motor threshold. The intervention was administered over multiple sessions during hospitalization.

Outcome Measurement

Cognitive function was assessed using the MoCA-Ina, a validated neuropsychological screening instrument that evaluates multiple cognitive domains, including attention, memory, executive function, language, and orientation. Assessments were performed at baseline (pre-test) prior to intervention and repeated after completion of therapy (post-test).

Data Analysis

Data were analyzed using SPSS version 26.0. Descriptive analysis was conducted to summarize the characteristics of the study population. Inferential analysis included paired t-test or Wilcoxon test to evaluate within-group differences between pre-test and post-test scores, and independent t-test or Mann–Whitney test to compare differences between the intervention and control groups. A p-value of less than 0.05 with a 95% confidence interval was considered statistically significant.

Ethical Considerations

This study was conducted in accordance with ethical principles, including respect for autonomy, beneficence, non-maleficence, and justice. Ethical approval was obtained from the relevant institutional ethics committee, and informed consent was obtained from all participants or their caregivers prior to inclusion in the study.

RESULTS

Participant Flow and Baseline Characteristics

A total of 36 patients who met the inclusion and exclusion criteria were initially enrolled in the study and allocated into two groups, with 18 participants in the intervention group and 18 in the control group. During implementation, one participant in the intervention group dropped out after completing only one rTMS session. In the final analysis, both groups were considered for pre–post cognitive assessment using MoCA-Ina. Baseline demographic and clinical characteristics were generally comparable between groups, including age, sex, marital status, education level, occupation, and duration of illness, with most variables

showing no statistically significant differences ($p > 0.05$) (Table 1).

Within-Group Changes in Cognitive Function

In the intervention group, which received adjunctive rTMS plus standard antipsychotic treatment, the mean MoCA-Ina score increased from 13.79 ± 9.05 at pre-test to 19.89 ± 8.48 at post-test, with a mean improvement of 6.10 ± 12.40 points. This change was statistically significant ($p = 0.000$), indicating a meaningful improvement in cognitive function after Rtms therapy.

Table 1. Subject Characteristics and Demographics

Characteristics		Group		*p-value*
		Intervention	Control	
Age	Mean ± SD	35.74 ± 9.152	33.58 ± 7.967	0.443 (b)
Age Range	< 20	0 (0%)	0 (0%)	
	20 - 29	6 (42.9%)	8 (57.1%)	0.586 (a)
	30 - 39	8 (61.5%)	5 (38.5%)	
	≥ 40	5 (45.5%)	6 (54.5%)	
Gender	Man	8 (40%)	12 (60%)	0.194 (a)
	Woman	11 (61.1%)	7 (38.9%)	
Marital status	Marry	6 (46.5%)	7 (53.8%)	
	Not married	11 (52.4%)	10 (47.6%)	0.940 (a)
	Divorce	2 (50%)	2 (50%)	
Education	No school	0 (0%)	0 (0%)	
	Elementary School	5 (50%)	5 (50%)	
	Junior High School	1 (16.7%)	5 (83.3%)	0.210 (a)
	Senior High School	9 (52.9%)	8 (47.1%)	
	PT	4 (80%)	1 (20%)	
Work	Work	8 (42.1%)	11 (57.9%)	
	Not working	11 (57.9%)	8 (42.1%)	0.330 (a)
	Other	0 (0%)	0 (0%)	
Early age of diagnosis	Mean ± SD	23.68 ± 5.850	23.58 ± 7.050	0.960 (b)
Length of Illness	1 - 5 years	5 (41.7%)	7 (58.3%)	
	6 - 10 years old	3 (37.5%)	5 (62.5%)	0.630 (a)
	11 - 15 years old	5 (62.5%)	3 (37.5%)	
	> 15 years	6 (60%)	4 (40%)	
Types of Drugs	APG 1	1 (25%)	3 (75%)	0.67 0 (a)
	APG 2	18 (50%)	16 (50%)	
RI Drug Count	1 type	1 (25%)	3 (75%)	
	2 types	3 (50%)	3 (50%)	
	3 types	8 (53.3%)	7 (46.7%)	0.676 (a)
	4 types	6 (54.5%)	5 (45.5%)	
	5 types	1 (100%)	0 (0%)	
	6 types	0 (0%)	1 (100%)	
Income	No income	14 (60.9%)	9 (39.1%)	
	< 1.5 million	2 (20%)	8 (80%)	0.087 (a)
	> 1.5 million	3 (60%)	2 (40%)	
Family History	There is	3 (50%)	3 (50%)	0.670 (a)
	There isn't any	16 (50%)	16 (50%)	
Hospitalization History	1 to 4	14 (51.9%)	13 (48.1%)	
	5 to 9	1 (16.7%)	5 (83.3%)	0.105 (a)
	>10	4 (80%)	1 (20%)	
Length of Hospitalization	< 10 days	3 (100%)	0 (0%)	
	10 – 15 days	15 (62.5%)	9 (37.5%)	0.003 (a)
	>15 days	1 (9.1%)	10 (90.9%)	
MOCAINA (Pretest)	*Mean* ± SD	14.32 ± 9.052	24.68 ± 5.854	0.443 (b)

Table 2. Differences in Cognitive Symptom Score Decrease (MoCA-Ina) between Treatment and Control Groups

Group	Pretest (Mean ± SD)	Posttest (Mean ± SD)	Score Decrease (Mean ± SD)	p value	95% CI: Lower	95% CI: Upper
Intervention (rTMS)	13.79 ± 9.05	19.89 ± 8.48	6.1 ± 12.40	0.000 (a)	−8.614	−3.596
Control	21.94 ± 5.85	24.79 ± 4.47	2.85 ± 7.36	0.000 (a)	−3.809	−1.874

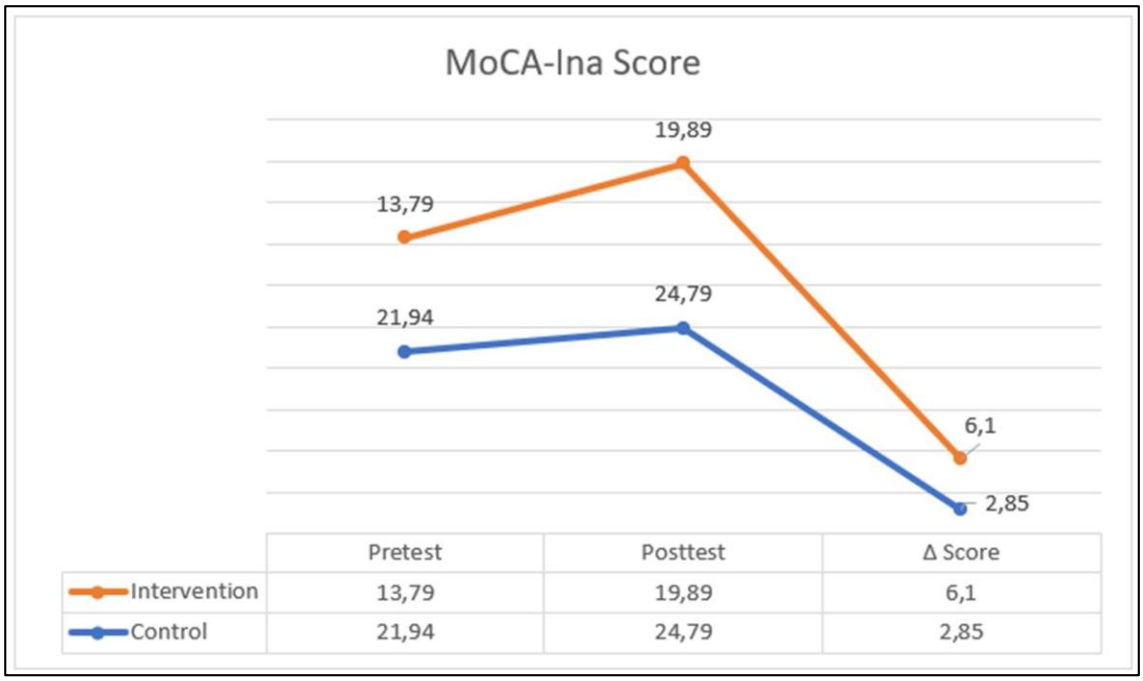


Figure 1. Graph of Cognitive Symptom Score Decrease in Treatment Group and Control Group

Table 3. Pre-Test Results for the Treatment and Control Groups

Measurement	Control (Mean ± SD)	Intervention (Mean ± SD)	p value	95% CI: Lower	95% CI: Upper
Cognitive Symptoms Subscore	21.94 ± 5.85	13.79 ± 9.05	0.007 (a)	−13.76096	−2.55483

Table 4. Post-Test Results for the Treatment and Control Groups

Measurement	Control (Mean ± SD)	Intervention (Mean ± SD)	p value	95% CI: Lower	95% CI: Upper
Cognitive Symptoms Subscore	24.79 ± 4.47	19.89 ± 8.48	0.005 (a)	−9.35610	−0.43338

In the control group, which received standard antipsychotic treatment alone, the mean MoCA-Ina score also improved significantly from 21.94 ± 5.85 at pre-test to 24.79 ± 4.47 at post-test, with a mean increase of 2.85 ± 7.36 points (p = 0.000). Although both groups improved, the magnitude of improvement was greater in the intervention group (Table 2 and Figure 1).

Between-Group Comparison (Pre-Test and Post-Test)

At baseline, the control group had significantly higher cognitive scores than the intervention group, with mean pre-test MoCA-

Ina scores of 21.94 ± 5.85 and 13.79 ± 9.05, respectively. The difference between groups at pre-test was statistically significant (p = 0.007), indicating an imbalance in baseline cognitive function. After intervention, post-test scores remained significantly higher in the control group (24.79 ± 4.47) compared with the intervention group (19.89 ± 8.48), with a statistically significant difference (p = 0.005). Despite this, the intervention group demonstrated a larger mean increase in MoCA-Ina score, suggesting a stronger treatment effect of adjunctive rTMS on cognitive improvement (Table 3 and Table 4).

DISCUSSION

This study demonstrated that adjunctive repetitive transcranial magnetic stimulation (rTMS) applied to the left temporo-parietal junction (TPJ) was associated with a significant improvement in cognitive function among patients with schizophrenia, as measured by MoCA-Ina. Although both the intervention and control groups showed statistically significant pre–post improvement, the magnitude of cognitive gain was greater in the rTMS group (+6.10 points) than in the control group (+2.85 points). These findings suggest that rTMS may provide additional benefit beyond standard antipsychotic therapy in addressing cognitive deficits, which are often persistent and difficult to treat in schizophrenia.

The observed cognitive improvement may be explained by the neurophysiological effects of rTMS on cortical excitability and neural plasticity. In schizophrenia, cognitive impairment has been linked to dysregulation of fronto-temporo-parietal networks and imbalance in glutamatergic, dopaminergic, and GABAergic neurotransmission. Low-frequency rTMS (1 Hz) over the left TPJ is thought to reduce abnormal cortical hyperactivity and improve synchronization between cortical regions involved in attention, memory, and executive processing. At the synaptic level, rTMS may induce long-term potentiation (LTP)-like and long-term depression (LTD)-like effects, facilitating adaptive plasticity and improving signal processing efficiency. These mechanisms are consistent with the hypothesis that rTMS can restore excitation–inhibition balance in cortical circuits and support cognitive recovery in schizophrenia.

The present findings are in line with prior literature indicating that rTMS can improve selected cognitive domains in schizophrenia, particularly working memory and attention. Several reviews and meta-analyses cited in the source manuscript have reported that neuromodulation techniques, especially when targeting cortical regions relevant to cognitive control, may produce clinically meaningful improvements in cognitive performance. The current study adds to this evidence by focusing on the left TPJ as the stimulation target, which is more commonly associated with auditory processing and hallucinations but may also influence broader cognitive network functioning.

Despite the positive findings, several limitations should be considered when interpreting the results. First, there was a significant baseline difference in pre-test MoCA-Ina scores between groups (p = 0.007), with the control group showing better initial cognitive function. This imbalance may have influenced post-test comparisons and limits the ability to draw definitive causal conclusions. Second, the sample size was relatively small, which reduces statistical power and limits generalizability. Third, the follow-up period was short and only assessed immediate post-treatment effects, so the durability of cognitive improvement remains unclear. Finally, the study used only one global cognitive screening instrument (MoCA-Ina), which may not capture detailed changes across specific cognitive domains such as processing speed, verbal learning, or social cognition.

Cognitive deficits are among the strongest predictors of functional disability in schizophrenia and are often insufficiently

addressed by pharmacotherapy alone. The present findings suggest that left TPJ rTMS may be considered as a promising adjunctive intervention to improve cognitive outcomes in clinical practice, particularly in inpatient settings where structured treatment protocols can be implemented. Given its non-invasive nature and generally favorable safety profile, rTMS may represent a practical option for patients with prominent cognitive symptoms. However, larger randomized controlled trials are still needed before routine incorporation into standard treatment guidelines.

CONCLUSION

Adjunctive low-frequency rTMS targeting the left TPJ significantly improved cognitive function in patients with schizophrenia, as demonstrated by increased MoCA-Ina scores after treatment. Although both the intervention and control groups showed significant improvement, the intervention group exhibited a greater mean increase in cognitive scores, supporting the potential therapeutic value of rTMS as an add-on treatment for cognitive deficits. Nevertheless, baseline group differences and methodological limitations warrant cautious interpretation. Further randomized controlled studies with larger samples, longer follow-up periods, and more comprehensive cognitive assessments are needed to confirm the long-term efficacy and optimize the clinical use of rTMS in schizophrenia.

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