

ARTICLE INFORMATION

Received: December, 29, 2024

Revised: April, 20, 2025

Available online: April, 21, 2025

at : <https://e-jurnal.iphorr.com/index.php/minh>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

Albertus Theo Lapien*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi,
Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi

Corresponding autor. *E-mail: abe.lapien@gmail.com

Abstract

Background: Visuospatial disorders refer to deficits in attention, exploration, and interaction with the contralateral side of space that cannot be attributed to primary sensory or motor dysfunction. These disorders are usually caused by lesions in the right hemisphere due to cerebral circulation disorders, such as stroke. Transcranial Magnetic Stimulation (TMS) has emerged as a noninvasive treatment option for addressing visuospatial deficits.

Purpose: To evaluate the effectiveness of TMS as a therapy for visuospatial disorders in post-stroke patients.

Method: This study was conducted using randomized controlled trials (RCTs) comparing TMS with sham treatment for post-stroke visuospatial impairment identified through searches in Google Scholar, PubMed/Medline, Clinical Key, Wiley Online, Science Direct, ResearchGate, and Neurona. A meta-analysis was conducted to assess the efficacy of TMS therapy for improving visuospatial deficits in post-stroke patients.

Results: A total of 189 studies on TMS were identified with four homogeneous articles finally included in the meta-analysis. The analysis combined visuospatial assessments using the Motor-Free Visual Perception Test (MVPT), Star Cancellation Test (SCT), Albert Test (AT), and Line Bisection Test (LBT). The meta-analysis revealed significant findings for the MVPT, with a weighted mean difference (WMD) of 2.43 (95% CI: 1.86 to 3.01, $p < 0.001$). For LBT, WMD was 2.69 (95% CI: 2.04 to 3.34, $p = 0.020$).

Conclusion: The improvements in visuospatial function observed in participants undergoing TMS suggest that TMS may serve as a potential therapeutic option for post-stroke patients with visuospatial impairment.

Keywords: Post Stroke; Transcranial Magnetic Stimulation; Visuospatial Disorders.

INTRODUCTION

Stroke is characterized by the rapid onset of clinical symptoms due to localized or widespread brain dysfunction. These symptoms persist for more than 24 hours or lead to death with no apparent cause other than vascular origin. Stroke remains the second leading cause of disability and death worldwide. Post-stroke conditions refer to the period following the acute phase of stroke that includes a variety of physical, cognitive, emotional, and social impacts that significantly affect the patient's quality of life (Coupland, Thapar, Qureshi, Jenkins, & Davies,

2017; Morone & Pichiorri, 2023; Sun, Tan, & Yu, 2014).

Visuospatial impairment is a cognitive dysfunction in which spatial awareness on the contralateral side is impaired due to unilateral brain lesions. This condition often accompanies stroke and can hinder the recovery process, affecting daily activities. Despite its high prevalence, evidence-based guidelines for managing post-stroke cognitive impairment are limited, as effective pharmacological and non-pharmacological therapies are scarce.

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment:
A meta-analysis

Recent research has highlighted the potential of neuromodulation techniques to improve cognitive function by harnessing neuroplasticity. One such method is transcranial magnetic stimulation (TMS) (Gammeri, Iacono, Ricci, & Salatino, 2020; Han, He, Chen, Gao, Wang, & Wang 2023).

TMS is a non-invasive brain stimulation technique that uses magnetic fields to modulate brain activity. It works by inducing electrical currents in the central nervous system, thereby altering the metabolic and neurophysiological activity of the brain. TMS has been widely used in treating cognitive disorders associated with neurological, psychiatric, and psychological conditions, including stroke, Alzheimer's disease, Parkinson's disease, and schizophrenia.

Patients with visuospatial disorders who use TMS can help restore the balance of cortical excitability between the intact and affected hemispheres. These disorders are associated with dysfunction of the dorsal visual stream, especially in Brodmann's areas 40 and 44. Consequently, the application of magnetic stimulation to the left and right parietal regions may provide therapeutic benefits (Cha & Kim, 2016; Han et al., 2023; Moses, Gray, Mischel, & Greenwald, 2023; Yang, Liu, Song, Zhang, Li, Cui, & Liu, 2015).

RESEARCH METHOD

This study used a systematic review and meta-analysis approach, relying on online searches to collect relevant articles. Data sources included Google Scholar, PubMed/Medline, Clinical Key, Wiley Library Online, Science Direct, ResearchGate, and Neurona. Analysis was performed using SPSS version 28 software. The study focused on randomized controlled trials (RCTs) that tested the effectiveness of transcranial magnetic stimulation (TMS) as a therapy for post-stroke visuospatial disorders compared with sham treatment.

Inclusion criteria required articles to be published in full text in English or Indonesian, used an RCT design, and included individuals with clinically diagnosed post-stroke visuospatial disorders or those with subjective or objective complaints of

visuospatial deficits without a formal diagnosis. Diagnostic assessments for visuospatial disorders included the Motor-Free Visual Perception Test (MVPT) and the Line Bisection Test (LBT). The TMS coil was placed over the left parietal area, corresponding to the P3 position in the 10-20 EEG system, delivering 1 Hz stimulation for 5 minutes with a 1-minute rest interval.

Transcranial magnetic stimulation (TMS) is operationally defined as a device that generates extracranial electromagnetic waves capable of traversing the skull and inducing neuronal depolarization or excitation in the cortex. Post-stroke visuospatial impairment is defined as the inability to perceive or respond to stimuli presented on the side opposite to the brain lesion.

Data analysis followed the PRISMA flowchart for article selection, with risk of bias assessed using the RoB-2 tool. Meta-analysis, conducted using SPSS version 28, evaluated effect sizes, heterogeneity, and p-values. The results were visualized through forest plots and funnel plots to present the findings.

RESEARCH RESULTS

The article search process was conducted in several databases, including Google Scholar, PubMed, Clinical Key, Wiley Online, Science Direct, ResearchGate, and Neurona. A total of 189 articles on TMS for post-stroke visuospatial disorders were identified. After excluding 12 duplicate articles, 177 articles remained. Further eligibility screening narrowed it down to 22 articles that were assessed based on the availability of their full text. Finally, 4 articles were selected for inclusion in the meta-analysis.

These four studies provided a total of 112 samples, evenly divided between the TMS intervention group (56 samples) and the sham group (56 samples). Both groups continued to receive rehabilitation therapy in addition to their respective treatments. After identifying articles that met the inclusion criteria, a meta-analysis was conducted using SPSS version 28 software. The article selection process is illustrated in the PRISMA diagram.

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment:
A meta-analysis

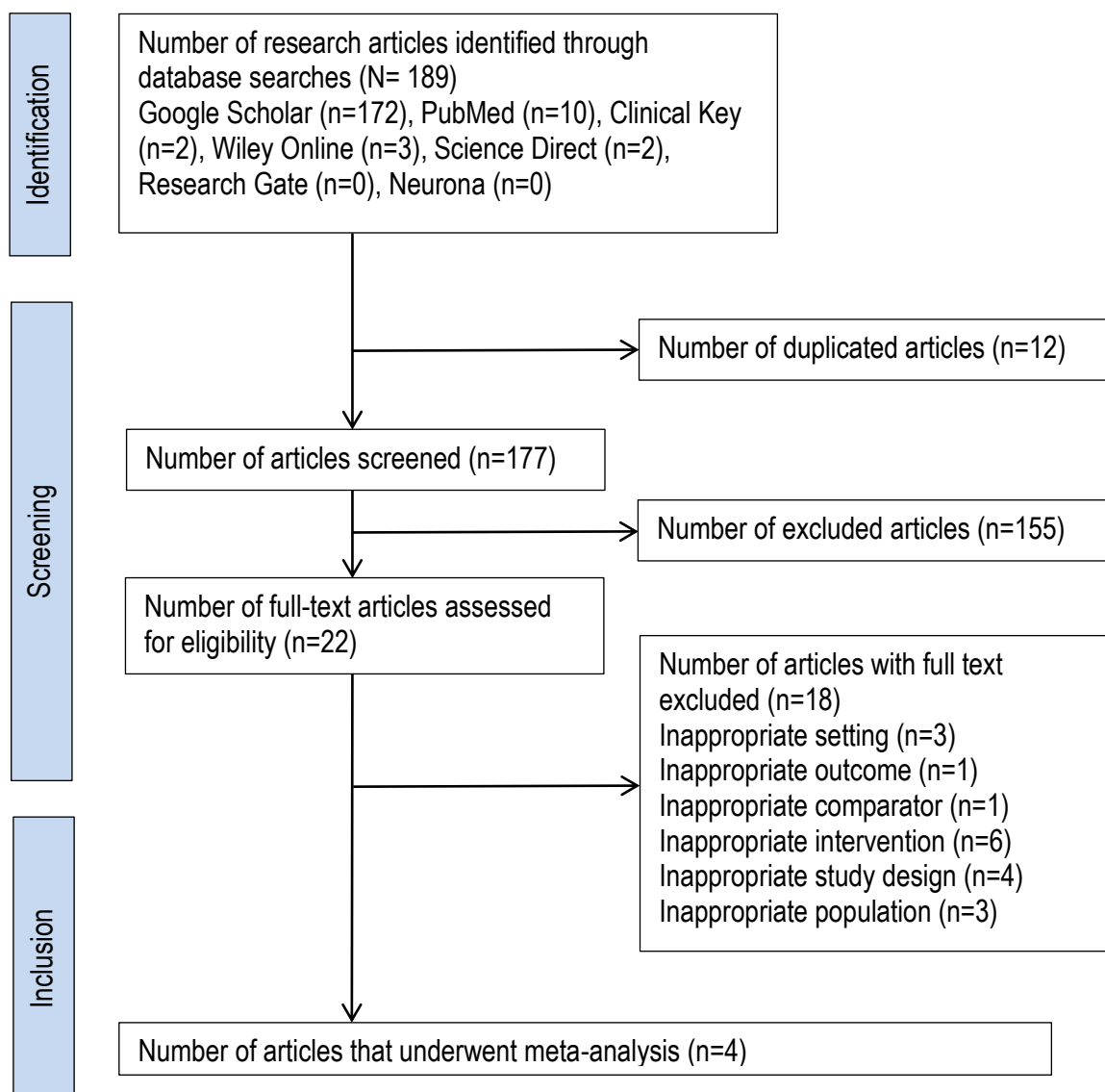


Figure 1. PRISMA Diagram

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	rTMS	Sham	Relative (95% CI)	Absolute (95% CI)		
Line bisection test in TMS group vs. Sham												
3	randomised trials	not serious	not serious	not serious	not serious	strong association	34	34	-	0 (2.04 higher to 3.34 higher)	⊕⊕⊕⊕ High	
Star cancellation test in TMS group vs. Sham												
2	randomised trials	not serious	not serious	not serious	not serious	strong association	19	19	-	0 (1.88 higher to 3.57 higher)	⊕⊕⊕⊕ High	
Albert test in TMS group vs. Sham												
2	randomised trials	not serious	not serious	not serious	not serious	strong association	25	25	-	0 (2.44 higher to 4.1 higher)	⊕⊕⊕⊕ High	
Motor-free visual perception test in TMS group vs. Sham												
3	randomised trials	not serious	not serious	not serious	not serious	strong association	41	41	-	0 (1.86 higher to 3.01 higher)	⊕⊕⊕⊕ High	

CI: confidence interval

Figure 2. RoB-2

Figure 2. presents the RoB-2 (Risk of Bias 2) tool used to assess the risk of bias in randomized controlled trials. The tool provides a visual representation of the risk of bias across multiple domains, including the randomization process, deviations from the intended intervention, missing outcome data, outcome measures, and selection of reported outcomes. This diagram helps evaluate the methodological quality of included studies and identify potential sources of bias that may impact the reliability of the results.

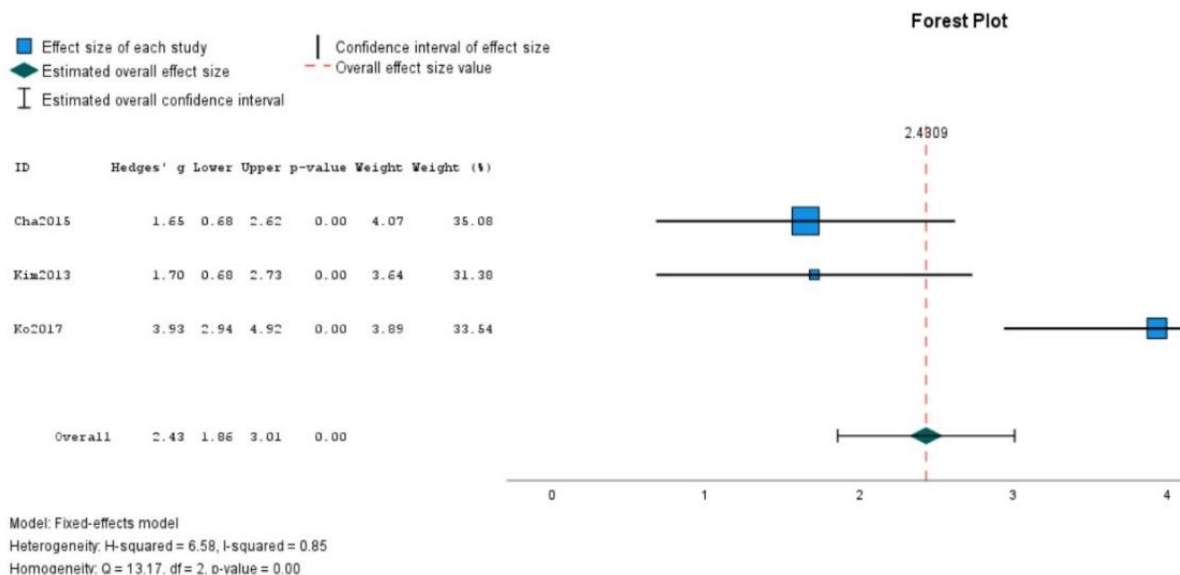


Figure 3. GradePro

Albertus Theo Lapijan*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapijan@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

Figure 3. illustrates the GradePro tool, which is used to assess the quality of evidence and strength of recommendations in systematic reviews and meta-analyses. This tool helps evaluate the certainty of evidence across outcomes by considering factors such as study design, consistency of results, risk of bias, imprecision, and indirectness. GradePro provides a clear visual summary of the quality of evidence, which aids in the interpretation and application of research findings.

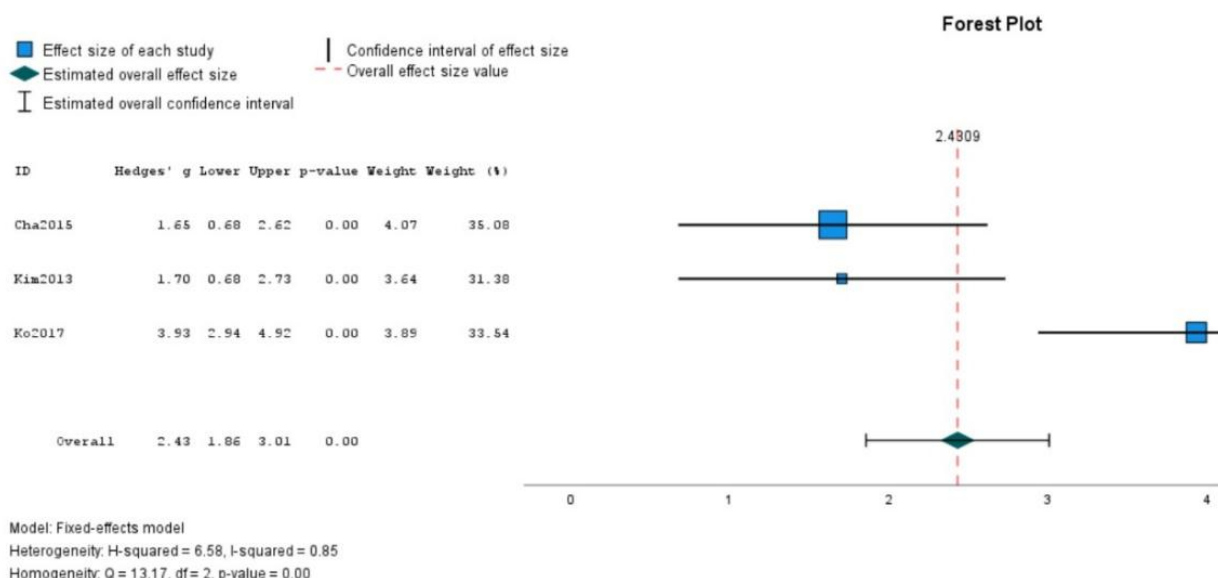


Figure 4. Forest Plot Comparing Motor-free Visual Perception Test Scores Between TMS and Sham Groups

Figure 4 presents a forest plot illustrating the results of the Motor-Free Visual Perception Test (MVPT) assessment, comparing the TMS group with the sham group. The plot visually depicts the effect sizes and confidence intervals for each study included in the analysis, highlighting the differences in MVPT performance between the two groups.

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

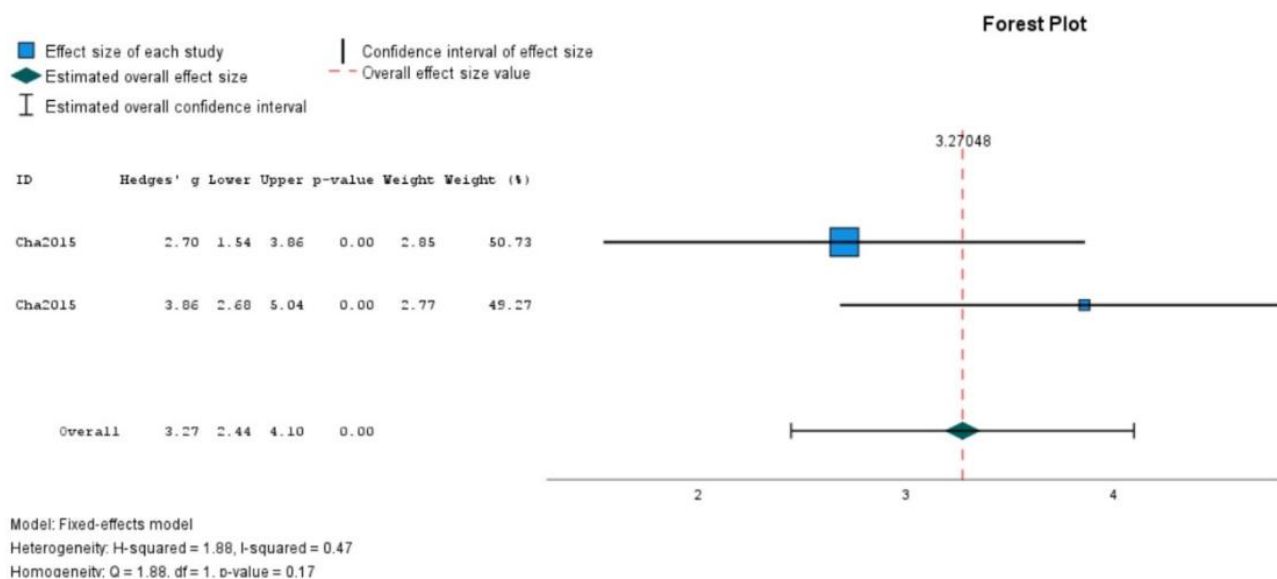


Figure 5. Forest Plot Comparing Line Bisection Test Scores Between TMS and Sham Groups

Figure 5 shows a forest plot of the Line Bisection Test (LBT) assessment, comparing the TMS group to the sham group. This figure visually depicts the effect sizes and confidence intervals for each study, illustrating the differences in LBT performance between the two groups.

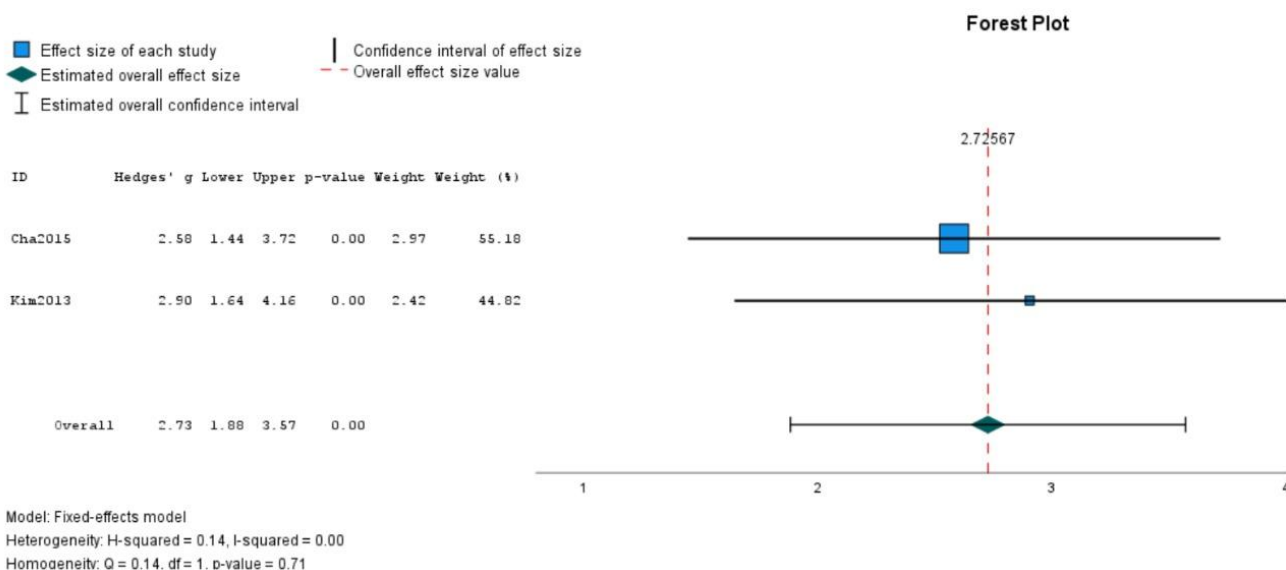


Figure 6. Forest Plot Comparing Albert Test Scores Between TMS and Sham Groups

Figure 6. presents a forest plot of the Albert Test assessment, comparing the TMS group with the sham group. The figure displays the effect sizes and confidence intervals for each study, highlighting the differences in Albert Test performance between the two groups.

Albertus Theo Lapien*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapien@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Table The Main Characteristics of Included Studies

(Author, Year) (Country)	Purpose	Methods	Results
(Cha & Kim, 2015) (Amsterdam)	This study aimed to evaluate the effects of repetitive transcranial magnetic stimulation on the functional recovery of stroke patients with unilateral neglect.	Twenty patients with stroke were randomly assigned to two groups: a repetitive transcranial magnetic stimulation group (experimental) and a control group. The stroke patients in the experimental group underwent repetitive transcranial magnetic stimulation therapy and comprehensive rehabilitation therapy. The stroke patients in the control group underwent sham magnetic stimulation therapy and comprehensive rehabilitation therapy. The patients in both groups received therapy 5 days per week for 4 weeks. The Motor Free Visual Perception Test (MVPT), Line Bisection Test (LBT), Albert Test (AT), and Star Cancellation Test (SCT) were assessed before and after the 4-week therapy period.	The experimental group showed a significant increase in the MVPT, LBT, AT, and SCT values compared with the preintervention values ($p < 0.05$). Furthermore, the control group showed a significant increase in the MVPT, LBT, and AT results compared with the preintervention results ($p < 0.05$). A significant difference in the post-training gains for the MVPT (8.9 ± 2.5 vs. 4.8 ± 3.0), LBT (-19.3 ± 7.5 vs. -6.5 ± 9.5), AT (13.1 ± 8.0 vs. 4.0 ± 1.9), and SCT (-13.6 ± 6.9 vs. -4.5 ± 6.9) were observed between the experimental group and the control group ($p < 0.05$). In addition, the effect size for gains in the experimental and control groups was very large in MVPT and AT (effect size = 3.25 and 2.90), respectively, and the effect size for gains in the experimental and control groups was small in LBT and SCT (effect size = 0.22 and 0.23, respectively).

Albertus Theo Lapien*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapien@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

(Author, Year) (Country)	Purpose	Methods	Results
(Cha & Kim, 2016) (Amerika Utara)	The objective of this study is to investigate the effect of repetitive transcranial magnetic stimulation (rTMS) on the functional recovery of stroke patients with unilateral neglect	Randomized controlled experimental study. Outpatient rehabilitation hospital. Thirty patients with stroke were randomly assigned to two groups: an rTMS group (experimental) and a control group. Stroke patients in the experimental group underwent comprehensive rehabilitation therapy and rTMS. Stroke patients in the control group underwent sham therapy and comprehensive rehabilitation therapy. Participants in both groups received therapy 5 days per week for 4 weeks. Main measures: Line bisection, Albert, Box and block and Grip strength tests were assessed before and after the four-week therapy period.	A significant difference in the post-training gains in Line bisection (16.53 SD 9.78 vs. 3.60 SD 5.02), Albert (14.13 SD 4.92 vs. 3.26 SD 2.01), Box and block (15.06 SD 9.68 vs. 6.93 SD 7.52), and Grip strength tests (3.60 SD 2.66 vs 0.80 SD 1.26) was observed between the experimental group and the control group ($P < 0.05$). In addition, the effect size for gains in the experimental and control groups was very strong in AT, BBT (effect size=2.15, 0.77 respectively).
(Brighina et al, 2003) (Amsterdam)	The aim of the study was to investigate whether low-frequency repetitive transcranial magnetic stimulation (rTMS) over the unaffected hemisphere can ameliorate visuospatial neglect.	We treated three right brain damaged patients with left neglect. 900 pulses (1 Hz frequency) were given over left posterior parietal cortex every other day for 2 weeks. Patients performed a computerized task requiring length judgement of prebisected lines, tachistoscopically presented for 150 ms. With respect to rTMS the task was given 15 days before, at the beginning, at the end and 15 days after. At these times patients performed also line bisection and clock drawing tasks.	rTMS induced a significant improvement of visuo-spatial performance that remained quite unchanged 15 days after. Patients performance at Time 3 and 4 improved also as concerns line bisection and clock drawing tasks.

Albertus Theo Lapien*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapien@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment: A meta-analysis

(Author, Year) (Country)	Purpose	Methods	Results
(Kashiwagi et al., 2018) (New Jersey)	To assess the impact of NIBS on USN after stroke	An extensive search was conducted up to July 2016. Studies were selected if they were controlled and noncontrolled trials examining transcranial direct current stimulation (tDCS), repetitive transcranial magnetic stimulation (rTMS), and theta burst stimulation (TBS) in USN after stroke, with outcomes measured by standardized USN and functional tests.	Twelve RCTs (273 participants) and 4 non-RCTs (94 participants) proved eligible. We observed a benefit in overall USN measured by the line bisection test with NIBS in comparison to sham (SMD -2.35, 95% CI -3.72, -0.98; $p = 0.0001$); the rTMS yielded results that were consistent with the overall meta-analysis (SMD -2.82, 95% CI -3.66, -1.98; $p = 0.09$). The rTMS compared with sham also suggested a benefit in overall USN measured by Motor-Free Visual Perception Test at both 1 Hz (SMD 1.46, 95% CI 0.73, 2.20; $p < 0.0001$) and 10 Hz (SMD 1.19, 95% CI 0.48, 1.89; $p = 0.54$). There was also a benefit in overall USN measured by Albert's test and the line crossing test with 1 Hz rTMS compared to sham (SMD 2.04, 95% CI 1.14, 2.95; $p < 0.0001$).

Albertus Theo Lapien*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapien@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

DISCUSSION

This study is a secondary analysis based on comprehensive screening of various articles. Initially, 189 articles were identified from five databases in Indonesian and English. Through a screening process that evaluated the title, abstract, and full manuscript based on inclusion and exclusion criteria, 22 articles were selected. The articles were further refined based on the type of intervention, comparison, study design, population, and outcomes, resulting in 4 articles suitable for systematic review and meta-analysis.

Overall, TMS has been shown to improve cognitive impairment in post-stroke patients. This is in line with previous research findings showing superior outcomes in cognitive function among stroke patients treated with TMS compared to the control group (Zhu, Huang, Chen, Pan, & Zhou, 2014).

This is in line with other studies that state positive cognitive improvements after TMS therapy in post-stroke patients (Liu, Bao, Bai, & Yu, 2021). These effects are likely due to the increase in cerebral blood flow and cortical metabolism induced by TMS, as well as changes in neurotransmitter gene expression and receptor activity after stimulation (Liu et al., 2021; Zhu et al., 2024). Meta-analysis revealed significant results in the Motor-Free Visual Perception Test (MVPT) and Line Bisection Test (LBT). TMS increased MVPT scores by 2.43 times ($p < 0.001$) and LBT scores by 2.69 times ($p < 0.02$). However, high heterogeneity was observed (85% in MVPT and 73% in LBT), possibly due to differences in total duration and frequency of TMS sessions and the use of non-raw data in some studies.

The studies of Cha & Kim (2015) and Cha & Kim (2016) administered TMS for 4 weeks, while Goh, Kim, & Zard (2013) and Kim, Son, & Yoon (2017) used shorter sessions spread over 2 weeks. In contrast, meta-analyses for the Albert Test (AT) and Star Cancellation Test (SCT) did not show statistically significant results, with p -values of 0.17 (AT) and 0.71 (SCT). Although positive effects were observed in the TMS group (3.27-fold improvement in AT and 2.73-fold improvement in SCT), the small sample size likely contributed to the lack of statistical significance. The results for the MVPT and LBT support previous findings that TMS reduces

visuospatial impairments in stroke patients. Low-frequency TMS applied to the left hemisphere improves hemispatial abilities in patients with right hemisphere infarction. In addition, significant improvements in MVPT and LBT scores after TMS treatment, although AT and SCT results were not significant (Brighina, Bisiach, Oliveri, Piazza, La Bua, Daniele, & Fiero, 2003; Kashiwagi, El Dib, Gomaa, Gawish, Suzumura, da Silva, & Bazan, 2018; Mansur, Fregni, Boggio, Riberto, Gallucci-Neto, Santos, & Pascual-Leone, 2005).

Oliveri and Vallar (2009) reported that TMS applied to dorsal areas, such as the angular gyrus, was more effective for line bisection tasks, while ventral areas, such as the supramarginal gyrus, were better for cancellation tasks. This is consistent with the use of TMS in this meta-analysis, where stimulation was applied to P3 (dorsal network site) in the 10-20 EEG system, resulting in significant improvements in LBT performance (Oliveri & Vallar, 2009; Cha & Kim, 2015).

Visuospatial disorders are often associated with damage to the right cerebral cortex, specifically areas within the dorsal visual pathway, such as Brodmann areas 40 and 44. TMS induces depolarization of cortical neurons and increases cortical excitability after repeated stimulation (Martin, Naeser, Theoret, Mariatormos, Nicholas, Kurland, Fregni, Seekins, Doron, & Pascual-Leone, 2004; Cha, Kim, Kim, Choi, Kim, & Kim, 2022) observed increased activity in the right angular gyrus via functional MRI, a region involved in cognitive functions such as visuospatial attention, decision-making, and reorientation.

The effects of TMS on parietal and prefrontal regions highlighted improvements in visuospatial, cognitive, and motor functions (Chou, That, Chen, Sundman, & Huang, 2020). In line with the findings of this study, other studies have suggested a positive effect on visuospatial function (Brighina et al., 2003; Cha et al., 2022; Martin et al., 2004). This study focused on well-defined measurement parameters to assess visuospatial disorders and included only RCTs considered the gold standard in clinical research. The selection process ensured homogeneity among the included studies, resulting in a robust meta-analysis of four RCTs with similar

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment:
A meta-analysis

characteristics. However, this study also has limitations. First, there was high heterogeneity due to variations in TMS parameters and intervention duration. Second, only published studies were included, which may introduce publication bias. Finally, the sample size was relatively small, as the number of eligible studies was limited.

CONCLUSION

Transcranial magnetic stimulation (TMS) has shown significant potential in improving cognitive function and reducing visuospatial impairment in post-stroke patients. While meta-analyses for MVPT and LBT showed statistically significant results, findings for AT and SCT were not statistically significant, likely due to high heterogeneity and small sample sizes.

Despite the limitations of these studies, TMS remains a promising intervention for post-stroke rehabilitation, especially when applied to specific brain regions associated with visuospatial and cognitive functions. Further studies with larger and more homogeneous sample sizes are recommended to validate these findings and optimize TMS protocols.

REFERENCES

- Brighina, F., Bisiach, E., Oliveri, M., Piazza, A., La Bua, V., Daniele, O., & Fierro, B. (2003). 1 Hz repetitive transcranial magnetic stimulation of the unaffected hemisphere ameliorates contralesional visuospatial neglect in humans. *Neuroscience letters*, 336(2), 131-133.
- Cha, B., Kim, J., Kim, J. M., Choi, J. W., Choi, J., Kim, K., & Kim, M. (2022). Therapeutic effect of repetitive transcranial magnetic stimulation for post-stroke vascular cognitive impairment: a prospective pilot study. *Frontiers in Neurology*, 13, 813597.
- Cha, H. G., & Kim, M. K. (2015). The effects of repetitive transcranial magnetic stimulation on unilateral neglect of acute stroke patients: a randomised controlled trial. *Hong Kong Physiotherapy Journal*, 33(2), 53-58.
- Cha, H. G., & Kim, M. K. (2016). Effects of repetitive transcranial magnetic stimulation on arm function and decreasing unilateral spatial neglect in subacute stroke: a randomized controlled trial. *Clinical Rehabilitation*, 30(7), 649-656.
- Chou, Y. H., That, V. T., Chen, A. Y. C., Sundman, M., & Huang, Y. Z. (2020). TMS-induced seizure cases stratified by population, stimulation protocol, and stimulation site: a systematic literature search. *Clinical neurophysiology: official journal of the International Federation of Clinical Neurophysiology*, 131(5), 1019.
- Coupland, A. P., Thapar, A., Qureshi, M. I., Jenkins, H., & Davies, A. H. (2017). The definition of stroke. *Journal of the Royal Society of Medicine*, 110(1), 9-12.
- Gammeri, R., Iacono, C., Ricci, R., & Salatino, A. (2020). Unilateral spatial neglect after stroke: current insights. *Neuropsychiatric disease and treatment*, 131-152.
- Goh, K. K. K., Kim, S., & Zard, S. Z. (2013). A Synthesis of (1 E, 3 E)-TMS Dienes from Keto-Xanthates via Chugaev-Type Elimination. *The Journal of Organic Chemistry*, 78(23), 12274-12279.
- Han, M., He, J., Chen, N., Gao, Y., Wang, Z., & Wang, K. (2023). Intermittent theta burst stimulation vs. high-frequency repetitive transcranial magnetic stimulation for post-stroke cognitive impairment: Protocol of a pilot randomized controlled double-blind trial. *Frontiers in Neuroscience*, 17, 1121043.
- Kashiwagi, F. T., El Dib, R., Gomaa, H., Gawish, N., Suzumura, E. A., da Silva, T. R., & Bazan, R. (2018). Noninvasive brain stimulations for unilateral spatial neglect after stroke: A systematic review and meta-analysis of randomized and nonrandomized controlled trials. *Neural plasticity*, 2018(1), 1638763.

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>

Effectiveness of non-invasive transcranial magnetic stimulation therapy as a therapy for post-stroke visuospatial impairment:
A meta-analysis

- Kim, J., Son, J., & Yoon, K. (2017). An improved TMS architecture for ships and offshore plants. *International Information Institute (Tokyo). Information*, 20(2A), 867-876.
- Liu, M., Bao, G., Bai, L., & Yu, E. (2021). The role of repetitive transcranial magnetic stimulation in the treatment of cognitive impairment in stroke patients: a systematic review and meta-analysis. *Science Progress*, 104(2), 00368504211004266.
- Mansur, C. G., Fregni, F., Boggio, P. S., Riberto, M., Gallucci-Neto, J., Santos, C. M., & Pascual-Leone, A. (2005). A sham stimulation-controlled trial of rTMS of the unaffected hemisphere in stroke patients. *Neurology*, 64(10), 1802-1804.
- Martin, P.I., Naeser, M.A., Theoret, H., Mariatormos, J., Nicholas, M., Kurland, J., Fregni, F., Seekins, H., Doron, K., Pascual-Leone, A. (2004). Complementary and alternative approaches to treating communication disorders. *Seminars in Speech and Language*. 22(02), 119-120.
- Morone, G., & Pichiorri, F. (2023). Editorial on the Special Issue "Advanced Hydrogels for the Repair of Cartilage Defects". *JOURNAL OF CLINICAL MEDICINE*, 12(2).
- Moses, T. E., Gray, E., Mischel, N., & Greenwald, M. K. (2023). Effects of neuromodulation on cognitive and emotional responses to psychosocial stressors in healthy humans. *Neurobiology of stress*, 22, 100515.
- Oliveri, M., & Vallar, G. (2009). Parietal versus temporal lobe components in spatial cognition: Setting the mid-point of a horizontal line. *Journal of Neuropsychology*, 3(2), 201-211.
- Sun, J. H., Tan, L., & Yu, J. T. (2014). Post-stroke cognitive impairment: epidemiology, mechanisms and management. *Annals of translational medicine*, 2(8), 80.
- Yang, W., Liu, T. T., Song, X. B., Zhang, Y., Li, Z. H., Cui, Z. H., & Liu, J. (2015). Comparison of different stimulation parameters of repetitive transcranial magnetic stimulation for unilateral spatial neglect in stroke patients. *Journal of the neurological sciences*, 359(1-2), 219-225.
- Zhu, M., Huang, S., Chen, W., Pan, G., & Zhou, Y. (2024). The effect of transcranial magnetic stimulation on cognitive function in post-stroke patients: a systematic review and meta-analysis. *BMC neurology*, 24(1), 234.

Albertus Theo Lapian*, Finny Warouw, Ansye Grace Nancy Momole, Junita Maja Pertiwi, Gilbert Tangkudung

Fakultas Kedokteran - Universitas Sam Ratulangi
Corresponding autor. *E-mail: abe.lapian@gmail.com

DOI: <https://doi.org/10.33024/minh.v8i2.552>