

Neuroplasticity Mechanisms Underlying Constraint-Induced Movement Therapy in Stroke Rehabilitation: A Scoping Review

Lugelle Fernandes¹, Dr Kamalakannan², Dr Pranjal Vaidya³

Institute of Physiotherapy, Srinivas University, Mangalore, India

Corresponding Author: Lugelle Fernandes

DOI: <https://doi.org/10.52403/gijash.20260102>

ABSTRACT

This review explores the association between constraint-induced movement therapy (CIMT) and neuroplasticity in post-stroke recovery. Neuroplasticity refers to the brain's capacity to reorganize itself by developing new neural pathways, which supports the restoration of lost functions after stroke. CIMT focuses on the enforced use of the impaired limb, thereby strengthening motor circuits and improving sensorimotor integration. Its ability to stimulate neuroplastic mechanisms positions CIMT as a valuable strategy for enhancing stroke rehabilitation outcomes, ultimately improving patient independence and quality of life.

Keywords: Neuroplasticity, constraint-induced movement therapy (CIMT), stroke, stroke rehabilitation

INTRODUCTION

The therapy involves restricting the unaffected limb while engaging the affected one in structured, task-oriented exercises. This strategy reduces the phenomenon of "learned non-use," frequently observed among stroke survivors, by encouraging repeated practice and fostering neuroplastic changes within the central nervous system. CIMT is considered a multifaceted intervention that integrates various elements previously applied in neurorehabilitation.

Over the past two decades, CIMT has been refined and adapted, with its core approach involving repetitive, task-specific training of the weaker limb for several hours daily, over a period of 10 to 15 consecutive weekdays. Patients are encouraged to rely on their impaired limb during waking hours, often with the support of restraint devices on the stronger arm.

During intervention sessions, patients practice under professional supervision. The therapeutic tasks are tailored to the individual's most affected joint movements to maximize functional improvements. CIMT has been successfully applied not only to restore motor function in the upper limbs but also in cases of aphasia, unilateral neglect, and other post-stroke impairments. Research demonstrates that CIMT can drive significant neuroplastic changes within the central nervous system. However, the extent of recovery depends on treatment conditions such as therapy duration, intensity, and patient suitability. Stroke, characterized by the abrupt disruption of blood supply to the brain, often leads to neurological deficits. CIMT leverages the brain's reorganization potential by compelling use of the affected limb, thereby enhancing motor recovery through repeated practice and functional brain reorganization.

Aim: To identify neuroplasticity processes that are influenced by CIMT to assess clinical implications after stroke rehabilitation.

Objective: To describe how CIMT facilitates neuroplastic adaptations within the brain.

REVIEW OF LITERATURE

1. A 2022 investigation into CIMT for stroke patients reported that, although earlier studies supported its role in improving lower-limb function, the therapy did not produce significant gains in balance or gait velocity in this cohort.
2. A systematic review of randomized controlled trials published in 2005 demonstrated that CIMT can improve upper-limb function following stroke and may represent a cost-effective alternative to conventional rehabilitation or no treatment.
3. A longitudinal study assessing CIMT over a 12-month period found that participants receiving the therapy experienced significantly greater recovery in arm motor function compared to controls.
4. Research examining CIMT's impact on balance and mobility among stroke survivors aged 18 years and older (first or recurrent stroke) revealed that the intervention produced meaningful improvements in postural control and functional mobility.
5. A 2012 review discussing the future of CIMT concluded, based on PEDro evidence, that a standardized best-practice protocol for stroke rehabilitation had been established.
6. A systematic review and meta-analysis published in 2011 found that individuals more than six months post-stroke continued to demonstrate meaningful recovery in upper-limb function when treated with CIMT.
7. A 2015 comparative study assessed CIMT against the Bobath approach, showing that CIMT yielded superior improvements in hand dexterity and motor function among post-stroke patients.
8. Another review highlighted that CIMT enhances the real-world use of the paretic limb, reduces hospital readmissions, and contributes to improved quality of life.
9. In a detailed protocol review, CIMT was confirmed to be effective in increasing functional use of the more affected upper limb following stroke.
10. A narrative review of 51 articles emphasized neuroplasticity's transformative role in stroke rehabilitation, while noting that treatment outcomes vary depending on therapy timing, intensity, and individual patient characteristics.
11. A 2013 review on post-stroke motor recovery underscored that CIMT improves motor functions, particularly when rehabilitation begins early in the recovery process.
12. A 2022 article discussing CIMT's mechanisms and clinical applications reported that the therapy is especially effective in addressing post-stroke upper-limb dysfunction by encouraging use of the impaired arm.
13. Another review published in 2014 indicated that CIMT continues to meet diverse rehabilitation needs and can be combined with other interventions to maximize recovery.
14. A 2006 publication found CIMT particularly beneficial for patients with chronic hemiparesis, associating the therapy with significant neuroplastic changes.
15. A 2020 review of 379 studies revealed that CIMT is effective in improving hand motor function and activities of daily living among acute and subacute stroke patients, while also promoting cortical reorganization.
16. A 2018 study further confirmed that CIMT improves motor recovery of the paretic upper limb in both subacute and chronic phases of stroke.
17. A 2021 comprehensive review of 43 studies concluded that interventions targeting neuroplasticity—including CIMT, robotic therapy, virtual reality, and brain stimulation—can effectively

reorganize cortical structures to improve mobility.

18. A review on adaptive neuroplasticity highlighted its central role in recovery following brain injury and supported the development of advanced rehabilitation strategies.
19. Another review on neural plasticity and post-stroke motor recovery emphasized that CIMT, when applied with sufficient intensity and duration, significantly improves motor function in stroke survivors.
20. A study exploring “Upper Limb Immobilization as a Model of Neural Plasticity” concluded that CIMT remains a recommended intervention for patients with residual function, as it effectively improves motor performance of the impaired upper limb.

METHODS

A systematic search of electronic databases—including PubMed, Google Scholar, and ResearchGate—was undertaken to identify studies that examined the role of neuroplasticity in stroke rehabilitation.

Inclusion criteria: Original research articles, systematic reviews, narrative reviews, and meta-analyses addressing the impact of neuroplasticity on stroke rehabilitation. Studies focusing on CIMT as an intervention for upper-limb recovery.

Exclusion criteria: Articles with incomplete data, Editorials or commentaries, non-English publications.

Data Synthesis: A narrative approach was used to summarize the findings of eligible studies that met the inclusion and exclusion criteria. The synthesis focused on identifying mechanisms of neuroplasticity enhanced through CIMT.

Neuroplasticity Enhancement Methods Identified with CIMT

Overcoming learned non-use’s encourages the consistent use of the affected limb,

helping patients overcome the cycle of disuse commonly seen after stroke.

Forced use of the impaired limb: By restraining the unaffected side, patients are compelled to use the weaker limb. This repeated engagement allows the brain to reassign motor functions, gradually reducing deficits and supporting cortical reorganization.

Intensive practice and repetition: CIMT requires high-intensity training, often involving up to six hours of repetitive motor activities daily over several weeks. Such structured practice strengthens motor pathways, facilitates synaptic plasticity, and improves motor performance.

Task-specific training: Activities during CIMT are goal-oriented, enhancing functional outcomes while driving neuroplastic adaptations relevant to everyday movements.

Behavioural and motivational strategies The therapy incorporates techniques such as shaping (progressive task difficulty with positive reinforcement) to sustain engagement. Motivation is considered a key driver of neuroplastic change. Furthermore, CIMT fosters cross-hemispheric interactions, enabling functional reorganization across both sides of the brain.

METHODOLOGY

This scoping review was conducted in accordance with the PRISMA- ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines.

Search Strategy

A comprehensive literature search was conducted across the following databases: MEDLINE, Embase, CINAHL, Cochrane Library, PsycINFO

Inclusion criteria: Studies with neuroimaging, electrophysiological, or clinical motor outcome measures.

Exclusion criteria: Non-English publications, Editorials, conference abstracts

without full text, Studies with incomplete data

Extracted data included: CIMT (duration, intensity, tasks), Neuroplasticity outcomes (cortical reorganization, white matter integrity, connectivity changes, molecular biomarkers), Clinical outcomes (motor recovery, functional independence), Quality indicators

The process of selecting in total, about 200 records were initially identified. After

eliminating duplicates, 150 articles remained for title and abstract screening. Out of these, 110 were excluded as they did not fulfill the inclusion requirements. Forty articles were assessed in full, of which 20 were excluded for reasons such as insufficient data, lack of focus on CIMT, being editorials, or being non-English. Eventually, 20 studies satisfied the inclusion criteria and were considered in this review. The PRISMA flow diagram outlines the selection process.

Author(year)	Study Design	Population	Intervention	Outcomes Measured	Key Findings
1) Taub et al (2006)	Experimental study	Stroke survivors	CIMT (task-specific training)	Motor recovery, cortical reorganization	CIMT improved motor outcomes and neuroplastic changes
2)Wolf et al (2006)	RCT	Stroke patients	Moment restriction therapy vs standard rehabilitation	Upper limb function	CIMT group showed significant motor recovery
3)Lang & Baum (2002)	Review	Stroke rehab patients	CIMT principles	Functional recovery	CIMT enhances task-specific motor learning
4)Schwartz & Taub (2019)	Review	Stroke Patients	CIMT	Neuroplasticity, rehab outcomes	CIMT supports brain reorganization
5)Reddy	Evidence synthesis and evidence integration	People affected by stroke	Forced use therapy	Functional ambulation	CIMT improved ambulation but no significant gait speed effect
6)Tedla et al (2002)	Systematic Review	Stroke Patients	CIMT	Balance, mobility	CIMT improved balance & mobility
7)Hakkennes & keating (2005)	Systematic Review	Post-stroke patients	CIMT	Upper limb recovery	CIMT beneficial over alternative rehab
8)Kwakkel et al (2002)	Clinical Trial	Stroke patients	CIMT	Arm function	CIMT group showed significant arm recovery
9)Reiss et al (2012)	Narrative review	Stroke Rehab	CIMT protocol	Long term outcomes	Established standardized CIMT protocol
10)McIntyre (2012)	Systematic review & meta-analysis	Prolonged illness	CIMT	Upper limb function	CIMT effective
11)Rehman (2015)	Comparative study	Post Stroke patients	CIMT vs Bobath	Motor and hand dexterity	CIMT more effective than bobath
12)Veerbeek et al (2015)	Review	Stroke Patients	CIMT	Arm recovery	CIMT improves upper limb function
13)Morrias et al (2006)	Clinical report	Stroke survivors	CIMT protocol	Motor activity	Effective in real-world use of impaired limb

14)Aderinto et al (2023)	Narrative review	Stroke rehab	CIMT, neuro plasticity	Mechanism	Neuroplasticity drives recovery with CIMT
15)Takeuchi & Izumi (2013)	Review	Post-Stroke patients	CIMT	Neuro plasticity	CIMT enhances neural reorganization
16)Wang et al (2022)	Clinical study	Stroke patients	CIMT	Upper limb disfunctions	CIMT effective in post-stroke upper limb recovery
17)Cui et al (2023)	Clinical review	Stroke patients	CIMT	Clinical applications	CIMT effective, especially in combination therapies
18)Mark et al (2006)	Review	Stroke rehab	CIMT	Neuroplasticity	CIMT linked to significant neuroplastic changes
19)Kabalan et al (2020)	Clinical Study	Early stroke patients	CIMT	Neuroplastic outcomes	CIMT promotes cortical reorganization
20)Almoghassil et al (2018)	Review	Chronic & stroke patients	CIMT	Hand motor recovery	CIMT effective in subacute and chronic stages

RESULTS

Analysis of the selected studies consistently demonstrated that constraint-induced movement therapy (CIMT) promotes neuroplasticity and facilitates motor recovery in individuals recovering from stroke. The evidence highlights CIMT's role in enhancing cortical activity, supporting reorganization of neural circuits, and improving functional outcomes of the impaired limb.

Key Neuroplastic and Clinical Outcomes

Increased cortical activation: Functional imaging studies reported heightened activation within motor-related cortical areas following CIMT interventions.

Cortical reorganization: Repetitive use of the affected arm encouraged synaptic strengthening and the formation of new neural pathways.

Improved functional connectivity's enhanced interhemispheric communication and strengthened sensorimotor network integration.

Motor recovery: Significant improvements were recorded in upper-limb strength, dexterity, and performance of task-specific activities.

Sustained benefits: Several studies noted that neuroplastic changes and motor improvements persisted beyond the therapy period, indicating long-term rehabilitation benefits.

Overall Findings

Collectively, the reviewed studies affirm that CIMT is a highly effective neurorehabilitation intervention. It not only supports structural and functional brain changes but also leads to tangible motor improvements, strengthening its role in stroke recovery programs.

Neuroplasticity Mechanisms Observed

Cortical Reorganization: Expansion of motor cortex representation, Increased activation in secondary motor areas

Structural Plasticity: Improved white matter integrity (DTI studies), Dendritic spine proliferation, Synaptic density increases in perilesional areas

Functional Connectivity: Enhanced interhemispheric connectivity, Strengthening of sensorimotor network pathways, Modulation of default mode network activity

Molecular Mechanisms: Increased Brain-Derived Neurotrophic Factor (BDNF) expression, Neurotransmitter modulation

(dopamine, glutamate), Upregulation of growth factors linked to axonal sprouting

DISCUSSION

Interpretation of Findings

Neuroplastic changes induced by CIMT differ from spontaneous post-stroke recovery because they result from targeted, repetitive, and task-specific training. CIMT drives cortical reorganization through deliberate engagement of the impaired limb, which enhances functional outcomes.

Dose–response effect: Studies indicate that greater intensity and longer duration of CIMT are associated with stronger neuroplastic adaptations and better motor recovery.

Time-sensitive benefits: Early initiation of CIMT in the subacute phase tends to yield more pronounced improvements, although patients in chronic stages also show meaningful gains.

Individual variability: Patient-related factors such as age, lesion characteristics, baseline motor ability, and motivation significantly influence rehabilitation outcomes.

Clinical Implications

Optimal timing: Starting CIMT during the subacute phase maximizes its potential to stimulate brain reorganization.

Patient suitability: CIMT is most effective in individuals who retain at least minimal voluntary movement (e.g., 10° wrist and finger extension).

Protocol flexibility: Combining CIMT with emerging technologies such as virtual reality, robotics, or non-invasive neuromodulation can enhance patient engagement and outcomes.

Integration with other therapies: Pairing CIMT with aerobic exercise or adjunctive interventions (e.g., brain stimulation) may further amplify neuroplastic responses.

Limitations of Current Evidence

Lack of uniformity in CIMT protocols across studies, Differences in methods used to measure neuroplasticity, Limited availability

of long-term follow-up data, Risk of publication bias in reported outcomes.

Directions for Future Research

Development of standardized biomarkers to measure neuroplasticity in CIMT trials, Exploration of personalized CIMT dosing strategies tailored to patient-specific profiles. Use of combined neuroimaging and molecular methods to better understand mechanisms. Longitudinal studies to assess the durability of neuroplastic and functional gains.

CONCLUSION

Constraint-induced movement therapy (CIMT) has established itself as a powerful and evidence-based approach in stroke rehabilitation by harnessing the brain's capacity for neuroplasticity. By restricting the unaffected limb and compelling use of the weaker upper extremity, CIMT stimulates cortical reorganization, strengthens neural connections, and supports both structural and functional brain changes.

Findings from the reviewed studies show that CIMT significantly improves motor recovery in the acute, subacute, and chronic phases of stroke. Importantly, these benefits extend beyond the intervention period, supporting long-term independence and quality of life. Given its demonstrated ability to induce lasting neuroplastic adaptations, CIMT should be regarded as a core component of modern neurorehabilitation programs.

CLINICAL RELEVANCE

CIMT represents a practical and effective rehabilitation strategy that capitalizes on the brain's inherent ability to reorganize and form new neural pathways. By limiting use of the unaffected limb, the therapy compels reliance on the impaired extremity, leading to improved motor recovery and cortical reorganization.

Clinically, CIMT has been shown to: Enhance upper-limb strength, dexterity, and motor control, reduce compensatory reliance on the unaffected limb, improve independence in daily activities and quality

of life, support durable neuroplastic changes, sustaining recovery long after treatment. CIMT's adaptability makes it suitable across various stages of stroke recovery—acute, subacute, and chronic. When integrated with other therapeutic techniques, such as robotics or neuromodulation, it offers additional benefits. Ultimately, CIMT plays a critical role in improving outcomes for stroke survivors and should be prioritized in rehabilitation practice.

Declaration by Authors

Ethical Approval: Not applicable

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Feigin VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA, et al. Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. *Lancet*. 2014;383(9913):245–54. doi:10.1016/S0140-6736(13)61953-4
2. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. *Lancet*. 2011;377(9778):1693–702. doi:10.1016/S0140-6736(11)60325-5
3. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. *Lancet Neurol*. 2009;8(8):741–54. doi:10.1016/S1474-4422(09)70150-4
4. Veerbeek JM, Kwakkel G, van Wegen EE, Ket JC, Heymans MW. Early prediction of outcome of activities of daily living after stroke: a systematic review. *Stroke*. 2011;42(5):1482–8. doi:10.1161/STROKEAHA.110.604090
5. Veerbeek JM, van Wegen EE, van Peppen RP, van der Wees PJ, Hendriks HJ, Rietberg MB, et al. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis. *PLoS One*. 2014;9(2):e87987. doi: 10.1371/journal.pone.0087987
6. Sirtori V, Corbetta D, Moja L, Gatti R. Constraint-induced movement therapy for upper extremities in stroke patients. *Cochrane Database Syst Rev*. 2009;(4):CD004433. doi: 10.1002/14651858.CD004433.pub2
7. Corbetta D, Sirtori V, Moja L, Gatti R. Constraint-induced movement therapy in stroke patients: systematic review and meta-analysis. *Eur J Phys Rehabil Med*. 2010;46(4):537–44. PMID: 21076377
8. Taub E, Uswatte G, Pidikiti R. Constraint-Induced Movement Therapy: a new approach to treatment in neurorehabilitation. *Neurorehabil Neural Repair*. 2006;20(3):282–93. doi:10.1177/1545968306287084
9. Wolf SL, Winstein CJ, Miller JP, Taub E, Uswatte G, Morris D, et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. *JAMA*. 2006;296(17):2095–104. doi:10.1001/jama.296.17.2095
10. Lang CE, Baum CM. Constraint-induced movement therapy: a new approach to stroke rehabilitation. *Neurorehabil Neural Repair*. 2002;16(2):112–22. doi:10.1177/154596830201600205
11. Schwartz I, Taub E. The impact of constraint-induced movement therapy on neuroplasticity: a review of mechanisms and applications in stroke rehabilitation. *Front Neurol*. 2019;10:529. doi:10.3389/fneur.2019.00529
12. Reddy RS, Gular K, Dixit S, Tedla JS, Gautam AP, Sangadala DR. Impact of constraint-induced movement therapy on functional ambulation in stroke patients: a systematic review and meta-analysis. *Int J Environ Res Public Health*. 2022;19(20):12809. doi:10.3390/ijerph192012809
13. Hakkennes S, Keating JL. Constraint-induced movement therapy following stroke: a systematic review of randomized controlled trials. *Aust J Physiother*. 2005;51(4):221–31. doi:10.1016/S0004-9514(05)70003-8
14. Kwakkel G, Rietberg MB, van Wegen EE. Constraint-induced movement therapy improves upper extremity motor function after stroke: a systematic review. *Aust J Physiother*. 2007;53(4):230–8. doi:10.1016/S0004-9514(07)70003-9
15. Tedla JS, Gular K, Reddy RS, Ferreira G, Rodrigues EC, Kakaraparthi VN, Sangadala DR, Kovala RK. Effectiveness of constraint-induced movement therapy on balance and functional mobility in stroke population: a systematic review and meta-analysis.

- Healthcare (Basel). 2022;10(3):495. doi:10.3390/healthcare10030495
16. Reiss S, Wolf SL, Hammel M, McLeod E, Williams E. Constraint-induced movement therapy: current perspectives and future directions. *NeuroRehabilitation*. 2012;31(2): 159–69. doi:10.3233/NRE-2012-0774
 17. McIntyre A, Viana R, Janzen S, Mehta S, Pereira S, Teasell R. Systematic review and meta-analysis of constraint-induced movement therapy in hemiparetic upper extremity more than six months post stroke. *Top Stroke Rehabil*. 2012;19(6):499–513. doi:10.1310/tsr1906-499
 18. Rehman R, Rawat S, Agarwal R, Kumar Verma A. Effectiveness of Bobath approach vs. constraint-induced movement therapy to improve arm motor function and hand dexterity in post-stroke patients. *Int J Physiother Res*. 2015;3(2):912–8. doi:10.16965/ijpr.2015.103
 19. Veerbeek JM, van Wegen EEH, van Peppen RP, et al. Constraint-induced movement therapy after stroke. *Lancet Neurol*. 2015;14(2):224–34. doi:10.1016/S1474-4422(14)70160-7
 20. Morris DM, Taub E, Mark VW. Constraint-induced movement therapy: characterizing the intervention protocol. *Eura Medicophys*. 2006;42(3):257–68. PMID: 17039224
 21. Aderinto A, Abdulbasit S, Olatunji O, Adejumo A. Exploring the transformative influence of neuroplasticity on stroke rehabilitation: a narrative review of current evidence. *Ann Med Surg (Lond)*. 2023; 85:4425–32. doi: 10.1016/j.amsu.2023.103442
 22. Takeuchi N, Izumi SI. Rehabilitation with poststroke motor recovery: a review with a focus on neural plasticity. *Neural Plast*. 2013; 2013:128641. doi:10.1155/2013/128641
 23. Wang D, Xiang J, Mao W, Dong L. The mechanism and clinical application of constraint-induced movement therapy in stroke rehabilitation. *Front Behav Neurosci*. 2022;16:828599. doi:10.3389/fnbeh.2022.828599
 24. Cui Y, Ma N, Li J, Zhang Y. Progress in the clinical application of constraint-induced movement therapy following stroke since 2014. *Front Neurol*. 2023; 14:1170420. doi:10.3389/fneur.2023.1170420
 25. Mark VW, Taub E, Morris DM. Neuroplasticity and constraint-induced movement therapy. *Eura Medicophys*. 2006;42(3):269–84. PMID: 17039225
 26. Kabalan W, Shantaf O, Wael H, Hassan M, Eddine H. Influence of constraint-induced movement therapy on neuroplasticity and its functional consequences in early stroke. *World J Pharm Pharm Sci*. 2020;9(8):1412–27.
 27. Almoghassil S. Constraint-induced movement therapy, neuroplasticity and upper extremity motor recovery after stroke. *J Med Clin Res Rev*. 2018;2(3):1–6.
 28. Sehar S, Mazhar M, Malik I, Asif I. Role of neuroplasticity in neurorehabilitation. *Asia Pac J Allied Health Sci*. 2021;4(1):23–9.
 29. Zotey P, Andhale S, Shegekar V, Jugnawar A. Adaptive neuroplasticity in brain injury: recovery strategies and insights. *DMIHER J Adv Physio Edu Res*. 2023;7(2):45–53.

How to cite this article: Lugelle Fernandes, Kamalakannan, Pranjali Vaidya. Neuroplasticity mechanisms underlying constraint-induced movement therapy in stroke rehabilitation: a scoping review. *Galore International Journal of Applied Sciences & Humanities*. 2026; 10(1): 11–18. DOI: [10.52403/gijash.20260102](https://doi.org/10.52403/gijash.20260102)
