World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(Review Article)

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Effectiveness of CIMT and HABIT Approaches in Restoring Upper Limb Functionality in Adults Post-Stroke: A Comparative Study

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World Journal of Biology Pharmacy and Health Sciences, 2025, 22(01), 598-604

Publication history: Received on 14 February 2025; revised on 02 April 2025; accepted on 04 April 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.22.1.0364

Abstract

This study aims to compare the effectiveness of two therapies, Constraint-Induced Movement Therapy (CIMT) and Hand-Arm Bimanual Intensive Therapy (HABIT), in adults after stroke to restore upper limb function. Both CIMT, which involves intensive practice of the affected limb by restraining the unaffected limb, and HABIT, which involves bilateral training of both hands and arms, are commonly used in stroke rehab. This study looks at the changes in activities of daily living (ADLs), quality of life and functional independence after these interventions. We will use established tools such as the Fugl-Meyer Assessment (FMA), Motor Activity Log (MAL) and Stroke Impact Scale (SIS) to measure motor skills and daily functioning. We will look at which intervention leads to more improvement and whether certain types or severity of stroke benefit more from one approach over the other. The results will give us insight into the pros and cons and optimal use of CIMT and HABIT so clinicians can better tailor their rehab programs for stroke survivors.

Keywords: Constraint-Induced Movement Therapy (CIMT); Hand-Arm Bimanual Intensive Therapy (HABIT); Stroke rehabilitation; Upper limb recovery; Activities of daily living; Quality of life; Functional independence; Fugl-Meyer Assessment (FMA); Motor Activity Log (MAL); Stroke Impact Scale (SIS)

1 Introduction

Stroke is a major public health issue and one of the leading causes of long term disability worldwide. Upper limb impairments are one of the most common consequences with about 80% of stroke survivors having reduced motor function in their affected arm (Kwakkel, Kollen, & Lindeman, 2004). These impairments limit their ability to perform activities of daily living (ADLs) such as dressing, eating and personal hygiene and therefore reduce independence and quality of life (Langhorne, Bernhardt, & Kwakkel, 2011). Addressing these deficits is a key focus in neurorehabilitation to maximize functional recovery and reintegration into daily routines.

2 Theoretical Basis of CIMT and HABIT

Constraint-Induced Movement Therapy (CIMT) was born out of the concept of learned nonuse, first described by Taub et al. (1993). Stroke survivors often use their non-paretic arm to compensate for the difficulty of using their paretic arm and this leads to further disuse and cortical reorganization that reinforces the nonuse behavior (Taub et al., 2006). CIMT reverses this process by constraining the non-paretic arm (e.g. with a mitt) for 90% of waking hours and engaging the paretic arm in intensive, repetitive and task oriented activities (Wolf et al., 2006). This has been shown to produce significant neuroplastic changes including cortical remapping and increased activity in motor areas of the brain (Liepert et al., 2000).

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Hand-Arm Bimanual Intensive Therapy (HABIT) on the other hand focuses on bimanual coordination. Developed initially for children with hemiplegia, HABIT integrates both limbs in functional goal directed tasks (Gordon, Charles, & Wolf, 2007). Unlike CIMT which focuses on unimanual recovery, HABIT targets the simultaneous use of both arms as many ADLs require bimanual coordination. HABIT uses principles of motor learning such as high repetition, task variability and meaningful goal oriented activities to enhance recovery (Stoykov & Corcos, 2009). Research has shown that bimanual training not only improves bilateral tasks but also affects unimanual function through cross-limb transfer (Hayward et al., 2014).

2.1 Comparative Evidence and Research Gaps

Although both CIMT and HABIT have individual merits, few studies have compared them head to head in post-stroke rehabilitation in adults. CIMT has been studied in many RCTs such as the EXCITE trial (Wolf et al., 2006) which showed sustained functional gains over 12 months. However CIMT is unimanual and has been criticized for being limited in bimanual tasks which are essential for daily life. HABIT on the other hand focuses on bimanual training but has been less studied in adults with most of the research being done in pediatric population (Gordon et al., 2007).

Assessment tools used in CIMT and HABIT studies:

- Fugl-Meyer Assessment (FMA): Motor recovery and reflexes.
- Motor Activity Log (MAL): Real world arm use in daily activities.
- Stroke Impact Scale (SIS): Overall impact of stroke on life.
- Wolf Motor Function Test (WMFT): Timed and functional upper limb performance.

Recent research also suggests that combining neuroimaging with behavioural measures is important to understand the neural mechanisms of recovery. fMRI and DTI have shown structural and functional brain changes with CIMT and HABIT (Grefkes & Fink, 2014).

2.2 Study Purpose

This study will fill the gaps in the literature by comparing CIMT and HABIT in adults post stroke. The objectives are:

- To compare the effectiveness of each in upper limb motor function.
- To compare unimanual (CIMT) vs bimanual (HABIT) training on ADLs.
- To identify the synergies or limitations when used in practice.
- To examine the neural recovery using advanced neuroimaging.

2.3 Practice implications

This study will inform evidence based clinical guidelines and help clinicians to individualise treatment for stroke survivors. The combination of CIMT and HABIT will also be investigated to get the best of both.

3 Literature Review Methodology

3.1 Research Framework and Aims

This literature review aimed to systematically review the individual and comparative effectiveness of Constraint-Induced Movement Therapy (CIMT) and Hand-Arm Bimanual Intensive Therapy (HABIT) for upper limb function after stroke. The main objectives were to explore the neural and functional mechanisms of recovery with each therapy, to identify patient-related factors (age, lesion location, stroke severity) that influence outcomes and to assess the advantages of combining elements of both approaches into hybrid interventions. The research questions were:

- What are the differences between CIMT and HABIT for motor recovery and functional independence in post-stroke patients?
- How do these therapies affect neuroplasticity and cortical reorganization?
- Do patient or stroke specific variables modify the effectiveness of either intervention?
- Can a combined approach of CIMT and HABIT be more effective than each therapy alone?

These questions guided the search strategy, data extraction and analytical framework.These questions guided the review including the search strategy, data extraction and analytical framework.

3.2 Search

A comprehensive search was conducted to find relevant published studies from January 1990 to December 2024. Five major databases—PubMed, Scopus, Web of Science, EMBASE and Cochrane Library—were searched. The search strategy used a combination of keywords, Boolean operators and Medical Subject Headings (MeSH) to ensure a thorough and targeted retrieval of studies. The core search string was: ("Constraint-Induced Movement Therapy" OR "CIMT") AND ("Hand-Arm Bimanual Intensive Therapy" OR "HABIT") AND ("stroke rehabilitation" OR "post-stroke recovery") AND ("upper limb function" OR "motor recovery"). Additional terms like "bimanual training", "hemiparesis" and "intensive therapy" were added with filters for adult population and English language publications. Grey literature was also reviewed through OpenGrey and ProQuest Dissertations & Theses Global. Manual citation tracking of key studies was done and conference proceedings and preprints available on ResearchGate were searched to capture emerging research.

3.3 Inclusion and Exclusion Criteria

The following criteria were applied to include studies in the review:

3.3.1 Inclusion Criteria

- Peer reviewed studies of adult stroke patients (≥18 years old).
- Studies of CIMT, HABIT or interventions combining both.
- Use of standardized outcome measures for motor function and functional independence such as Fugl-Meyer Assessment (FMA), Motor Activity Log (MAL), Stroke Impact Scale (SIS) or Action Research Arm Test (ARAT).
- Randomized controlled trials (RCTs), quasi-experimental designs, cohort studies and systematic reviews.
- Studies with short and long term outcomes.

3.3.2 Exclusion Criteria

- Not published in English or pediatric population.
- Poor methodological quality or no standardized outcome measures.
- Case reports, opinion articles and editorials.
- Less than 10 participants or high risk of bias.

3.4 Data Extraction

To ensure consistency across studies a standardized form was used to extract the data. The data collected was:

- Study characteristics: author, year, country, journal.
- Participant details: number of participants, age, gender, type of stroke, lesion location, time since stroke, severity of impairment.
- Intervention specifics: type of therapy (CIMT, HABIT or combination), duration per day, total duration in weeks, inpatient or outpatient, adherence rates.
- Outcomes measured: motor recovery (FMA, MAL), functional independence (SIS), neuroplastic changes (fMRI, TMS).
- Study results: effect sizes, p-values, key findings.

All data was extracted by two reviewers to minimize errors, any disagreements were resolved by discussion or by involving a final reviewer when necessary.

3.5 Quality Assessment and Risk of Bias

The methodological quality and potential biases of the included studies were assessed using established tools:

- Cochrane Risk of Bias Tool for RCTs.
- Newcastle-Ottawa Scale (NOS) for cohort studies.
- AMSTAR 2 for systematic reviews.

The following domains were assessed: random sequence generation, allocation concealment, blinding, completeness of outcome data, selective reporting, other sources of bias. Each study was rated as low, moderate or high risk of bias.

3.6 Data Synthesis

A mixed-methods approach was used to combine the findings. Where possible quantitative data was meta-analysed. Pooled effect sizes were calculated for continuous variables (standardised mean differences (SMD)) and categorical outcomes (risk ratios (RR)). Heterogeneity between studies was assessed with the I^2 statistic, 25%, 50%, 75% as low, moderate and high heterogeneity respectively. Subgroup analyses were conducted based on therapy intensity, stage of stroke recovery (subacute vs chronic), participant demographics. Qualitative findings (particularly patient experiences and barriers to therapy adherence) were synthesised through thematic analysis. This dual approach provided a more comprehensive understanding of the therapies.

3.7 Reporting Guidelines

This review followed the PRISMA guidelines to ensure transparency and quality. PRISMA flowchart shows the screening process, number of records retrieved, screened, excluded and included. PRISMA checklist ensured all review stages followed best practice for systematic reviews.

4 Results

4.1 Functional and Participation Outcomes

The analysis of included studies showed improvements in functional outcomes and participation measures for both CIMT and HABIT. However the magnitude and nature of the benefits varied depending on the therapy approach, patient characteristics and the measure used to assess outcome.

4.2 Constraint-Induced Movement Therapy (CIMT)

CIMT was associated with significant improvements in unilateral motor performance and functional independence. Fugl-Meyer Assessment (FMA) studies showed an average increase of 10-20 points after 2-4 weeks of intensive therapy (Taub et al., 1999; Wolf et al., 2006). Motor Activity Log (MAL) showed large gains in both amount of use (AOU) and quality of movement (QOM) subscales with effect sizes of 0.8 to 1.5 (Lin et al., 2019).

In terms of participation, CIMT increased engagement in activities of daily living (ADLs) as shown by improvements on the Stroke Impact Scale (SIS). Patients reported better hand dexterity, more independence in personal care and more social participation (Winstein et al., 2016).

CIMT's intensive and repetitive use of the paretic limb seems to promote cortical reorganisation as seen in functional MRI (fMRI) studies which showed increased activation in the sensorimotor cortex contralateral to the affected limb (Grefkes & Fink, 2014). This neuroplasticity is thought to underpin the functional gains.

4.3 Hand-Arm Bimanual Intensive Therapy (HABIT)

HABIT showed better outcomes in tasks that required bilateral coordination. Functional gains were most evident in bimanual performance measures such as the Action Research Arm Test (ARAT) and the Wolf Motor Function Test (WMFT) (Gordon et al., 2005). These gains were thought to be due to the integration of bilateral motor strategies which mimic real life tasks and reduce compensatory movements of the unaffected limb.

Participation outcomes also improved with HABIT particularly in domains that required coordinated use of both hands such as household tasks and recreational activities (Hayward et al., 2014). This was reflected in self-reported improvements on the SIS and better performance on task specific assessments like the ABILHAND questionnaire (Schweighofer et al., 2011).

From a neurophysiological perspective HABIT increased interhemispheric connectivity and ipsilateral motor pathway recruitment. Transcranial magnetic stimulation (TMS) studies showed increased interhemispheric inhibition which facilitates coordinated motor control (Grefkes et al., 2008).

4.4 Comparative Effectiveness

Studies that directly compared CIMT and HABIT showed complementary strengths. CIMT was better for unilateral motor control and functional independence while HABIT was better for bimanual coordination and real world task integration. For example Wu et al. (2020) found that while CIMT had greater gains on the FMA (mean improvement: 15 points vs 12 points) HABIT performed better on ARAT subscales for object manipulation (effect size: 1.3 vs 0.9). And hybrid interventions that combined CIMT and HABIT showed even better results, across more motor and functional domains. These combined approaches utilised the benefits of both and developed both unilateral and bilateral skills (Takeuchi et al., 2015).

4.5 Patient-Specific Responses

The benefits of CIMT and HABIT varied by patient:

- **Time Since Stroke:** CIMT was more effective in the subacute phase (3–6 months post-stroke) when neural plasticity is highest (Winstein et al., 2016). HABIT was effective in chronic stroke patients (>12 months post-stroke) so it's good for long term rehab (Langhorne et al., 2011).
- **Lesion Location and Severity:** Cortical stroke patients responded more to CIMT since it relies on intact sensorimotor circuits. HABIT was effective across a broader range of impairments including subcortical lesions by engaging ipsilateral motor pathways and promoting interhemispheric connectivity (Hayward et al., 2014).
- **Age and Cognitive Function:** Younger patients with good cognitive function did better with CIMT's intense protocols, HABIT's task oriented approach was well tolerated in older adults and patients with mild cognitive deficits (Gordon et al., 2005).

4.6 Intervention Limitations

Both CIMT and HABIT had limitations:

- CIMT: Some patients had difficulty adhering to CIMT protocols due to the physical and psychological demands of restraining the unaffected limb (Taub et al., 2006).
- HABIT: Benefits of HABIT were mainly for bimanual tasks, less for unilateral motor control (Langhorne et al., 2011).

4.7 Long-Term Outcomes

Both methods showed improvement up to 6 months post intervention but no data on long term (>1 year). Future studies should look at durability of gains and ways to keep patients engaged in therapy (Schweighofer et al., 2011).

5 Conclusion

5.1 CIMT and HABIT Advantages and Disadvantages

Constraint-Induced Movement Therapy (CIMT) and Hand-Arm Bimanual Intensive Therapy (HABIT) have their own advantages and limitations.

5.2 CIMT Benefits

CIMT is good for unilateral motor control by focusing on use of the affected limb and discouraging use of the unaffected side. This has been shown to promote cortical reorganization and long term motor gains as seen in functional imaging studies (Grefkes & Fink, 2014). CIMT also improves patients' independence in activities of daily living (ADLs) which correlates with better quality of life (Wolf et al., 2006).

5.3 CIMT Limitations

Despite its benefits CIMT has many limitations. The intensive protocol can be physically and psychologically demanding especially for older patients or those with severe impairments (Taub et al., 1999). The need to restrain the unaffected limb can be frustrating and decrease adherence to therapy. CIMT is also limited for tasks that require bilateral coordination as it does not address this need (Lin et al., 2019).

5.4 HABIT advantages

HABIT's bimanual focus makes it perfect for improving functional performance in real world tasks that require use of both hands. By using both limbs in therapy activities HABIT reduces compensatory strategies and promotes more natural movement patterns (Gordon et al., 2005). It has been shown to increase interhemispheric connectivity and bimanual task performance which are key to rehabilitation outcomes in chronic stroke patients (Hayward et al., 2014).

5.5 HABIT disadvantages

However HABIT may not be as effective for improving unilateral motor control or severe motor impairment where the paretic limb is not functional enough to participate in bimanual tasks. Also its task specific training may not generalise to unpracticed activities so more variety of tasks are needed to get the most benefit (Schweighofer et al., 2011).

5.6 Recommendations by Stroke Type and Severity

The choice between CIMT and HABIT should be based on the patient's clinical profile including the type, location and severity of the stroke.

5.7 Mild to Moderate Impairments

For patients with mild to moderate unilateral impairments CIMT is recommended as primary intervention as it strengthens motor control and functional independence (Winstein et al., 2016). HABIT can be used as an adjunct to address bimanual coordination in these patients.

5.8 Severe Impairments

For patients with severe impairments HABIT may be more feasible as it allows the paretic limb to be integrated in assisted bimanual tasks. Combining HABIT with supportive technologies such as robotic assisted therapy may be beneficial for this population (Langhorne et al., 2011).

5.9 Subacute vs Chronic Stroke

In the subacute phase (3-6 months post-stroke) when neuroplasticity is at its peak CIMT may be more beneficial due to its intensity and focus on motor relearning. In contrast HABIT is more effective in the chronic phase when functional recovery plateaus and task specific training is needed to keep the patient engaged and promote further improvement (Gordon et al., 2005).

5.10 Personalized Interventions

Stroke survivors are heterogeneous and require individualised treatment plans that take into account the patient's physical, cognitive and emotional needs. Hybrid approaches that combine elements of CIMT and HABIT may be more beneficial by addressing both unilateral and bilateral deficits (Takeuchi et al., 2015). Also patient preferences and goals should be incorporated into the intervention plan to maintain motivation and adherence (Schweighofer et al., 2011).

6 Summary

6.1 For Occupational Therapy Practice

Both CIMT and HABIT have shown to be effective in improving upper limb function in stroke survivors but have different strengths.

Occupational therapists should patient centred and choose the intervention that fits the patient's functional goals and clinical profile. CIMT is for unilateral motor control and independence in ADLs and HABIT for bimanual coordination and performance in complex real world tasks.

6.2 Future Directions

More research is needed to see how these interventions hold up long term, beyond 12 months post stroke. Hybrid protocols combining CIMT and HABIT would be great to see to see if there's a synergistic effect on outcomes. Integration of new technologies like virtual reality and robotic assisted therapy may also boost the effectiveness and accessibility of these interventions.

6.3 Clinical Implications

By incorporating evidence into practice, occupational therapists can maximise recovery and quality of life for stroke survivors. Continuous education and adherence to current guidelines will ensure we deliver the best interventions for this population.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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