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# The Effect of Constraint-Induced Movement Therapy on Arm Function and Activities of Daily Living in Post-stroke Patients: A Systematic Review and Meta-Analysis

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## HIGHLIGHTS

- Constraint-induced movement therapy (CIMT) can improve upper limb function in stroke patients with hemiplegia.
- CIMT can facilitate arm impairment recovery in stroke patients with hemiplegia.
- CIMT can improve activities of daily living in stroke patients with hemiplegia.

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## ABSTRACT

This meta-analysis aimed to evaluate the effect of constraint-induced movement therapy (CIMT) on arm function and daily living compared with conventional rehabilitation in stroke patients with hemiplegia. We searched three international electronic databases—MEDLINE, Embase, and the Cochrane Library—for relevant studies. The risk of bias was evaluated using Cochrane's Risk of Bias version 1.0, and the certainty of evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluations method. A total of 34 randomized controlled trials (RCTs) were included herein. Specifically, 21 RCTs regarding arm motor function, 13 on upper limb motor impairment, and 12 on activities of daily living (ADL) performance were analyzed. The results of the meta-analysis demonstrated that CIMT was significantly more effective than conventional therapy in improving arm motor function, reducing upper limb motor impairment, and enhancing ADL performance. CIMT should be implemented and tailored to the strength of the affected upper limb to improve upper limb function and ADL performance in post-stroke patients with hemiplegia.

**Keywords:** Constraint-Induced Movement Therapy; Upper Extremity; Stroke Rehabilitation

## INTRODUCTION

Functional impairment following stroke is closely associated with persistent upper limb dysfunction. Approximately 40% of stroke survivors experience chronic functional impairment; however, only 6% of such patients report satisfaction regarding the functional recovery of their paralyzed upper limb [1-3]. Loss of arm function significantly affects the quality of life as it is crucial for performing basic activities of daily living (ADL) [4]. Consequently, various rehabilitation methods are implemented to enhance upper limb function.

Constraint-induced movement therapy (CIMT) was designed to enhance upper limb function in patients with hemiplegia. The underlying principle of CIMT is to counteract the learned non-use of the affected limb by encouraging its use through the limitation of the movement of the unaffected limb [5]. This therapy is particularly suitable for patients who have achieved

**Conflict of Interest**
The authors have no potential conflicts of interest to disclose.

**Author Contributions**
Conceptualization: Choi H; Data analysis: Choi H; Investigation: Choi H, Kim HJ; Visualization: Choi H; Writing - original draft: Choi H; Writing - review & editing: Kim HJ.

a certain level of motor function recovery, especially those who can extend their wrists and fingers to some degree.

The original procedure for CIMT involved immobilization of the unaffected upper limb with a brace for 2 weeks while conducting intensive one-on-one therapy sessions for 6 hours a day, 5 days a week [5]. These sessions emphasized repetitive task-specific training and encouraged the use of the affected limb in ADLs. Recently, modified versions of CIMT with varying frequencies and durations of sessions have been introduced to better suit practical treatment needs and patient circumstances [6].

Many clinical practice guidelines recommend CIMT implementation in suitable patients [7-9]. A previous study demonstrated a significant improvement in upper limb motor function but no significant improvement in ADL performance following CIMT [6]. This meta-analysis compared the effects of CIMT with those of conventional therapy in post-stroke patients, carefully excluding studies that might increase heterogeneity and incorporating the most recent evidence.

## MATERIALS AND METHODS

### Study protocol registration

The study protocol was conceived during systematic consensus meetings conducted to develop the guidelines for the Rehabilitation of Motor Function as part of the Clinical Practice Guidelines for Stroke Rehabilitation in Korea.

### Enrolment criteria

Study selection was based on the principles of Patient, Intervention, Comparison, and Outcomes (PICO) as follows.

(1) Patient: Adult stroke patients with hemiplegia (including both cerebral hemorrhage and cerebral infarction in patients aged ≥ 18 years).
(2) Intervention: CIMT.
(3) Comparison: Between the efficacies of CIMT and conventional therapies.
(4) Outcomes: Upper extremity motor function, upper extremity impairment and activities of daily living.

### Search strategy

Literature searches were performed using three international electronic databases: PubMed (http://pubmed.ncbi.nlm.nih.gov), Embase (http://embase.com), and the Cochrane Library (http://cochranelibrary.com). To conduct an extensive literature search, the timeframe was left open-ended without specific restrictions on the start date, and the search was concluded on February 28, 2022. MeSH terms were searched in MEDLINE and the Cochrane Library, whereas Emtree terms were used for searches in Embase. To increase the search sensitivity, natural language terms (constraint-induced therapy and forced use) were included in the search (**Supplementary Table 1**).

### Study selection

Two independent authors performed the study selection according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Only studies that directly compared conventional rehabilitation therapy with CIMT (including traditional CIMT, modified CIMT, or forced use) in patients with stroke-induced hemiplegia were included.

Studies that did not meet the PICO criteria or those published in languages other than English or Korean were excluded. Outcome measures, such as upper limb motor function and ADL evaluations, were selected to assess upper limb motor function, upper limb impairment, and functional independence. The results were analyzed based on outcome measures immediately after the intervention period. The extracted data included the following measures: upper limb function evaluated using the Action Research Arm Test, the Wolf Motor Function Test, and the Modified Motor Assessment Scale; upper limb motor impairment assessed using the Fugl-Meyer Assessment and Chedoke-McMaster Impairment Inventory; and ADL measured using the Functional Independence Measure, Barthel Index, and Modified Barthel Index. After screening the titles and abstracts, the full texts of the selected studies were reviewed. After selecting studies in accordance with the PRISMA guidelines, studies from which data could not be extracted were excluded. Additionally, studies with significant bias or a small number of participants, which contributed to increased heterogeneity, were excluded from the meta-analysis following risk of bias (ROB) and heterogeneity assessments.

### ROB assessment

The final selection of the studies was independently assessed by 2 authors using a literature screening evaluation tool. Randomized controlled trials (RCTs) were assessed using Cochrane's Risk of Bias version 1.0 (RoB 1.0) tool to evaluate bias regarding the following items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessments, incomplete outcome data, selective reporting, and other biases [10]. Two authors reviewed and discussed the findings until a consensus was reached.

### Statistical analysis of evidence

Meta-analyses were conducted using RevMan 5.2 (Nordic Cochrane Center, Copenhagen, Denmark). The impact of CIMT on each outcome measure was assessed using standardized mean difference (SMD). To address differences across studies, a random-effects model was applied to estimate the combined SMD and associated 95% confidence intervals (CIs). Data heterogeneity was evaluated using the $I^2$ value to quantify the extent of variability across studies by indicating the proportion of the total variation.

### Assessment of certainty of evidence

The certainty of evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) method, following the GRADE Handbook [11]. Evidence was rated as high, moderate, low, or very low. Two reviewers independently assessed the evidence and a consensus regarding the ratings was reached through discussions.

## RESULTS

Following an extensive literature search, 3,860 studies were screened after removing duplicates. Of these, 34 RCTs were selected using the PRISMA guidelines (**Fig. 1**) [5,6,12-43]. The studies by Liu et al. [25] and Rocha et al. [29] were excluded from the meta-analysis because data extraction was not possible. Furthermore, significant bias regarding blinding and other aspects were observed in the studies by Page et al. [5], Atteya [12], and Singh and Pradhan [30] (**Fig. 2**). Including them in the meta-analysis would have significantly increased heterogeneity; therefore, they were excluded from the analysis. Finally, 29 studies were included in the meta-analysis. Details of the selected studies are presented in **Supplementary Table 2** [6,13-24,26-28,31-43].

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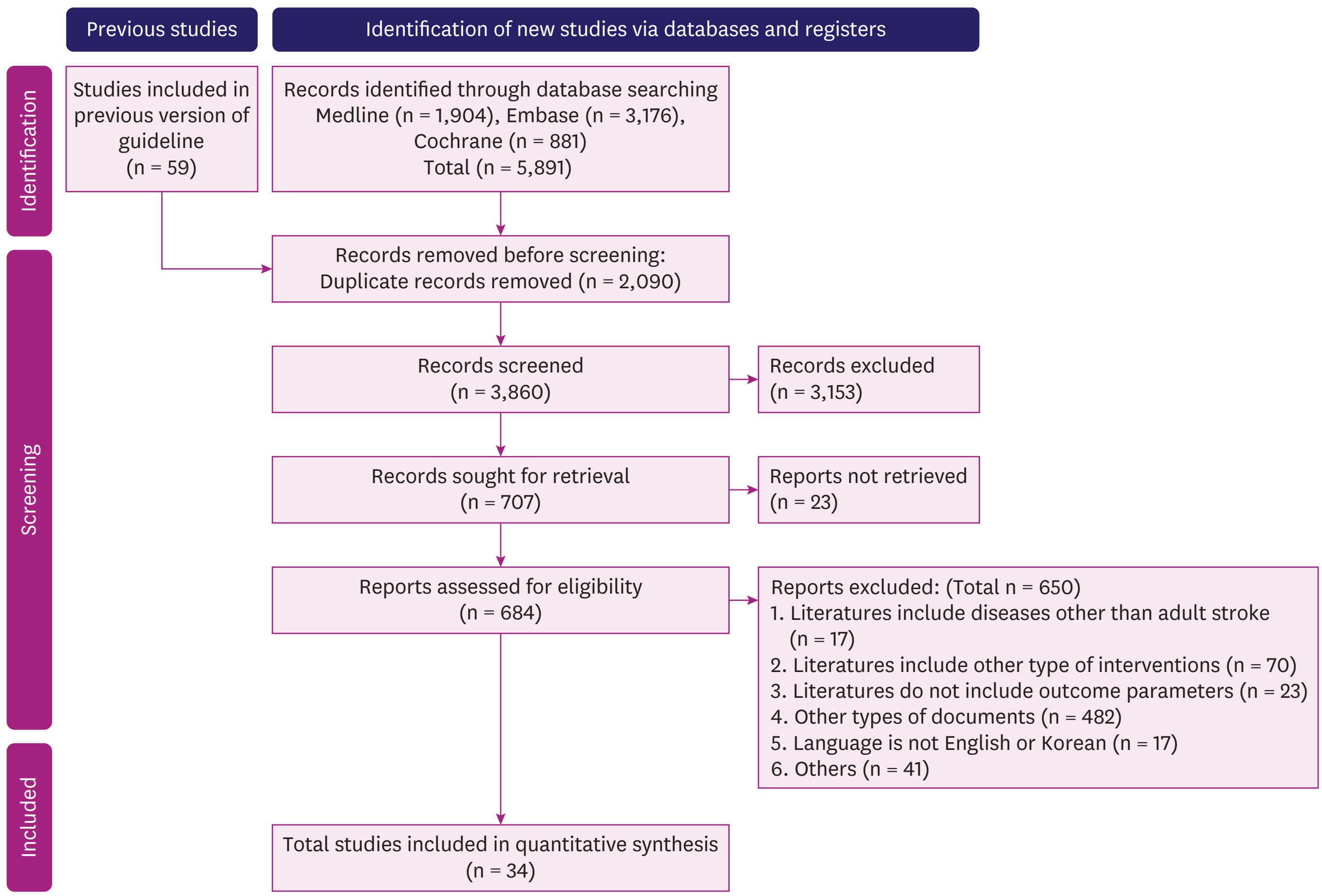



**Fig. 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

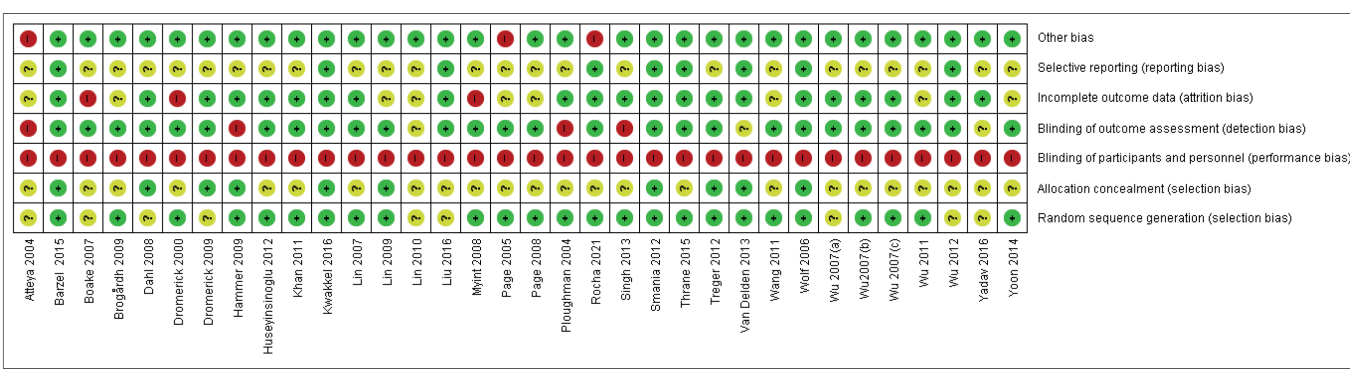



**Fig. 2.** Risk of bias summary for all selected studies.

## Upper limb motor function

A total of 21 studies were included in the assessment of upper limb motor function [6,14-21,26-28,31-36,40,41,43]. The meta-analysis revealed that CIMT had a superior effect on improvements in upper limb motor function compared with conventional rehabilitation therapy (SMD, 0.36; 95% CI, 0.11–0.62; p = 0.005) (**Fig. 3**).

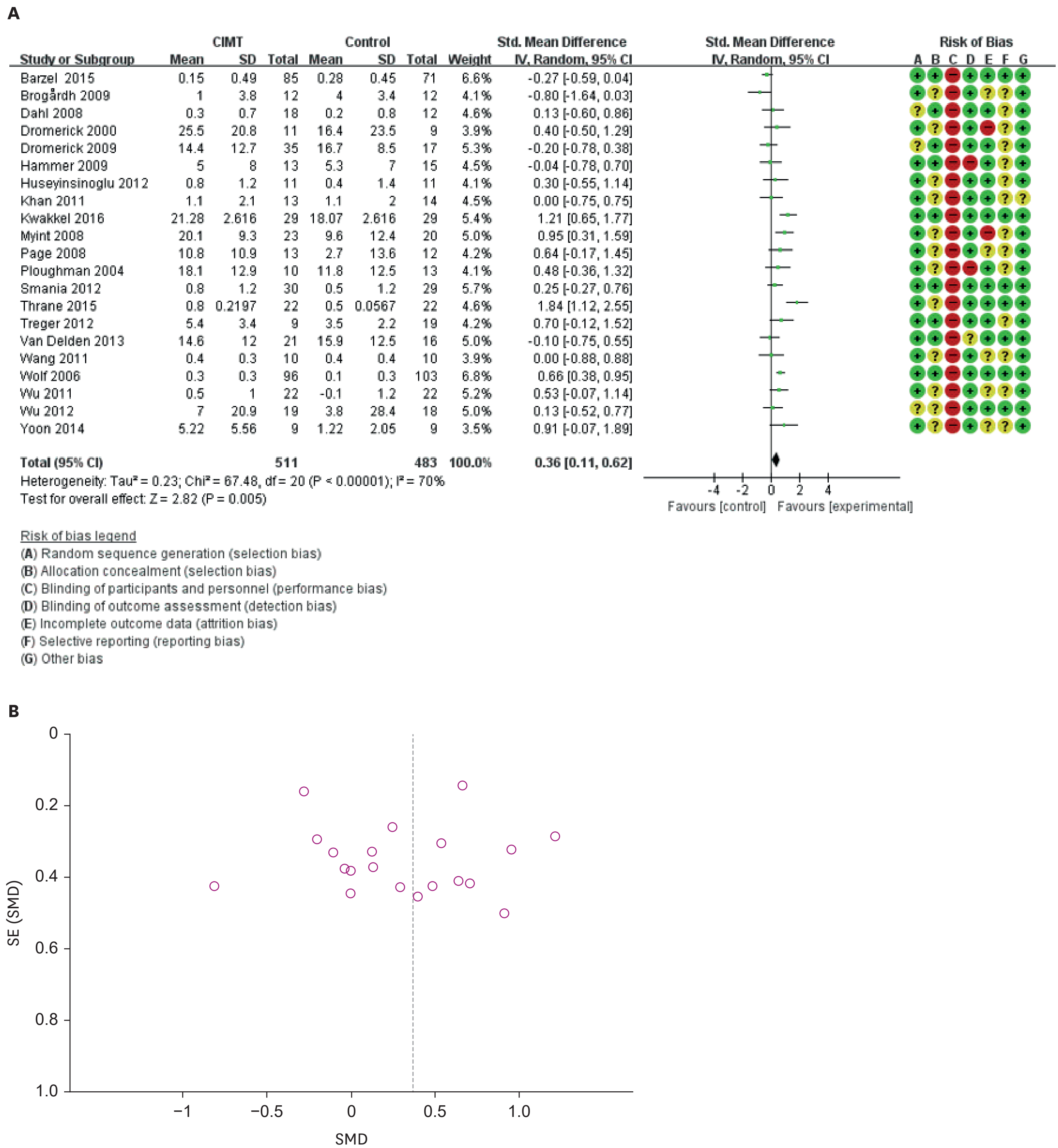



**Fig. 3.** Arm motor function. (A) Forest plot of meta-analyses. (B) Funnel plots.
CIMT, constraint-induced movement therapy; SD, standard deviation; IV, inverse variance; CI, confidence interval; SE, standard error; SMD, standardized mean difference.

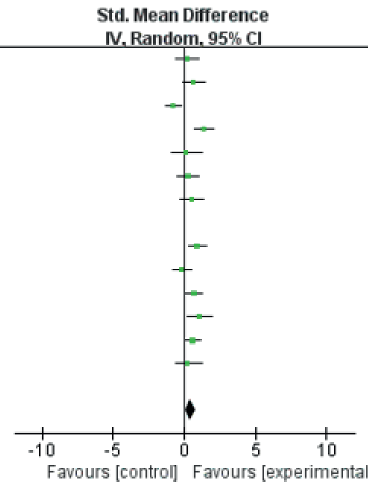
## Upper limb impairment

A total of 13 studies were included in the assessment of upper limb impairment [13,18,21,23,24,27,28,33,34,38,39,42,43]. CIMT showed a superior effect on improvements in upper limb impairment compared with conventional rehabilitation therapy (SMD, 0.44; 95% CI, 0.09–0.78; p = 0.01) (**Fig. 4**).

**A**

| | CIMT | | | Control | | | | Std. Mean Difference | Risk of Bias | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI | A | B | C | D | E | F | G |
| Boake 2007 | 18.2 | 14.2 | 10 | 14.1 | 23.1 | 12 | 7.0% | 0.20 [-0.64, 1.04] | ? | ? | − | + | − | ? | + |
| Hammer 2009 | 3.8 | 3 | 13 | 1.8 | 2.9 | 15 | 7.5% | 0.66 [-0.11, 1.42] | + | + | − | − | + | ? | + |
| Kwakkel 2016 | 15.86 | 2.24 | 29 | 17.61 | 2.24 | 29 | 9.3% | -0.77 [-1.31, -0.24] | + | + | − | + | + | + | + |
| Lin 2009 | 6.3 | 3.4 | 20 | 1.5 | 3.4 | 20 | 8.0% | 1.38 [0.69, 2.08] | + | + | − | + | ? | ? | + |
| Lin 2010 | 5.6 | 7.6 | 5 | 3.5 | 15.8 | 8 | 5.3% | 0.15 [-0.97, 1.27] | ? | ? | − | ? | ? | ? | + |
| Page 2008 | 7.9 | 10.9 | 13 | 3.9 | 16.3 | 12 | 7.3% | 0.28 [-0.51, 1.07] | + | ? | − | + | ? | ? | + |
| Ploughman 2004 | 1.7 | 2.3 | 10 | 0.8 | 1.1 | 13 | 7.0% | 0.50 [-0.34, 1.34] | + | ? | − | − | + | ? | + |
| Singh 2013 | 24.95 | 3.74 | 20 | 9.5 | 2.7 | 20 | 0.0% | 4.64 [3.40, 5.88] | + | ? | − | − | + | ? | + |
| Thrane 2015 | 7.5 | 3.01 | 22 | 5 | 2.501 | 22 | 8.6% | 0.89 [0.27, 1.51] | + | ? | − | + | + | + | + |
| Van Delden 2013 | 7.8 | 9.4 | 21 | 9.2 | 7.3 | 16 | 8.4% | -0.16 [-0.81, 0.49] | + | + | − | ? | + | + | + |
| Wu2007(b) | 7.3 | 6.6 | 24 | 3 | 5.9 | 23 | 8.8% | 0.67 [0.09, 1.26] | + | ? | − | + | + | ? | + |
| Wu 2007(c) | 7.7 | 6.2 | 13 | 2.3 | 2.8 | 13 | 7.0% | 1.09 [0.25, 1.92] | + | ? | − | + | + | ? | + |
| Yadav 2016 | 48.1 | 5.42 | 30 | 45.4 | 3.42 | 30 | 9.4% | 0.59 [0.07, 1.11] | ? | ? | − | ? | + | ? | + |
| Yoon 2014 | 5.44 | 4.67 | 9 | 4.33 | 2.65 | 9 | 6.4% | 0.28 [-0.65, 1.21] | + | ? | − | + | ? | ? | + |
| **Total (95% CI)** | | | **219** | | | **222** | **100.0%** | **0.44 [0.09, 0.78]** | | | | | | | |

Heterogeneity: Tau² = 0.26; Chi² = 36.26, df = 12 (P = 0.0003); I² = 67%
Test for overall effect: Z = 2.49 (P = 0.01)




Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Other bias

**B**

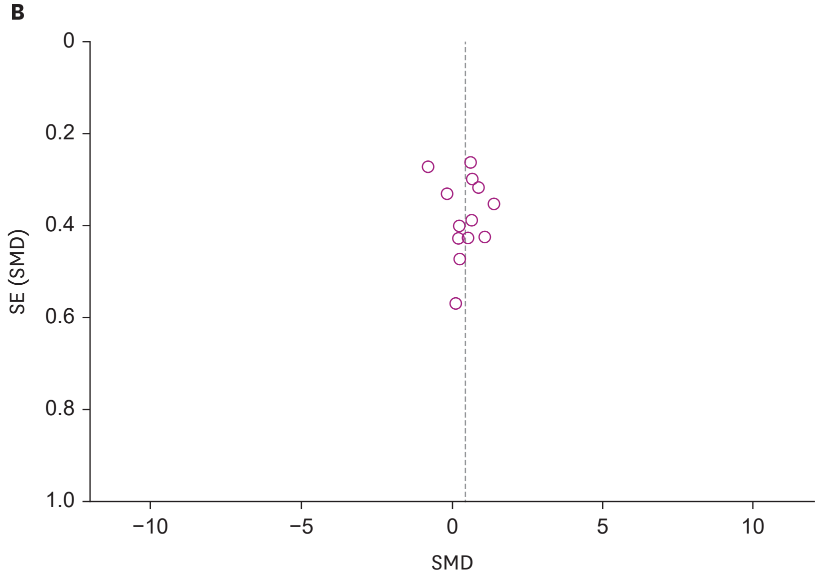



**Fig. 4.** Arm motor impairment. (A) Forest plot of meta-analyses. (B) Funnel plots.
CIMT, constraint-induced movement therapy; SD, standard deviation; IV, inverse variance; CI, confidence interval; SE, standard error; SMD, standardized mean difference.

## ADL

A total of 12 studies were included in the assessment of ADL [6,15,17,19,22,23,26,28,33,37,39,43]. CIMT showed a superior effect on improvements in ADL compared with conventional rehabilitation therapy (SMD, 0.24; 95% CI, 0.01–0.48; p = 0.04) (**Fig. 5**).

**Table 1** summarizes the evidence and GRADE assessments.

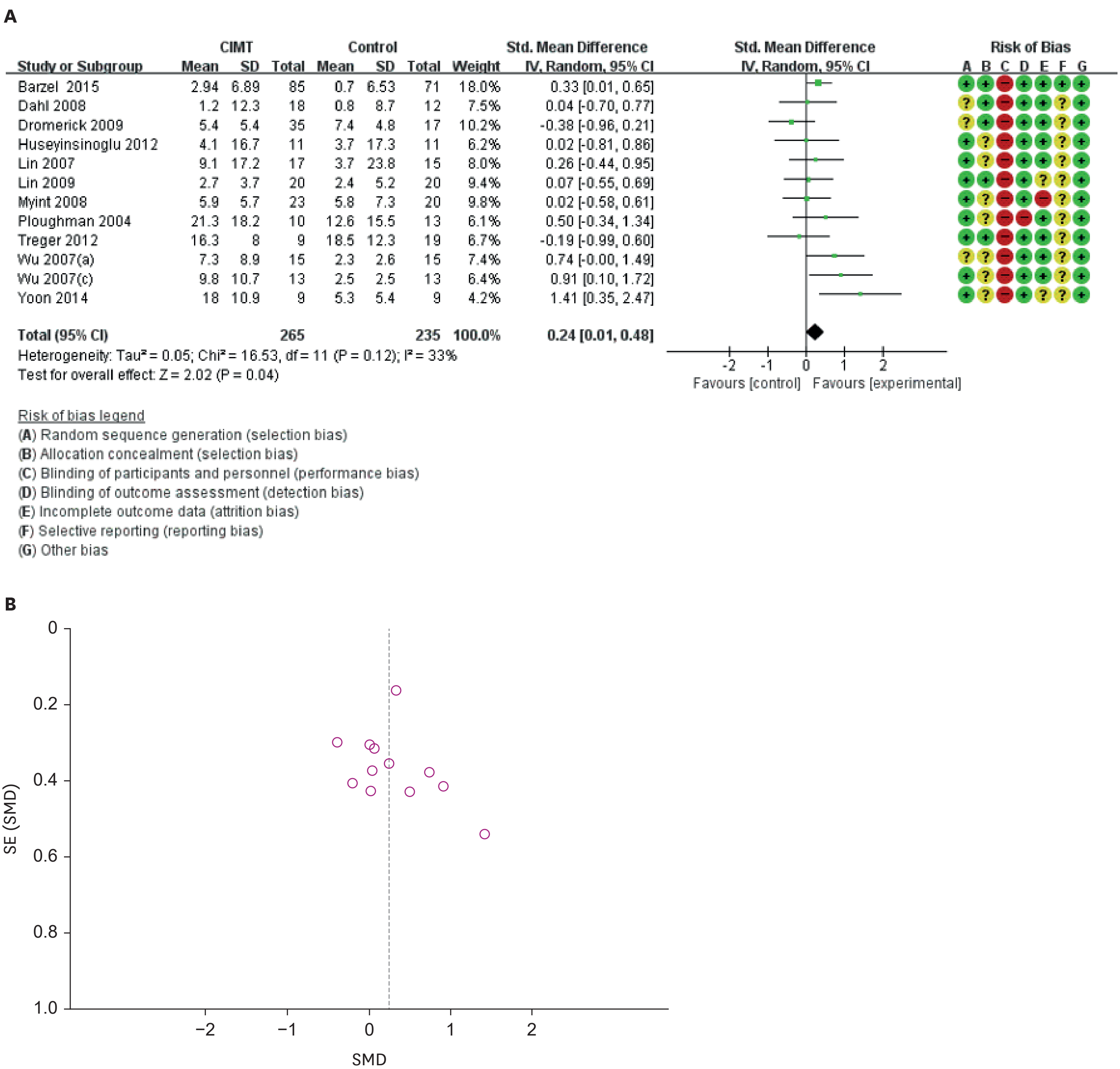



**Fig. 5.** ADL. (A) Forest plot of meta-analyses. (B) Funnel plots.
ADL, activities of daily living; CIMT, constraint-induced movement therapy; SD, standard deviation; IV, inverse variance; CI, confidence interval; SE, standard error; SMD, standardized mean difference.


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**Table 1.** Evidence summaries and GRADEs

| Outcomes | No. of participants (No. of studies) | Certainty of evidence (GRADE) | Statistical method | Effect size |
|---|---|---|---|---|
| Arm motor function | 994 (21) | Low | SMD (IV, Random, 95% CI) | 0.36 (0.11, 0.62) |
| Arm motor impairment | 441 (13) | Low | SMD (IV, Random, 95% CI) | 0.44 (0.09, 0.78) |
| ADL | 500 (12) | Moderate | SMD (IV, Random, 95% CI) | 0.24 (0.01, 0.48) |

GRADE, Grading of Recommendations Assessment, Development, and Evaluation; SMD, standardized mean difference; IV, inverse variance; CI, confidence interval; ADL, activities of daily living.

## DISCUSSION

Our meta-analysis revealed that CIMT was significantly more effective than conventional therapy in improving arm motor function, reducing arm motor impairment, and enhancing ADL.

Our results are consistent with the findings of a previous systematic review, which showed significant improvements in arm motor function and impairment following CIMT [44]. However, that study had limitations regarding the generalization of the results due to the inclusion of studies with small numbers of participants or those that contributed to increased heterogeneity. Herein, we excluded such studies and included more recent reports [6,21,32,42]. Despite these changes, CIMT demonstrated significant effects, which is consistent with previous findings. Regarding ADL, this study demonstrated statistically significant improvements with CIMT than with conventional therapy, despite having an effect size similar to that reported in the aforementioned systematic review, which only showed trends favoring CIMT over conventional therapy. The significant observation herein was likely due to the inclusion of a single RCT that had a larger sample size than those included in previous analyses, which increased the overall statistical power [6]. The variability in modulation factors across RCTs, including differences in outcome measures, duration and method of CIMT application, intensity and type of intensive therapy, and other methodological differences, may have contributed to the discrepancies in the results. Large-scale RCTs are required to further investigate the effects of CIMT in stroke patients.

When evaluating the certainty of evidence for key outcome indicators using the GRADE method, bias was observed in the blinding of participants for all outcome indicators. It is important to acknowledge that none of the studies included herein employed blinding of participants. Therefore, these results should be interpreted with caution.

Regarding the application of CIMT, certain clinical aspects—such as benefits and harms, patient values and preferences, implementation barriers, and resources—should be considered.

In patients with stroke-induced hemiplegia, CIMT improved upper-limb motor function, reduced upper-limb impairment, and enhanced ADL performance. No adverse events associated with the use of CIMT were observed.

The patient preferences for CIMT varied. Increasing the use of the affected limb during therapy may enhance satisfaction with rehabilitation and motivation to participate. In contrast, restricting the unaffected limb may cause discomfort and lead to negative feelings toward the therapy. Therefore, it is important to consider patient values and preferences when implementing CIMT.

Currently, no specific reimbursement code for CIMT exists in Korea. Therefore, it is implemented using conventional treatment prescriptions. However, these existing prescriptions have limitations in allowing focused monitoring of the restriction of the unaffected limb and providing an adequate amount of therapy. Therefore, the development of a practical reimbursement structure within the healthcare system is necessary to support the effective implementation of CIMT.

The additional costs associated with implementing CIMT are not significant, and only expenses related to extra rehabilitation therapy are necessary.

In conclusion, if CIMT can be tailored to the strength of the affected upper limb, it should be utilized to enhance upper limb function and ADL performance in post-stroke patients with hemiplegia. Clinicians should implement CIMT considering the unique values and preferences of each patient.

## SUPPLEMENTARY MATERIALS

### Supplementary Table 1

Search terms and strategies

### Supplementary Table 2

Characteristics of included studies

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