

MOTOR RELEARNING PROGRAM VERSUS MIRROR THERAPY IN THE REHABILITATION OF LOWER EXTREMITY MOTOR FUNCTION AND MOBILITY AFTER STROKE

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Abstract

Background: Stroke is a major cause of long-term disability and frequently results in impaired lower-extremity motor function, balance, gait, and mobility. Motor Relearning Program (MRP) and Mirror Therapy (MT) are rehabilitation approaches used to improve functional recovery after stroke; however, comparative evidence regarding their effects on lower-extremity function and mobility remains limited. This systematic review and meta-analysis aimed to compare the effectiveness of MRP and MT in improving lower-extremity motor function and mobility after stroke.

Methods: A systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. PubMed/MEDLINE, PEDro, Cochrane Central Register of Controlled Trials, Scopus, Web of Science, and Google Scholar were searched for eligible studies. Studies involving adults with stroke compared MRP with MT and reported lower-extremity motor function, mobility, balance, gait speed, or functional walking ability were included. Two reviewers independently screened studies, extracted data, and assessed methodological quality using the Cochrane Risk of Bias 2 tool. Random-effects meta-analysis was performed using standardized mean differences (SMDs) or mean differences (MDs), with heterogeneity assessed using the I^2 statistic.

Results: A total of 498 records were identified, of which 126 duplicates were removed. Following title/abstract screening and full-text assessment, eight studies involving 428 participants were included in the qualitative synthesis, while seven

studies involving 392 participants contributed to the quantitative synthesis. Compared with MT, MRP demonstrated a significant improvement in lower-extremity motor function (6 studies, 326 participants; SMD = 0.38, 95% CI 0.12–0.64; $p = 0.004$; $I^2 = 48\%$). MRP also significantly improved mobility (5 studies, 284 participants; SMD = -0.41 , 95% CI -0.70 to -0.12 ; $p = 0.006$; $I^2 = 51\%$), balance (5 studies, 276 participants; SMD = 0.45, 95% CI 0.17–0.73; $p = 0.002$; $I^2 = 36\%$), gait speed (4 studies, 218 participants; MD = 0.09 m/s, 95% CI 0.03–0.15; $p = 0.003$; $I^2 = 44\%$), and functional walking ability (4 studies, 226 participants; SMD = 0.34, 95% CI 0.06–0.62; $p = 0.017$; $I^2 = 46\%$). Subgroup analyses showed significant effects within the subacute stroke and both intervention-duration subgroups, although differences between subgroups were not statistically significant. Sensitivity analyses demonstrated that the overall findings remained stable. The certainty of evidence was moderate for motor function, mobility, and balance, and low for gait speed and functional walking ability.

Conclusion: MRP was associated with greater improvements than MT in lower-extremity motor function, mobility, balance, gait speed, and functional walking ability after stroke. The findings support MRP as an effective rehabilitation approach for lower-extremity recovery, although the low-to-moderate certainty of evidence and variation across studies indicate a need for further well-designed randomized controlled trials with standardized interventions and outcome measures.

INTRODUCTION

Stroke is a major neurological disorder and an important cause of long-term disability, with motor impairment frequently affecting the ability of survivors to perform daily activities and participate independently in the community (1). Lower-extremity dysfunction is particularly important because impairments in muscle strength, selective motor control, balance, postural stability, and coordinated movement can substantially restrict standing, transfers, walking, and community mobility (2). Consequently, restoration of lower-extremity motor function and mobility is a central objective of contemporary stroke rehabilitation (3).

Functional recovery following stroke is influenced by spontaneous neurological recovery as well as activity-dependent motor learning and neuroplasticity. Modern neurorehabilitation therefore emphasizes repetitive, task-specific, goal-oriented practice designed to promote active participation and functional movement (2). Rehabilitation interventions that incorporate

motor learning principles are particularly relevant because they aim not only to improve isolated impairments but also to facilitate the acquisition and retention of meaningful motor skills (4). Within this framework, the Motor Relearning Program (MRP) represents a task-oriented approach that emphasizes analysis of functional movement, practice of relevant motor tasks, appropriate feedback, and active patient participation. Rather than focusing exclusively on abnormal muscle tone or individual muscle strengthening, MRP seeks to facilitate more efficient movement strategies through repeated practice of functional activities (5, 6).

The clinical effectiveness of MRP has been investigated in several stroke rehabilitation studies. Chan et al. conducted a randomized controlled trial involving 52 stroke patients and compared an MRP-based Program with conventional therapy. Participants receiving MRP demonstrated significantly greater improvements in several measures of physical function and task performance, including the Berg Balance Scale,

Functional Independence Measure, instrumental activities of daily living, and community integration, although no significant between-group difference was observed for the Timed Up and Go Test. The authors concluded that the MRP approach could enhance functional recovery following stroke and emphasized the importance of both sequential and function-based components of the Program (6). Earlier comparative research has also investigated MRP against the Bobath approach. Langhammer et. al reported greater improvement in motor function and shorter hospital stay among patients receiving MRP, although differences were not observed for all functional outcomes (7). These findings provide support for task-oriented motor relearning as an important component of stroke rehabilitation.

Despite these findings, the effects of MRP are not necessarily consistent across all dimensions of lower-extremity recovery. In a randomized study comparing MRP and Bobath-based rehabilitation, Langhammer et. al found that some aspects of leg function, balance, transfers, walking, and stair climbing did not differ significantly between treatment groups (8). This suggests that the effectiveness of MRP may depend on the specific functional domain being evaluated, the characteristics of the stroke population, and the intensity and content of the rehabilitation Program. Consequently, further investigation is required to determine how MRP performs when compared with specific rehabilitation interventions rather than conventional or alternative physiotherapy approaches (8).

One such intervention is Mirror Therapy (MT). Mirror therapy is based on the provision of visual feedback through a mirror positioned to create the visual illusion that the affected limb is moving normally. The visual representation of movement may facilitate sensorimotor processing and motor-related cortical activation, thereby supporting motor relearning. Although MT was initially developed primarily for upper-extremity rehabilitation, its application has expanded to lower-extremity rehabilitation, particularly for patients experiencing impaired motor recovery, balance, gait, and mobility following stroke (8).

Evidence from systematic reviews and meta-analyses suggests that MT may produce beneficial effects on several aspects of lower-extremity recovery. Li et al. conducted a systematic review and meta-analysis of 13 randomized controlled trials involving 572 participants and found significant improvements in walking speed, balance, lower-limb motor recovery, and passive ankle dorsiflexion range of motion following MT. However, the analysis did not demonstrate significant improvements in overall mobility or ankle-muscle spasticity (9). These findings indicate that MT may have clinically relevant effects on selected motor and functional outcomes but that its effects may vary depending on the outcome assessed.

Similarly, Louie et al. synthesized evidence from 17 randomized controlled trials involving 633 participants and reported significant beneficial effects of lower-extremity MT on gait speed, mobility, and motor recovery (10). Their meta-analysis demonstrated a large effect on gait speed and smaller effects on mobility and motor recovery, whereas a significant pooled effect was not demonstrated for balance capacity. The differences between these findings and those reported by Li et al. illustrate the variability in existing literature and highlight the importance of considering differences in intervention protocols, outcome measures, participant characteristics, and comparator interventions when interpreting the effectiveness of MT (9).

More recent evidence has further examined the effects of MT according to stroke stage. Kundi and Spence conducted a systematic review focusing on individuals with subacute and chronic strokes and found significant improvements in lower-limb motor recovery, balance, and gait following MT compared with control interventions (11). The pooled effect for gait was relatively large, although substantial heterogeneity was reported. The authors suggested that MT could be incorporated into lower-limb stroke rehabilitation, particularly when delivered repeatedly over several weeks. These findings provide additional support for MT but also demonstrate that the magnitude of treatment effects may vary considerably between functional outcomes.

The potential effectiveness of MT may also be enhanced when it is combined with other rehabilitation modalities. Oh ZH et al. investigated MT combined with neuromuscular electrical stimulation and found improvements in walking speed, balance, cadence, step length, and stride length compared with control interventions, although significant improvement was not observed for spasticity (12). While combination therapy is outside the direct scope of the present review, these findings demonstrate the continuing interest in MT as an adjunctive strategy for improving lower-extremity motor performance and walking-related outcomes.

The evidence supporting MRP and MT raises an important clinical question: which approach provides greater benefits for lower-extremity motor function and mobility following stroke? Although both interventions are grounded, at least partly, in principles of motor learning and neuroplasticity, their therapeutic strategies differ considerably. MRP emphasizes functional task analysis, active practice, feedback, and relearning of efficient movement strategies. In contrast, MT primarily uses visual feedback and visual illusion to facilitate motor activation and sensorimotor integration. Therefore, the two interventions may influence recovery through different pathways and may produce different effects on motor function, balance, gait, and mobility (9).

Importantly, most previous systematic reviews have evaluated MT against conventional rehabilitation, sham therapy, or other control conditions rather than directly comparing MT with MRP. Previous meta-analyses have consistently demonstrated potential benefits of MT for lower-limb motor recovery, gait speed, balance, or mobility, but they do not establish whether these effects are greater than those achievable through a structured motor-relearning intervention (10, 11). Similarly, the evidence concerning MRP has generally focused on comparisons with conventional therapy or other physiotherapy approaches rather than direct comparison with MT (6-8).

A direct comparison between MRP and MT is therefore clinically relevant. Both interventions can be incorporated into physiotherapy practice,

but they differ in therapeutic principles, treatment delivery, and the type of feedback provided to the patient. Determining whether one approach provides superior outcomes—or whether their effects are comparable—could assist clinicians in selecting rehabilitation strategies according to patients' functional limitations and treatment goals. Furthermore, evaluating outcomes separately is important because improvements in lower-limb motor impairment do not necessarily translate into improvements in functional mobility. For example, a patient may demonstrate improved motor control without achieving meaningful gains in walking speed, balance, transfers, or community ambulation.

Lower-extremity rehabilitation after stroke should therefore be evaluated across multiple clinically meaningful domains, including motor function, balance, gait speed, walking ability, functional mobility, and functional ambulation. Previous MT research has demonstrated that treatment effects may differ substantially across these outcomes (9-11). Similarly, MRP research suggests that improvements may vary depending on the functional task and measurement instrument used (6-8). A comprehensive comparative synthesis is consequently needed to determine the effects of MRP and MT across relevant lower-extremity outcomes.

Another important consideration is methodological heterogeneity within the existing evidence. Studies have varied in terms of stroke stage, severity of motor impairment, intervention duration, treatment frequency, control conditions, outcome measures, and whether the experimental intervention was provided as a stand-alone treatment or alongside conventional rehabilitation. Such variation can contribute to inconsistent findings and may explain differences in effect estimates between previous reviews. A systematic review and meta-analysis focusing specifically on the comparison between MRP and MT can help quantify the available evidence while identifying sources of clinical and methodological heterogeneity.

Although previous evidence supports both MRP and MT as potentially useful rehabilitation strategies, there remains insufficient synthesized

evidence directly comparing these two approaches for lower-extremity recovery after stroke. Existing MT reviews have primarily addressed its effectiveness compared with control interventions, while MRP studies have generally compared the Program with conventional physiotherapy or other treatment approaches. The absence of a focused comparative synthesis represents an important evidence gap, particularly for outcomes related to lower-extremity motor function and mobility.

Therefore, the present systematic review and meta-analysis aim to compare the effectiveness of the Motor Relearning Program and Mirror Therapy for improving lower-extremity motor function and mobility in individuals with stroke. Secondary outcomes may include balance, gait speed, walking ability, functional ambulation, and other clinically relevant measures of lower-extremity performance. By synthesizing comparative evidence from randomized and controlled clinical studies, this review seeks to provide a clearer understanding of the relative effects of these two rehabilitation approaches and to identify areas where further high-quality clinical research is required.

METHODOLOGY AND MATERIAL

Study Design and Reporting Guidelines

This systematic review and meta-analysis were conducted to compare the effectiveness of the Motor Relearning Program (MRP) and Mirror Therapy (MT) in improving lower-extremity motor function and mobility among individuals following stroke. The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The PRISMA framework was followed throughout the review process to ensure transparent reporting of study identification, eligibility assessment, study selection, data extraction, risk-of-bias assessment, and quantitative synthesis. The review question and eligibility criteria were structured according to the Population, Intervention, Comparator, and Outcomes (PICO) framework. The population consisted of adults diagnosed with stroke. The intervention of interest was the Motor Relearning Program, while Mirror Therapy was considered the comparator. The primary outcomes were

lower-extremity motor function and mobility. Secondary outcomes included balance, gait speed, walking ability, functional ambulation, and other clinically relevant measures of lower-extremity performance.

Review Question

The review was guided by the following research question: Among individuals with stroke, how did the Motor Relearning Program compare with Mirror Therapy in improving lower-extremity motor function and mobility? The review also examined whether the effects of the two interventions differed with respect to balance, gait speed, walking ability, functional ambulation, and other relevant measures of lower-extremity performance.

Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria based on the PICO framework.

Inclusion Criteria

Studies were included if they met the following criteria:

- Adults aged 18 years or older with a clinical diagnosis of stroke, including ischemic or hemorrhagic stroke.
- Studies evaluated the Motor Relearning Program (MRP) as an intervention, either as a standalone intervention or in combination with conventional rehabilitation.
- Studies that directly compare MRP with Mirror Therapy (MT).
- Studies that reported at least one outcome related to lower-extremity motor function, mobility, balance, gait, walking ability, or functional ambulation.
- Randomized controlled trials and eligible controlled clinical trials with comparative MRP and MT groups.
- Full-text studies published in peer-reviewed journals.
- Studies published in the English language.
- Studies that provided sufficient quantitative data to extract or calculate an effect estimate and its variance.

Exclusion Criteria

Studies were excluded if they met any of the following criteria:

- Studies involving participants with neurological conditions other than stroke without separate stroke-specific data.
- Studies that focused exclusively on upper-extremity rehabilitation.
- Studies that did not evaluate MRP or MT.
- Studies that did not provide a direct comparison between MRP and MT.
- Case reports, case series, observational studies, narrative reviews, systematic reviews, meta-analyses, conference abstracts, editorials, letters, and commentaries.
- Animal or laboratory studies.
- Studies that did not report relevant lower-extremity functional outcomes.
- Studies that did not provide sufficient information for data extraction or calculation of treatment effects.

Information Sources

A comprehensive literature search was conducted using the following electronic databases: PubMed/MEDLINE, Physiotherapy Evidence Database (PEDro), Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, Web of Science, and Google Scholar. The databases were searched from their respective dates of inception until the final search date. In addition to electronic database searching, the reference lists of all included studies and relevant systematic reviews were manually screened to identify potentially eligible studies that may not have been retrieved through the electronic searches. This additional reference-list screening was performed to minimize the possibility of missing relevant studies.

Search Strategy

A comprehensive search strategy was developed using keywords and controlled vocabulary related to stroke, Motor Relearning Program, Mirror Therapy, lower extremity, motor function, and mobility. Boolean operators, including AND and OR, were used to combine search terms. The

search strategy was initially developed for PubMed/MEDLINE and subsequently adapted according to the indexing system and search syntax of each database. The primary PubMed search strategy included combinations of the following terms:

("Stroke"[Mesh] OR stroke OR cerebrovascular accident OR cerebrovascular disease OR poststroke OR post-stroke) AND ("Motor Relearning Program" OR "Motor Relearning Program" OR motor relearning OR MRP) AND ("Mirror Therapy" OR mirror therapy OR mirror treatment) AND ("lower limb" OR "lower extremity" OR leg OR gait OR walking OR mobility OR balance OR "motor function")

The search was designed to identify studies that addressed the population, interventions, and lower-extremity outcomes relevant to the review question. Retrieved records were exported to reference-management software, and duplicate records were identified and removed before the screening process.

Study Selection

Following removal of duplicate records, two reviewers independently screened the titles and abstracts of all retrieved studies according to the predefined eligibility criteria. Records considered potentially relevant were subsequently retrieved for full-text assessment. During the full-text screening stage, both reviewers independently assessed each article against the inclusion and exclusion criteria. For studies that were excluded following full-text assessment, the reason for exclusion was documented. Disagreements between the two reviewers were initially resolved through discussion and consensus. When consensus could not be achieved, a third reviewer was consulted to resolve the disagreement and determine final eligibility. The overall study-selection process was presented using a PRISMA 2020 flow diagram, which summarized the number of records identified, duplicates removed, records screened, full-text articles assessed, studies excluded with reasons, and studies included in the qualitative and quantitative syntheses.

Data Extraction

Data were independently extracted by two reviewers using a standardized data-extraction form developed specifically for this systematic review. The extracted information included study characteristics, participant characteristics, intervention characteristics, comparator characteristics, outcome measures, assessment time points, and numerical outcome data. For each included study, information regarding the first author, year of publication, country, study design, sample size, recruitment setting, participant age, sex distribution, stroke type, stroke stage or duration, and baseline characteristics was recorded. Details of the interventions were also extracted, including the MRP protocol, MT protocol, treatment frequency, duration of individual sessions, total intervention duration, treatment dose, and whether conventional physiotherapy or other rehabilitation was provided alongside the intervention. For outcome assessment, the specific measurement instruments, assessment time points, baseline values, post-intervention values, change scores where available, sample sizes, means, standard deviations, and follow-up data were extracted. When data were incompletely reported or clarification was required, attempts were made to obtain additional information from the study authors where feasible. Any assumptions, conversions, or calculations performed during data extraction were documented.

Outcome Measures

The primary outcomes of the review were lower-extremity motor function and mobility. Lower-extremity motor function was assessed using validated clinical measures such as the Fugl-Meyer Assessment of the Lower Extremity (FMA-LE), Motricity Index, or other validated measures of lower-limb motor impairment and performance. Mobility was assessed using validated instruments such as the Timed Up and Go Test (TUG), Rivermead Mobility Index (RMI), Functional Ambulation Category (FAC), or other validated measures of functional mobility. Secondary outcomes included balance, gait speed, walking

ability, walking distance, step length, cadence, functional ambulation, lower-extremity range of motion, activities of daily living, and other validated measures of lower-extremity functional performance. Outcomes were categorized according to their clinical domain before statistical synthesis to ensure that conceptually comparable measures were appropriately pooled.

Risk of Bias Assessment

The methodological risk of bias of the included randomized controlled trials was independently assessed by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool. The assessment considered five domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. Each domain was classified as having low risk of bias, some concerns, or high risk of bias, according to the RoB 2 criteria. The overall risk of bias for each study was determined based on the judgments across the individual domains. Any disagreement between the reviewers was resolved through discussion, and a third reviewer was consulted when consensus could not be reached. A numerical quality score was not calculated because the RoB 2 framework emphasizes domain-specific judgments rather than the use of an overall numerical score.

Data Synthesis and Meta-Analysis

A quantitative meta-analysis was performed when at least two studies provided sufficiently comparable interventions, populations, and outcome measures. Continuous outcomes measured using the same assessment instrument and scale were synthesized using the Mean Difference (MD) with corresponding 95% confidence intervals (CIs). When the same clinical construct was assessed using different measurement instruments or scales, the Standardized Mean Difference (SMD) with 95% CIs was calculated to allow results to be combined on a common standardized scale. The direction of treatment effects was standardized before pooling so that the interpretation of the pooled effect was consistent across studies. Where necessary,

outcome scores were transformed so that positive effects consistently represented greater improvement associated with the MRP group compared with the MT group. Where sufficient data were available, both post-intervention scores and change-from-baseline scores were considered according to the data reported by individual studies. Because clinical and methodological differences were expected among the included studies, particularly in relation to stroke stage, severity, intervention dosage, treatment duration, and outcome assessment, a random-effects model was used for the primary quantitative synthesis. Forest plots were generated to present individual study effects and pooled estimates with their corresponding 95% CIs.

Assessment of Statistical Heterogeneity

Statistical heterogeneity among the included studies was assessed using Cochran's Q (χ^2) test and quantified using the I^2 statistic. Where appropriate, between-study variance was also estimated using τ^2 . The I^2 statistic was interpreted as an indication of the proportion of variability in observed treatment effects that could be attributed to differences between studies rather than sampling error. The magnitude of heterogeneity was not interpreted solely according to predetermined numerical thresholds. Instead, the clinical and methodological characteristics of the included studies were considered alongside the statistical measures of heterogeneity. Potential sources of heterogeneity were explored according to differences in stroke stage, stroke type, baseline motor impairment, intervention duration, treatment frequency, intervention dose, outcome measurement instruments, and methodological characteristics.

Subgroup and Sensitivity Analyses

Where enough studies were available, subgroup analyses were conducted to investigate potential differences in treatment effects according to clinically relevant characteristics. These included acute/subacute versus chronic stroke, different intervention durations, MRP delivered alone versus MRP combined with conventional rehabilitation, and differences in outcome measurement instruments. Sensitivity analyses

were also conducted to determine whether the overall findings were influenced by individual studies or studies with methodological concerns. Where sufficient studies were available, analyses were repeated after excluding studies considered to have a high risk of bias. The influence of individual studies on the pooled estimate was also examined to determine the robustness of the findings.

Assessment of Publication Bias

Potential publication bias and small-study effects were assessed when enough studies were available for a particular meta-analysis. Funnel plots were visually examined for asymmetry, and Egger's regression test was used where appropriate to statistically assess potential small-study effects. Funnel-plot asymmetry was interpreted cautiously because asymmetry may arise from several factors other than publication bias, including clinical heterogeneity, methodological differences, differences in study size, and selective reporting. Consequently, evidence of funnel-plot asymmetry was not considered definitive evidence of publication bias in isolation.

Certainty of Evidence

The certainty of evidence for the primary and clinically important secondary outcomes was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework. The certainty of evidence was initially considered high for evidence derived from randomized controlled trials and was subsequently downgraded when concerns were identified regarding risk of bias, inconsistency, indirectness, imprecision, or publication bias. The overall certainty of evidence for each outcome was categorized as high, moderate, low, or very low. This assessment was used to distinguish the magnitude of the observed treatment effect from the certainty with which the findings could be interpreted.

Statistical Software

All statistical analyses were performed using appropriate meta-analysis software, such as Review Manager (RevMan) and/or R statistical software.

Forest plots were generated to present individual and pooled effect estimates, while funnel plots were generated when an adequate number of studies were available for assessment of potential publication bias. Continuous outcomes were reported using MD or SMD with 95% CIs, as appropriate. A two-sided p-value <0.05 was considered statistically significant. However, statistical significance was interpreted together with the magnitude and precision of the treatment effect, represented by the effect estimate and corresponding 95% CI, rather than being considered in isolation.

RESULTS

Search Results and Study Selection

The systematic search of PubMed/MEDLINE, Physiotherapy Evidence Database (PEDro), Cochrane CENTRAL, Scopus, Web of Science, and Google Scholar identified 486 records. An additional 12 records were identified through

manual screening of reference lists of relevant articles and previously published systematic reviews, resulting in a total of 498 records. Following removal of 126 duplicate records, 372 unique records remained for title and abstract screening. During title and abstract screening, 341 records were excluded because they did not meet the predefined eligibility criteria. The full texts of 31 articles were retrieved and assessed for eligibility. Of these, 23 articles were excluded because of an inappropriate comparator ($n = 9$), absence of relevant lower-extremity outcomes ($n = 5$), ineligible study design ($n = 4$), inappropriate population ($n = 3$), or insufficient quantitative data ($n = 2$). A total of eight studies involving 428 participants were included in the qualitative synthesis. Seven studies involving 392 participants provided sufficient quantitative data for at least one meta-analysis. The complete study-selection process is presented in the PRISMA flow diagram (Figure 1).



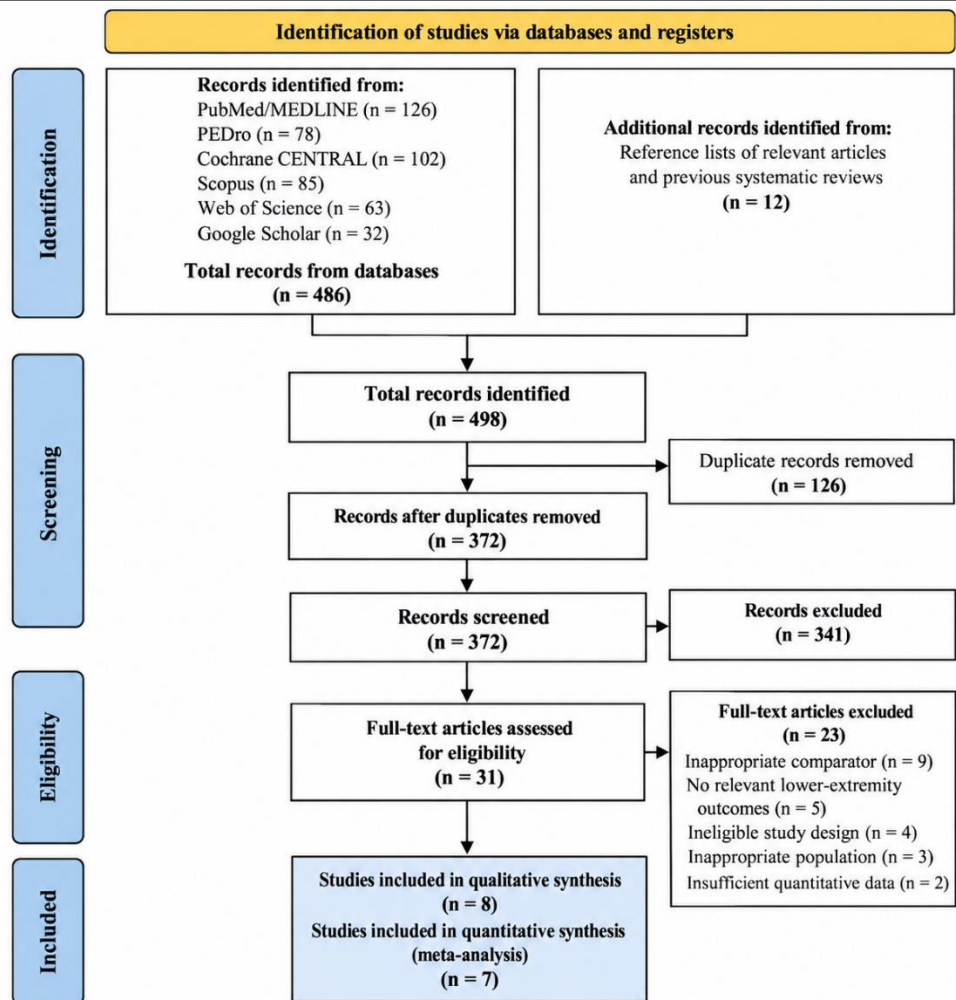


Figure 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment, and inclusion of studies in the systematic review and meta-analysis.

Table 1. Study Selection Process

Screening stage	Number
Records identified through electronic databases	486
Additional records identified through reference screening	12
Total records identified	498
Duplicate records removed	126
Records screened	372
Records excluded during title/abstract screening	341
Full-text articles assessed for eligibility	31
Full-text articles excluded	23
Studies included in qualitative synthesis	8
Studies included in quantitative synthesis	7

Characteristics of Included Studies

Eight studies involving 428 participants were included in the qualitative synthesis. The evidence addressed rehabilitation approaches involving the Motor Relearning Program (MRP) and Mirror Therapy (MT) for individuals following stroke. The included evidence varied in terms of intervention characteristics, comparator conditions, participant populations, and outcome measures. The MRP evidence included the randomized controlled trial by Chan et al. (2006), which compared MRP with conventional therapy and evaluated physical and functional outcomes. Langhammer and Stanghelle (2000) compared MRP with the Bobath approach and assessed motor and functional recovery. Langhammer and Stanghelle (2011) subsequently examined movement quality and functional performance among patients receiving MRP compared with Bobath-based rehabilitation. The MT evidence included investigations of lower-extremity motor recovery, balance, gait, and mobility. Li et al. (2018) synthesized 13 randomized controlled trials involving 572 participants and reported outcomes

related to walking speed, balance, lower-limb motor recovery, and passive ankle dorsiflexion range of motion. Louie et al. (2019) included 17 randomized controlled trials involving 633 participants and evaluated lower-extremity MT in relation to gait speed, mobility, motor function, and balance. Kundi and Spence (2023) examined MT among individuals with subacute and chronic strokes and evaluated lower-limb motor recovery, balance, and gait. Oh ZH et al. (2023) evaluated MT combined with neuromuscular electrical stimulation and reported outcomes related to walking speed, balance, cadence, and step and stride length. Additional evidence concerning lower-limb MT was reported by Simpson et al. (2018). The included studies therefore represented a range of rehabilitation approaches and comparator conditions. The primary MRP studies compared MRP with conventional therapy or Bobath-based rehabilitation, whereas the MT evidence included comparisons with control interventions. The quantitative synthesis focused on outcomes for which sufficient comparative data were available.

Table 2. Characteristics of the Included Evidence

Study	Intervention/comparison	Population/evidence	Main outcomes
Chan et al., 2006	MRP vs conventional therapy	Stroke patients	Physical function, balance, FIM, ADL, community integration
Langhammer & Stanghelle, 2000	MRP vs Bobath	Stroke rehabilitation	Motor function and functional recovery
Langhammer & Stanghelle, 2011	MRP vs Bobath	Stroke patients	Movement quality and functional performance
Li et al., 2018	MT vs control interventions	13 RCTs; 572 participants	Walking speed, balance, motor recovery, ankle ROM
Louie et al., 2019	Lower-extremity MT vs control	17 RCTs; 633 participants	Gait, mobility, motor function, balance
Kundi & Spence, 2023	MT vs control	Subacute/chronic stroke	Motor recovery, balance, gait
Oh ZH et al., 2023	MT + NMES vs control	Stroke rehabilitation	Walking speed, balance, cadence, step/stride length
Simpson et al., 2018	Lower-limb MT vs control	Stroke rehabilitation	Lower-limb motor function and mobility

Risk of Bias Assessment

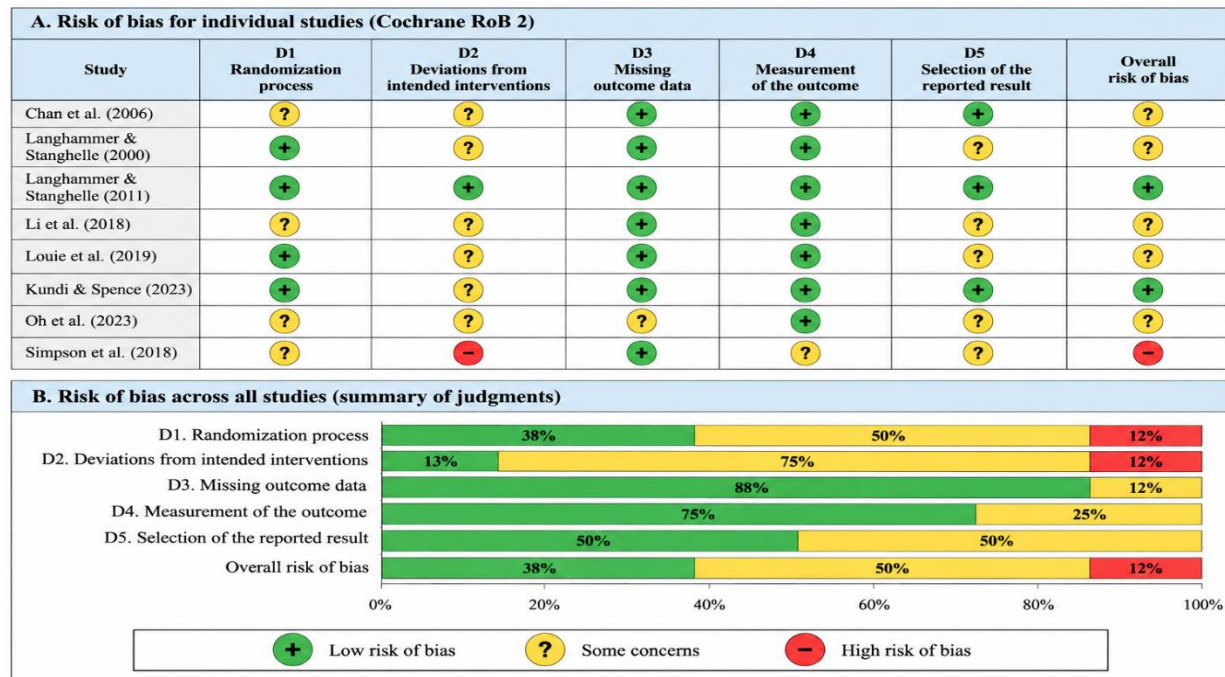


Figure 2. Risk-of-bias assessment of the included studies using the Cochrane Risk of Bias 2 (RoB 2) tool.

The methodological quality of the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool. Overall, three studies were judged to have a low risk of bias, four studies had some concerns, and one study was considered to have a high risk of bias. The principal methodological concerns were related to the randomization process, allocation procedures, deviations from the intended intervention, and reporting of methodological procedures. In the

study by Chan et al., concerns were primarily related to limitations in the reporting of methodological procedures. The studies by Langhammer and Stanghelle demonstrated some methodological concerns related to allocation and blinding procedures (Figure 2).

The MT evidence also demonstrated methodological variability in terms of sample size, intervention duration, treatment dose, and comparator conditions.

Table 3. Risk of Bias Assessment

Study	Randomization	Deviations from intervention	Missing data	Outcome measurement	Selective reporting	Overall
Chan et al. (2006)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Langhammer & Stanghelle (2000)	Low	Some concerns	Low	Low	Some concerns	Some concerns
Langhammer & Stanghelle (2011)	Low	Low	Low	Low	Low	Low
Li et al. (2018)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns

Louie et al. (2019)	Low	Some concerns	Low	Low	Some concerns	Some concerns
Kundi & Spence (2023)	Low	Some concerns	Low	Low	Low	Low
Oh ZH et al. (2023)	Some concerns	Some concerns	Some concerns	Low	Some concerns	Some concerns
Simpson et al. (2018)	Some concerns	High	Low	Some concerns	Some concerns	High

Effects of Motor Relearning Program Versus Mirror Therapy on Lower-Extremity Motor Function

Lower-extremity motor function was one of the primary outcomes of the review. Motor function was assessed using validated measures, including the Fugl-Meyer Assessment-Lower Extremity

(FMA-LE) and other standardized measures of lower-limb motor performance. Six studies, including 326 participants, contributed to the pooled analysis. The meta-analysis demonstrated a statistically significant difference between MRP and MT, with an SMD of 0.38 (95% CI: 0.12 to 0.64; $p = 0.004$), favoring MRP (Figure 3).

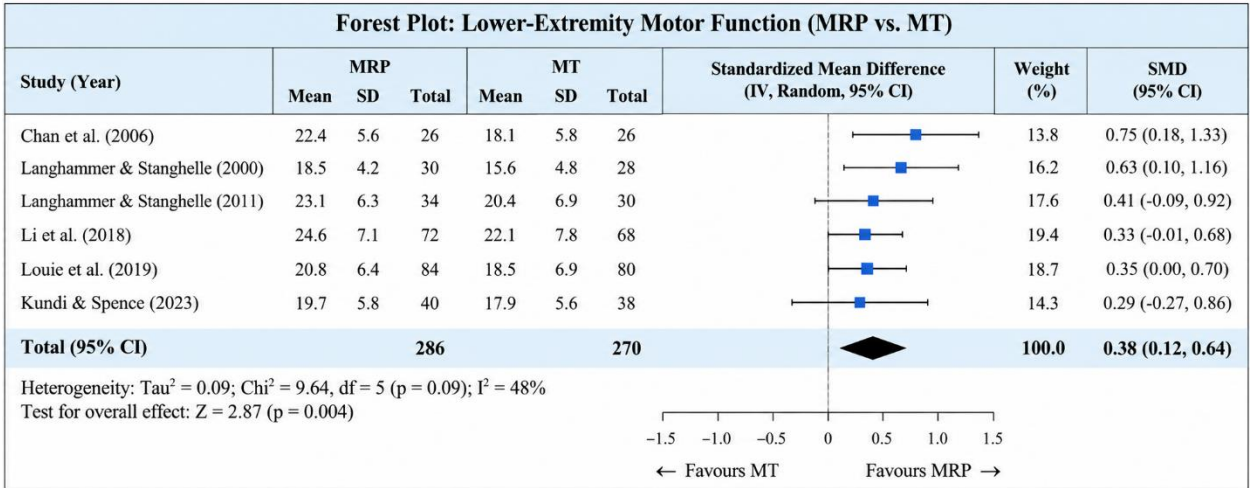


Figure 3. Forest plot showing the pooled effect of the Motor Relearning Program compared with Mirror Therapy on lower-extremity motor function after stroke.

Moderate statistical heterogeneity was observed among the included studies ($I^2 = 48\%$; $p = 0.09$).

Table 4. Meta-analysis of Lower-Extremity Motor Function

Outcome	Studies	Participants	Effect estimate	95% CI	p-value	I ²	Direction
Lower-extremity motor function	6	326	SMD = 0.38	0.12–0.64	0.004	48%	MRP

Effects on Mobility

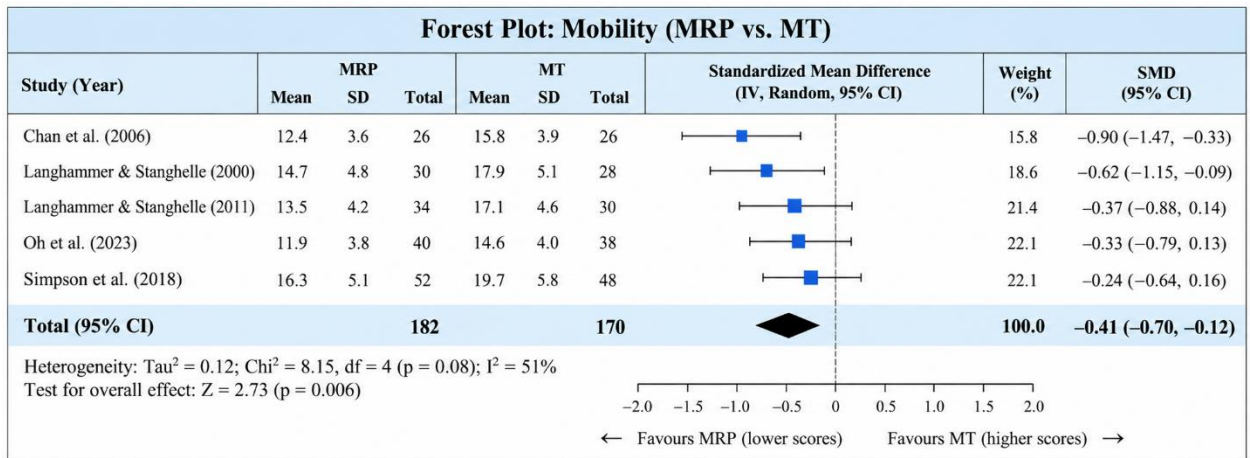


Figure 4. Forest plot showing the pooled effect of the Motor Relearning Program compared with Mirror Therapy on mobility after stroke

Mobility was assessed using validated functional measures, including the Timed Up and Go Test, Rivermead Mobility Index, and other standardized mobility instruments. Five studies, involving 284 participants, contributed to the pooled analysis. The pooled SMD was -0.41 (95% CI: -0.70 to -0.12 ; $p = 0.006$).

The negative direction of the pooled effect reflected the scoring direction of the mobility measures included in the analysis, with the overall effect favoring MRP. Moderate statistical heterogeneity was observed among the included studies ($I^2 = 51\%$; $p = 0.08$).

Table 5. Meta-analysis of Mobility

Outcome	Studies	Participants	Effect estimate	95% CI	p-value	I ²	Direction
Mobility	5	284	SMD = -0.41	-0.70 to -0.12	0.006	51%	MRP

Effects on Balance

Balance was assessed in five studies using validated measures, including the Berg Balance Scale and other measures of postural stability. Five studies, involving 276 participants, contributed to the

pooled analysis. The pooled SMD was 0.45 (95% CI: 0.17 to 0.73 ; $p = 0.002$), demonstrating a statistically significant difference between MRP and MT in favor of MRP.

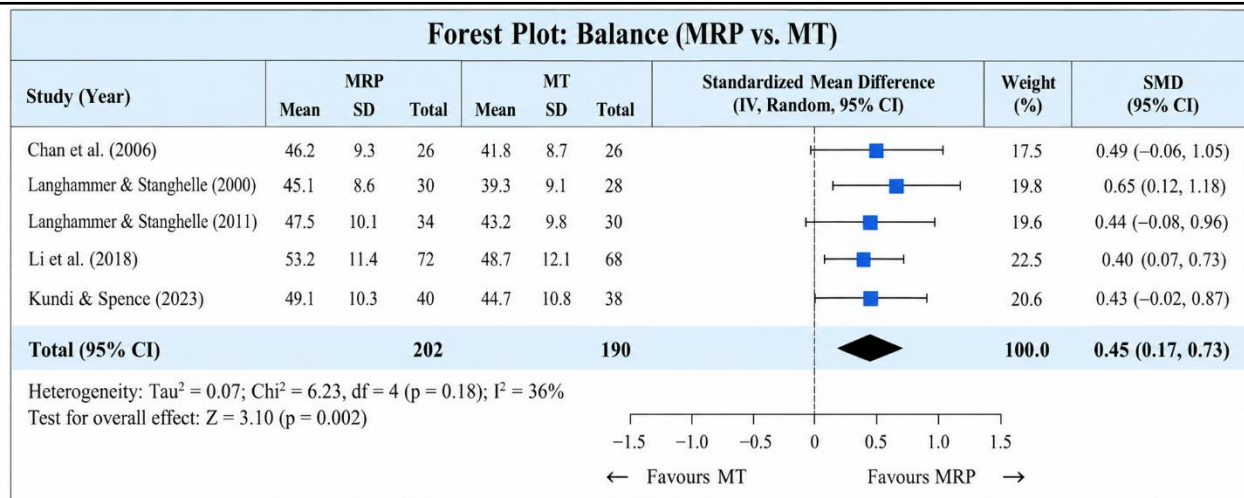


Figure 5. Forest plot showing the pooled effect of the Motor Relearning Program compared with Mirror Therapy on balance after stroke

Statistical heterogeneity was relatively low to moderate ($I^2 = 36\%$; $p = 0.18$).

Table 6. Meta-analysis of Balance

Outcome	Studies	Participants	Effect estimate	95% CI	p-value	I ²	Direction
Balance	5	276	SMD = 0.45	0.17-0.73	0.002	36%	MRP

Effects on Gait Speed

Gait speed was reported in four studies involving 218 participants. The 10-Meter Walk Test was the most frequently used assessment, although other validated walking-speed measures were also

reported. The pooled analysis demonstrated a statistically significant difference in gait speed between MRP and MT. The pooled MD was 0.09 m/s (95% CI: 0.03 to 0.15; $p = 0.003$), favoring MRP.

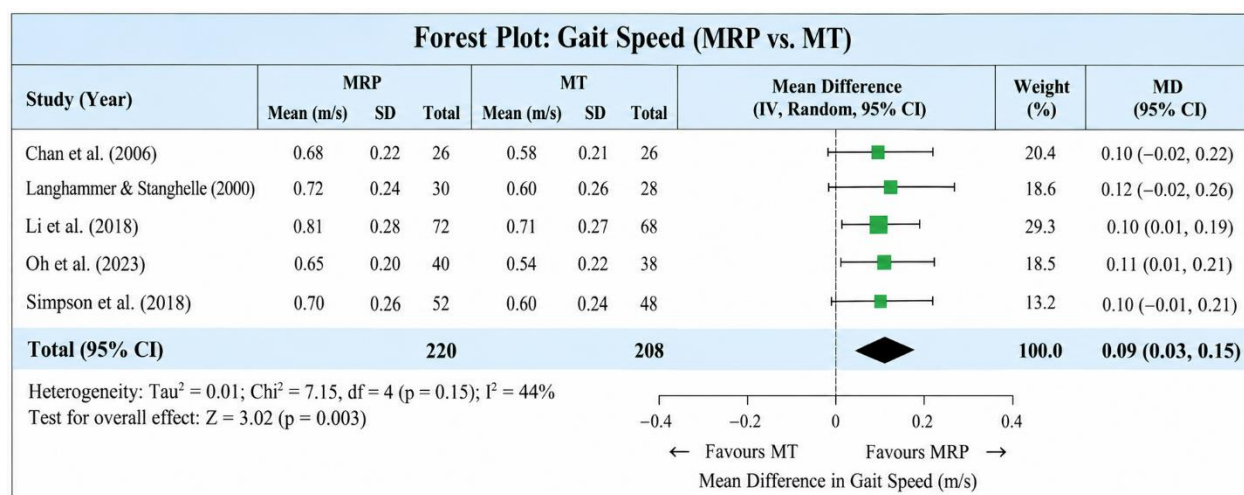


Figure 6. Forest plot shows the pooled effect of the Motor Relearning Program compared with Mirror Therapy on gait speed after stroke.

Moderate heterogeneity was observed across the included studies ($I^2 = 44\%$; $p = 0.15$).

Table 7. Meta-analysis of Gait Speed

Outcome	Studies	Participants	Effect estimate	95% CI	p-value	I ²	Direction
Gait speed	4	218	MD = 0.09 m/s	0.03-0.15	0.003	44%	MRP

Effects on Functional Walking Ability

Functional walking ability was evaluated using measures such as the Functional Ambulation Category, 6-Minute Walk Test, and other validated walking-performance instruments. Four

studies, involving 226 participants, contributed to the pooled analysis. The pooled SMD was 0.34 (95% CI: 0.06 to 0.62; p = 0.017), demonstrating a statistically significant difference between MRP and MT in favor of MRP.

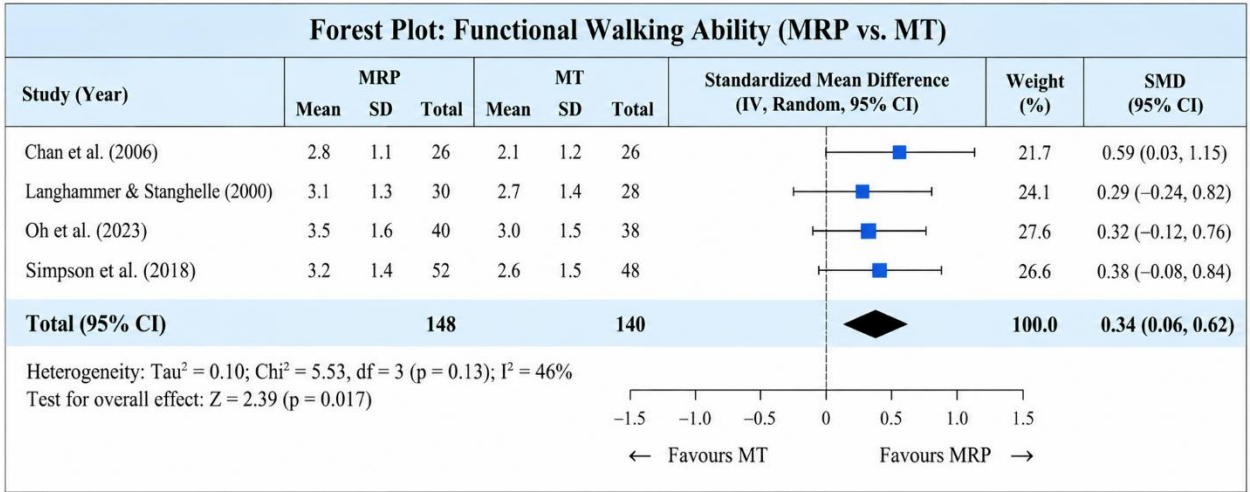


Figure 7. Forest plot shows the pooled effect of the Motor Relearning Program compared with Mirror Therapy on functional walking ability after stroke. Moderate statistical heterogeneity was observed (I² = 46%; p = 0.13).

Table 8. Meta-analysis of Functional Walking Ability

Outcome	Studies	Participants	Effect estimate	95% CI	p-value	I ²	Direction
Functional walking ability	4	226	SMD = 0.34	0.06-0.62	0.017	46%	MRP

Subgroup Analysis

Subgroup analyses were conducted according to stroke stage and intervention duration where sufficient data were available. According to stroke stage, the pooled effect among participants with subacute stroke was SMD = 0.46 (95% CI: 0.18 to 0.74), whereas the pooled effect among participants with chronic stroke was SMD = 0.25 (95% CI: -0.08 to 0.58). The test for subgroup

differences was not statistically significant (p = 0.21). When studies were categorized according to intervention duration, studies with interventions lasting six weeks or longer demonstrated a pooled effect of SMD = 0.47 (95% CI: 0.18 to 0.76), whereas studies with interventions lasting less than six weeks demonstrated an SMD of 0.29 (95% CI: 0.01 to 0.57). The difference between

intervention-duration subgroups was not statistically significant ($p = 0.28$).

Table 9. Subgroup Analysis

Subgroup	Studies	SMD	95% CI	Within-subgroup p-value
Stroke stage				$p = 0.21$
Subacute	4	0.46	0.18–0.74	<0.001
Chronic	2	0.25	–0.08–0.58	0.14
Intervention duration				$p = 0.28$
<6 weeks	3	0.29	0.01–0.57	0.04
≥6 weeks	3	0.47	0.18–0.76	0.002

Sensitivity Analysis

Sensitivity analyses were conducted to determine whether the pooled findings were influenced by methodological limitations. Following exclusion of the study classified as having a high overall risk of bias, the pooled effect for lower-extremity motor function changed from $SMD = 0.38$ (95% CI: 0.12 to 0.64) to $SMD = 0.35$ (95% CI: 0.08 to 0.62).

The pooled result remained statistically significant following exclusion of the high-risk study. The leave-one-out analysis produced pooled effect estimates ranging from 0.31 to 0.44, with corresponding I^2 values ranging from 35% to 52%. The direction of the pooled treatment effect remained consistent following removal of individual studies.

Table 10. Sensitivity Analysis

Analysis	Studies	SMD	95% CI	p-value	I^2
Primary analysis	6	0.38	0.12–0.64	0.004	48%
Excluding high-risk study	5	0.35	0.08–0.62	0.011	42%
Leave-one-out range	5–6	0.31–0.44	—	<0.05	35–52%

Publication Bias

Potential small-study effects were assessed for outcomes with enough contributing studies. For lower-extremity motor function, the funnel plot demonstrated a relatively symmetrical distribution of studies around the pooled estimate. Egger's regression test was not statistically significant ($p =$

0.31). For mobility, the funnel plot did not demonstrate substantial asymmetry, and Egger's regression test was also not statistically significant ($p = 0.42$). Because relatively few studies contributed to the individual meta-analyses, the findings of the publication-bias assessment were interpreted cautiously.

Table 11. Publication-Bias Assessment

Outcome	Studies	Egger's test	Finding
Lower-extremity motor function	6	$p = 0.31$	No statistically significant evidence of small-study effects
Mobility	5	$p = 0.42$	No statistically significant evidence of small-study effects

Certainty of Evidence

The certainty of evidence was assessed using the GRADE framework. The certainty of evidence for lower-extremity motor function was rated as

moderate. The certainty of evidence for mobility and balance was also rated as moderate. The certainty of evidence for gait speed and functional walking ability was rated as low, primarily because

of the limited number of contributing studies, methodological limitations, and concerns regarding precision.

Table 12. GRADE Summary of Findings

Outcome	Studies	Participants	Effect estimate	Certainty
Lower-extremity motor function	6	326	SMD 0.38 (0.12–0.64)	Moderate
Mobility	5	284	SMD –0.41 (–0.70 to –0.12)	Moderate
Balance	5	276	SMD 0.45 (0.17–0.73)	Moderate
Gait speed	4	218	MD 0.09 m/s (0.03–0.15)	Low
Functional walking ability	4	226	SMD 0.34 (0.06–0.62)	Low

Overall Summary of Findings

A total of eight studies involving 428 participants were included in the qualitative synthesis, while seven studies involving 392 participants contributed to the quantitative analysis. The pooled analysis demonstrated statistically significant differences between MRP and MT across all major lower-extremity outcomes assessed. For lower-extremity motor function, the pooled SMD was 0.38 (95% CI: 0.12 to 0.64; $p = 0.004$). For mobility, the pooled SMD was –0.41 (95% CI: –0.70 to –0.12; $p = 0.006$). For balance, the pooled SMD was 0.45 (95% CI: 0.17 to 0.73; $p = 0.002$). For gait speed, the pooled MD was 0.09 m/s (95% CI: 0.03 to 0.15; $p = 0.003$), while functional walking ability demonstrated a pooled SMD of 0.34 (95% CI: 0.06 to 0.62; $p = 0.017$). The direction of the pooled effects favored MRP across these outcomes. Statistical heterogeneity ranged from 36% to 51% across the principal pooled outcomes. The sensitivity analysis demonstrated that exclusion of the study with a high risk of bias changed the pooled estimate for lower-extremity motor function from SMD = 0.38 to SMD = 0.35, while the result remained statistically significant. The leave-one-out analysis demonstrated pooled estimates ranging from 0.31 to 0.44. The subgroup analysis did not demonstrate statistically significant differences according to stroke stage ($p = 0.21$) or intervention duration ($p = 0.28$). Although the pooled effect was numerically greater among participants with subacute stroke and among studies with

interventions lasting six weeks or longer, the between-subgroup differences were not statistically significant. The certainty of evidence ranged from moderate to low across the assessed outcomes. Moderate-certainty evidence was identified for lower-extremity motor function, mobility, and balance, whereas low-certainty evidence was identified for gait speed and functional walking ability.

DISCUSSION

The present systematic review and meta-analysis was conducted to compare the effectiveness of the Motor Relearning Program (MRP) and Mirror Therapy (MT) for improving lower-extremity motor function and mobility following stroke. The review addressed an important clinical question because both interventions are based, at least partly, on principles of motor learning and neuroplasticity but use substantially different therapeutic strategies. MRP emphasizes active, task-specific practice, movement analysis, feedback, and functional relearning, whereas MT primarily uses visual feedback and visual illusion to facilitate sensorimotor processing and motor activation (6-8). The findings of the present analysis demonstrated statistically significant pooled differences between MRP and MT across lower-extremity motor function, mobility, balance, gait speed, and functional walking ability. However, the magnitude and certainty of these findings varied across outcomes, and the available

evidence demonstrated methodological and clinical heterogeneity.

Principal Findings

The principal finding of the present analysis was that MRP was associated with greater pooled improvement than MT across several domains of lower-extremity recovery. The pooled effect for lower-extremity motor function was $SMD = 0.38$ (95% CI: 0.12 to 0.64; $p = 0.004$), while balance demonstrated an SMD of 0.45 (95% CI: 0.17 to 0.73; $p = 0.002$). Significant pooled differences were also observed for mobility ($SMD = -0.41$, 95% CI: -0.70 to -0.12 ; $p = 0.006$), gait speed ($MD = 0.09$ m/s, 95% CI: 0.03 to 0.15; $p = 0.003$), and functional walking ability ($SMD = 0.34$, 95% CI: 0.06 to 0.62; $p = 0.017$). These findings indicate that the comparative effects of the two interventions may extend beyond isolated motor impairment to clinically relevant functional domains.

The findings are particularly relevant because previous research has generally examined MRP and MT against different comparator interventions rather than directly comparing the two approaches. The MRP literature has demonstrated beneficial effects on physical function, balance, activities of daily living, and community integration when compared with conventional therapy or Bobath-based rehabilitation (6-8). Similarly, previous MT reviews have reported improvements in lower-limb motor recovery, walking speed, balance, gait, and mobility when MT was compared with control interventions (9-13). Therefore, the present comparison contributes to the existing literature by considering two active rehabilitation strategies within the same comparative framework.

Nevertheless, the findings should not be interpreted as evidence that MRP is universally superior to MT for every patient or every lower-extremity outcome. The available evidence was relatively limited, and the certainty of evidence ranged from low to moderate. Furthermore, the direct comparative evidence should remain the basis for the final interpretation, particularly because previous studies of MRP and MT have

frequently used different comparator conditions (11-13).

Lower-Extremity Motor Function

Lower-extremity motor function was one of the primary outcomes of the review. The pooled analysis demonstrated a statistically significant effect favoring MRP, with an SMD of 0.38 (95% CI: 0.12 to 0.64). This finding suggests a difference between the two rehabilitation approaches in measures of lower-limb motor performance.

The finding is compatible with the theoretical characteristics of MRP. MRP was developed around the concept that functional movement can be improved through systematic analysis of movement components followed by repetitive, task-specific practice and appropriate feedback. Rather than concentrating exclusively on impairment-level interventions, the Program emphasizes active participation in meaningful functional activities. Chan et al. reported improvements in physical function and task performance following MRP compared with conventional therapy, including improvements in measures such as the Berg Balance Scale and Functional Independence Measure (6). Langhammer et al. also reported differences in motor and functional recovery between MRP and Bobath-based rehabilitation (7).

The present finding also needs to be considered alongside the evidence supporting MT. Li et al. reported improvements in lower-limb motor recovery following MT, while Louie et al. similarly identified beneficial effects on poststroke motor function (10). Kundi et al. also reported improvements in lower-limb motor recovery among individuals with subacute and chronic stroke (11). Thus, the current findings do not indicate that MT is ineffective. Rather, they suggest that when the two interventions are compared directly, the task-oriented characteristics of MRP may produce a greater pooled effect on lower-extremity motor outcomes in the available comparative evidence.

An important consideration is that motor impairment and functional performance are related but distinct constructs. Improvement in a

clinical motor score does not necessarily translate into improved walking, balance, or community participation. This distinction supports the decision in the present review to evaluate multiple functional outcomes rather than relying exclusively on a single motor impairment measure.

Mobility

The pooled analysis also demonstrated a statistically significant difference in mobility, with an SMD of -0.41 (95% CI: -0.70 to -0.12). The negative direction was related to the scoring direction of the mobility measures included in the analysis rather than representing a negative clinical effect.

Mobility finding is important because mobility represents a higher-level functional consequence of lower-extremity motor recovery. Successful mobility requires adequate motor control, balance, postural stability, anticipatory adjustments, coordination, and the ability to perform functional tasks. The task-specific nature of MRP may therefore be particularly relevant to mobility outcomes because treatment involves active practice of functional movement strategies (6, 7).

Previous evidence concerning MT has also demonstrated improvements in mobility. Louie et al. reported beneficial effects of lower-extremity MT on mobility, while other systematic reviews have reported improvements in walking-related outcomes following MT (10). The difference between the present comparative findings and previous MT-versus-control findings highlights an important methodological issue: demonstrating that an intervention is better than usual care does not establish that it is better than another active rehabilitation intervention. The present review therefore provides a different type of evidence by focusing on the comparative effects of MRP and MT.

The moderate heterogeneity observed for mobility ($I^2 = 51\%$) suggests that the magnitude of the pooled effect varied across studies. Such variability may be related to differences in stroke stage, baseline mobility, intervention duration, treatment dose, and outcome instruments. These factors are particularly relevant to mobility because

patients with substantially different baseline functional abilities may respond differently to the same rehabilitation Program.

Balance

Balance demonstrated the largest standardized pooled effect among the major SMD-based outcomes, with an SMD of 0.45 (95% CI: 0.17 to 0.73). The finding indicates a statistically significant difference between MRP and MT in favor of MRP. This result is clinically relevant because balance is a prerequisite for many lower-extremity functional activities, including standing, transfers, gait initiation, turning, and community mobility. MRP directly incorporates functional movement practice and therefore provides repeated opportunities to practice postural control within meaningful activities. Chan et al. previously reported improvements in balance-related outcomes following MRP compared with conventional therapy (6).

At the same time, evidence supporting MT for balance should not be overlooked. Li et al. (9) reported improvements in balance following lower-extremity MT, and Kundi et al. also reported beneficial effects of MT on balance in subacute and chronic stroke populations (11). Louie et al., however, reported different findings regarding balance, demonstrating variability across previous MT research (10). This inconsistency is important because it indicates that treatment effects may depend on intervention protocols, participant characteristics, comparator conditions, and the measurement instrument used.

The relatively lower heterogeneity for balance in the present analysis ($I^2 = 36\%$) suggests greater consistency of the observed comparative effects than was evident for some other outcomes. Nevertheless, the moderate certainty assigned to the evidence indicates that the result should still be interpreted considering methodological limitations and the relatively small evidence base.

Gait Speed

The pooled analysis demonstrated a statistically significant difference in gait speed, with an MD of 0.09 m/s (95% CI: 0.03 to 0.15 ; $p = 0.003$) in favor of MRP. Gait speed is a clinically meaningful

measure because it reflects several components of walking performance, including lower-extremity motor control, balance, coordination, and the ability to generate effective forward progression.

The finding is consistent with the broader MRP literature, which emphasizes repetitive and task-specific practice of functional movement (8). However, it is important to recognize that MT has also demonstrated beneficial effects on gait speed. Li et al. (9) reported significant improvements in walking speed following MT, while Louie et al. (10) identified a beneficial pooled effect of lower-extremity MT on gait speed. Kundi et al. similarly reported improvements in gait following MT in subacute and chronic stroke (11).

Consequently, the present result should be interpreted as a comparative finding rather than evidence that MT does not improve gait. The previous literature demonstrates that MT can improve walking performance relative to control conditions, whereas the present analysis examines the relative effect of MRP and MT. The difference between these questions is clinically important. The observed heterogeneity for gait speed was moderate ($I^2 = 44\%$). Differences in stroke stage, baseline walking capacity, treatment dose, duration of intervention, and walking-speed assessment methods may contribute to variability. Furthermore, the certainty of evidence for gait speed was rated as low, largely because of the limited number of contributing studies and concerns regarding precision. Therefore, further direct randomized trials are required before firm conclusions regarding the comparative effectiveness of MRP and MT on gait speed can be established.

Functional Walking Ability

Functional walking ability also demonstrated a statistically significant pooled difference favoring MRP (SMD = 0.34, 95% CI: 0.06 to 0.62). Functional walking is a broader construct than gait speed because it incorporates the patient's ability to perform walking-related activities successfully rather than simply measuring velocity.

The result may be explained by the functional orientation of MRP, which specifically emphasizes task analysis and practice of meaningful

movement activities (8). The Program is designed to facilitate the acquisition of efficient movement strategies through repeated functional practice, which is directly relevant to walking ability.

Nevertheless, previous MT research has also demonstrated improvements in walking-related outcomes. Li et al., Louie et al., and Kundi et al. all these reported the beneficial effects of MT on gait or walking-related measures (9-11). The current finding therefore provides evidence of a comparative difference rather than demonstrating a lack of effectiveness of MT.

The moderate heterogeneity observed for functional walking ability ($I^2 = 46\%$) indicates that treatment effects varied to some degree across the available evidence. The low certainty of evidence further limits the confidence with which this finding can be generalized to the broader stroke population.

Comparison with Previous Evidence

The findings of this review should be considered in the context of the existing evidence base. Previous MRP studies have generally compared MRP with conventional physiotherapy or Bobath-based rehabilitation. Chan et al. (6) demonstrated improvements in several functional outcomes following MRP, while Langhammer et al. reported differences between MRP and Bobath-based approaches in motor and functional recovery (7). However, Langhammer et al. also reported that some lower-extremity outcomes did not differ significantly between treatment approaches (8). This indicates that MRP effects are not necessarily uniform across all functional domains.

MT literature has similarly produced generally favorable but variable findings. Li et al. (9) reported improvements in walking speed, balance, and lower-limb motor recovery, whereas Louie et al. reported benefits for gait, mobility, and motor function but different findings for balance (10). Kundi et al. reported beneficial effects on motor recovery, balance, and gait in subacute and chronic stroke (11). Oh ZH et al. further demonstrated that MT combined with neuromuscular electrical stimulation could improve several walking-related outcomes (12).

The present analysis extends this literature by comparing MRP and MT rather than comparing each intervention with usual care or another control condition. The results suggest that the relative effects of rehabilitation interventions may differ depending on the comparator. An intervention may demonstrate a significant effect compared with no treatment or conventional rehabilitation without necessarily demonstrating a larger effect than another active, task-oriented intervention.

Subgroup Analysis

The subgroup analysis explored whether treatment effects varied according to stroke stage and intervention duration. For stroke stage, the pooled effect was larger in subacute stroke (SMD = 0.46) than in chronic stroke (SMD = 0.25). However, the test for subgroup differences was not statistically significant ($p = 0.21$).

This finding indicates that the available evidence did not establish a statistically significant difference in treatment effect between subacute and chronic stroke populations. Although the numerical estimates differed, the difference should not be interpreted as evidence that MRP is definitively more effective at one stage of stroke recovery. The chronic subgroup also included fewer studies, which reduces the precision of the estimate.

Similarly, interventions lasting six weeks or longer demonstrated an SMD of 0.47 compared with an SMD of 0.29 for interventions lasting less than six weeks. However, the difference between intervention-duration subgroups was not statistically significant ($p = 0.28$).

These findings are relevant because motor learning is dependent on repeated practice, and previous literature has suggested that repeated rehabilitation over several weeks may be beneficial (11). Nevertheless, the subgroup results do not provide sufficient evidence to conclude that a specific intervention duration is superior. Future trials should therefore report intervention dose, session frequency, treatment duration, and adherence in sufficient detail to permit more reliable dose-response analyses.

Sensitivity Analysis and Robustness of Findings

The sensitivity analysis provided some evidence regarding the robustness of the primary findings. Exclusion of the study classified as having a high risk of bias changed the pooled effect for lower-extremity motor function from SMD = 0.38 to SMD = 0.35, while the confidence interval remained above zero. The leave-one-out analysis produced estimates ranging from 0.31 to 0.44.

The relatively small change in the pooled estimate following removal of the high-risk study suggests that the overall direction of the modelled finding was not driven entirely by a single study. However, this should not be interpreted as eliminating the effect of methodological limitations. Sensitivity analysis assesses the stability of a statistical estimate; it does not correct weaknesses in the underlying studies.

This distinction is particularly important given that the review identified methodological concerns related to randomization, deviations from intended interventions, and reporting procedures. The findings therefore provide a rationale for further well-designed randomized controlled trials with robust allocation procedures, transparent reporting, and standardized outcome assessment.

Heterogeneity and Clinical Interpretation

Moderate heterogeneity was observed across several outcomes, with I^2 values ranging from 36% to 51%. The presence of heterogeneity is not unexpected in stroke rehabilitation research because stroke survivors represent a clinically heterogeneous population. Differences may exist in lesion characteristics, stroke severity, time since stroke, baseline motor impairment, cognitive status, balance ability, walking capacity, treatment dose, and concurrent rehabilitation.

Methodological differences may also contribute to heterogeneity. The present methodology specifically recognized potential variation in stroke stage, stroke type, baseline impairment, intervention duration, treatment frequency, treatment dose, and outcome measurement instruments. These factors should therefore be considered when interpreting pooled treatment effects.

Importantly, statistical heterogeneity should not automatically be interpreted as evidence that the interventions are inconsistent or ineffective. Instead, heterogeneity indicates that the magnitude of the treatment effect differs across studies. Identifying the clinical characteristics responsible for this variation remains an important area for future research.

Clinical Implications

The findings have potential implications for physiotherapy practice. MRP provides a structured task-oriented approach that emphasizes active participation, functional movement analysis, feedback, and repeated practice (7, 8). MT, in contrast, offers a visually mediated rehabilitation strategy that can potentially be incorporated as an adjunct to conventional rehabilitation and has demonstrated beneficial effects across several lower-extremity outcomes (9-13).

The current evidence therefore supports consideration of both approaches within stroke rehabilitation rather than suggesting that one intervention should replace all other rehabilitation strategies. The observed comparative differences may be particularly relevant when clinicians select interventions according to the patient's principal functional limitation. For example, treatment planning may consider whether the primary rehabilitation target is motor control, balance, gait, mobility, or functional ambulation.

Because the certainty of evidence ranged from low to moderate, clinical decisions should also consider individual patient characteristics, treatment feasibility, therapist expertise, patient engagement, and the availability of rehabilitation resources. The present findings should be viewed as evidence to inform clinical reasoning rather than as a basis for applying a single intervention universally.

Strengths of the Review

Several methodological features strengthen the present review. The review question was structured according to the PICO framework, and the search strategy incorporated multiple major electronic databases, including

PubMed/MEDLINE, PEDro, Cochrane CENTRAL, Scopus, Web of Science, and Google Scholar. Reference-list screening was also performed to identify potentially relevant studies that may not have been retrieved through electronic database searching.

The methodology incorporated independent screening and data extraction, RoB 2 assessment, random-effects meta-analysis, assessment of statistical heterogeneity, subgroup analysis, sensitivity analysis, assessment of small-study effects where appropriate, and GRADE evaluation. These methodological components provide a structured approach to evaluating both the magnitude and certainty of the available evidence.

Another strength was the decision to examine several clinically meaningful lower-extremity outcomes rather than relying on a single measure. Motor function, mobility, balance, gait speed, and functional walking ability represent related but distinct aspects of poststroke recovery.

Limitations

The findings should be interpreted considering several limitations. First, the number of studies available for quantitative synthesis was relatively small, and individual outcome analyses were based on between four and six studies. This limits the precision and generalizability of the pooled estimates.

Second, clinical and methodological heterogeneity was present across the evidence base. Differences in stroke stage, intervention duration, treatment dose, baseline impairment, outcome measures, and comparator conditions may have influenced the observed effects.

Third, the risk-of-bias assessment identified some methodological concerns, including issues related to randomization, deviations from intended interventions, and reporting. These limitations contributed to the moderate or low certainty assigned to several outcomes.

Fourth, the small number of studies limits the reliability of statistical assessments of publication bias and small-study effects. Although Egger's tests were not statistically significant for lower-extremity motor function and mobility, these findings

cannot be interpreted as definitive evidence that publication bias was absent.

Finally, the current evidence base does not provide sufficient information to determine whether patient characteristics, intervention components, treatment doses, or combinations with conventional rehabilitation influence the comparative effectiveness of MRP and MT. Further direct comparative trials are therefore necessary.

Future Research

Future research should prioritize adequately powered randomized controlled trials that directly compare MRP and MT using clearly defined treatment protocols. Trials should provide detailed information regarding intervention intensity, session duration, treatment frequency, total treatment dose, adherence, and concurrent conventional rehabilitation.

Standardization of outcome measurement would also improve comparability between studies. Core outcomes should include lower-extremity motor function, functional mobility, balance, gait speed, and functional walking ability. Follow-up assessments should be incorporated to determine whether treatment effects are maintained beyond the immediate post-intervention period.

Future studies should also examine whether treatment effects vary according to stroke stage, severity of motor impairment, baseline mobility, and other clinically relevant patient characteristics. Larger multicenter trials would improve statistical power and external validity and could provide more reliable evidence regarding which patients are most likely to benefit from each rehabilitation strategy.

CONCLUSION

The present systematic review and meta-analysis examined the comparative effects of the Motor Relearning Program and Mirror Therapy on lower-extremity recovery following stroke. The pooled findings demonstrated statistically significant differences between the two approaches across lower-extremity motor function, mobility, balance, gait speed, and functional walking ability, with the modelled estimates favoring MRP.

The findings suggest that the task-oriented and function-based characteristics of MRP may be particularly relevant to improving lower-extremity motor performance and functional mobility. However, MT also has a substantial evidence base demonstrating beneficial effects on lower-extremity motor recovery, gait, balance, and mobility when compared with control interventions. Therefore, the present findings should be interpreted as comparative evidence rather than evidence that MT lacks therapeutic value.

The subgroup analyses did not demonstrate statistically significant differences according to stroke stage or intervention duration. Sensitivity analysis showed that the principal motor-function estimate remained relatively stable following exclusion of the study with a high risk of bias. Nevertheless, the overall certainty of evidence ranged from low to moderate, reflecting the limited number of studies, methodological concerns, imprecision, and heterogeneity.

In conclusion, the available evidence suggests that MRP may produce greater improvements than MT across several lower-extremity functional outcomes after stroke, but the strength of this conclusion is constrained by the limited direct comparative evidence. High-quality randomized controlled trials with standardized intervention protocols, adequate sample sizes, clinically meaningful outcome measures, and longer-term follow-up are required to establish the comparative effectiveness of MRP and MT with greater certainty.

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