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REVIEW ARTICLE (META-ANALYSIS)

# Systematic Review and Meta-Analysis of the Effectiveness of Mental Practice for the Upper Limb After Stroke: Imagined or Real Benefit?

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**Abstract**

**Objectives:** This systematic review sought to determine the effectiveness of mental practice (MP) on the activity limitations of the upper limb in individuals after stroke, as well as when, in whom, and how MP should be delivered.

**Data Sources:** Ten electronic databases were searched from November 2009 to May 2020. Search terms included: Arm, Practice, Stroke rehabilitation, Imagination, Paresis, Recovery of function, and Stroke. Studies from a Cochrane review of MP (up to November 2009) were automatically included. The review was registered with the PROSPERO database of systematic reviews (reference no.: CRD42019126044).

**Study Selection:** Randomized controlled trials of adults after stroke using MP for the upper limb were included if they compared MP to usual care, conventional therapy, or no treatment and reported activity limitations of the upper limb as outcomes. Independent screening was conducted by 2 reviewers.

**Data Extraction:** One reviewer extracted data using a tool based on the Template for Intervention Description and Replication. Data extraction was independently verified by a second reviewer. Quality was assessed using the PEDro tool.

**Data Synthesis:** Fifteen studies (n=486) were included and 12 (n=328) underwent meta-analysis. MP demonstrated significant benefit on upper limb activities compared with usual treatment (standardized mean difference [SMD], 0.6; 95% confidence interval [CI], 0.32-0.88). Subgroup analyses demonstrated that MP was most effective in the first 3 months after stroke (SMD, 1.01; 95% CI, 0.53-1.50) and in individuals with the most severe upper limb deficits (weighted mean difference, 7.33; 95% CI, 0.94-13.72).

**Conclusions:** This review demonstrates that MP is effective in reducing activity limitations of the upper limb after stroke, particularly in the first 3 months after stroke and in individuals with the most severe upper limb dysfunction. There was no clear pattern of the ideal dosage of MP.

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Stroke is the single main cause of acquired disability in high income countries.[1] Difficulties in using the arm, wrist, and hand (upper limb) is the most common deficit after stroke, and is reported by at least 70% of stroke survivors.[2] This has a significant effect on daily activities, and has been shown to reduce independence, the likelihood of returning to employment and hobbies, and poorer mental health and quality of life.[3,4]

Mental practice (MP) is one of only a handful of interventions included in evidence-based guidelines for the rehabilitation of the upper limb after stroke.[5,6] It comprises the repeated practice of motor (or kinesthetic) imagery.[7] During MP, participants are typically guided to cognitively rehearse, but not physically perform, movements of the upper limb often to complete a functional task[8,9] or to consider how one might perform a task (eg, grip a cup).[10] This can be from a first person perspective (egocentric, through one's own eyes) or a third person perspective (as an observer watching from a distance).[11] MP was initially developed in sports psychology to improve performance, and it has been used in both cognitive and physical therapies.[12,13] Although the precise mechanisms by which MP may work have not been fully elucidated, it is agreed that mental imagery uses stored multimodal (motor and sensory) representational formats or

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previous experiences of movements.[14] It has been shown that MP activates many of the same areas of the brain that are stimulated when physically executing a movement.[15,16] These include the premotor cortex, basal ganglia, cerebellum, and associative parietal cortex.[7,15] Consequently, MP may provide a "back door" to the motor cortex as it facilitates motor cortex activity and neuroplasticity without physical movement.[15,17-19]

Studies indicate that most individuals can undertake MP within the first 6 weeks after stroke. This varies depending on the test used to assess MP ability,[16,20,21] but the ability to undertake MP after stroke does not appear to be significantly influenced by age.[22] It is also one of very few treatments that can be used by those who have no voluntary movement of their upper limb. This enables participation in an upper limb rehabilitative intervention for those who could not undertake exercise-based interventions for the upper limb, such as constraint-induced movement therapy or repetitive task practice.[23,24] Conversely, its use in high performance sport indicates that it is suitable to be used by individuals with good upper limb function to refine high-level skills after stroke.[7] Crucially, as MP does not require any actual physical movement, it is safe for individuals after stroke to undertake with only minimal or no supervision. This means that if MP can be shown to be effective, it could provide multiple practice opportunities and be a useful method to supplement the amount of therapist-provided rehabilitation for the upper limb after stroke and improve outcomes.

Several trials of MP for the upper limb after stroke have shown it to be as effective as some forms of physical practice on impairments, and it appears particularly efficacious if used alongside physical therapy.[8,9,25,26] However, others have reported no differences in activity limitations when compared with usual care interventions,[27] suggesting that its effectiveness cannot be assumed. The most recent Cochrane review of MP for the upper limb after stroke was published in 2020[8] and found that MP had a significant benefit on upper limb motor recovery and activities. Further reviews largely support this finding,[28,29] although the magnitude of the effect appears to differ between studies. Even with the increase in available trials, there is still uncertainty as to whether the changes elicited by MP could specifically reduce activity limitations of the upper limb, a recognized and shared priority for individuals after stroke and clinicians.[30] Furthermore, the optimal parameters of use of MP for the upper limb remain unclear. Specifically, the time period after stroke during which MP might be most effective (when) and the effect of dose upon activity limitations (how much)[31] have not been identified.

Therefore, this review seeks to address this shortcoming by (1) examining the effectiveness of MP on outcomes that specifically measure activities and activity limitations, (2) describing when and in whom MP might have the most benefit to upper limb activity outcomes after stroke, and (3) investigating if and how the dose affects the effectiveness of MP.

*List of abbreviations:*

| | |
|---|---|
| **ARAT** | **Action Research Arm Test** |
| **CI** | **confidence interval** |
| **MP** | **mental practice** |
| **PEDro** | **Physiotherapy Evidence Database** |
| **SMD** | **standardized mean difference** |
| **TIDieR** | **Template for Intervention Description and Replication** |
| **WMD** | **weighted mean difference** |

The lack of clear guidance regarding how and in whom MP should be used clinically may, in part, explain why MP is reported to be rarely used in practice despite its inclusion in stroke guidelines.[32] The information generated by this review will provide greater clarity for clinicians regarding how they might choose to use MP in practice and identify clear indications of priorities for future research.

## Methods

This review follows the Cochrane Reviews of mental practice and used the same search criteria.[8] It was registered with the PROSPERO database of systematic reviews (reference no.: CRD42019126044) and followed published checklists and guidance on systematic reviews (PRISMA and Cochrane).[33,34]

Electronic searches of the following databases were completed: Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, CINAHL, PsycINFO, Scopus, Web of Science, the Physiotherapy Evidence Database (PEDro) (http://www.pedro.org.au/), and the specialist rehabilitation research databases CIRRIE (http://cirrie.buffalo.edu) and REHABDATA (www.naric.com). The databases were searched from the point of the last Cochrane review (November 2009) until May 4, 2020. Search terms included: Arm, Practice, Stroke rehabilitation, Imagination, Paresis, Recovery of function, and Stroke. The search strategy is documented in supplemental appendix 1 (available online only at http://www.archives-pmr.org/).

### Screening and selection

Titles and abstracts were independently screened by 2 reviewers (R.C.S. and K.J.). Studies were included if they were a parallel group randomized controlled trial; participants were older than 16 years of age with a confirmed diagnosis of stroke (clinical criteria or scanning) and had a sensorimotor upper-limb involvement as a result of their stroke; compared an MP intervention, defined as cognitive rehearsal of a movement or task for the upper limb,[9] with conventional therapy, usual care, a defined placebo intervention, or no therapy; and if the effects of MP could be delineated from other interventions. Only studies for which the full text was available in English and those that used outcomes that measured upper limb activities before and after the intervention were included. Upper limb activities were defined according to the World Health Organization criteria[35] and included lifting, carrying, and putting down (d4300, 4301, 4302, 4305), fine hand use (d440), and hand and arm use (d445).

After title and abstract screening, the full texts of selected studies were retrieved, independently read, and assessed for inclusion. Any studies for which suitability was unclear were reviewed by 2 reviewers (R.C.S. and K.J.), and a decision was made through discussion.

### Data extraction

Data were extracted by one reviewer (P.B.) into a data extraction spreadsheet that was developed based on the Template for Intervention Description and Replication (TIDieR) checklist.[31] Data extraction was checked by a second reviewer (R.C.S.).

The following data were extracted: citation details; aims; total number of participants; number of groups; number in each group; number lost to attrition in each group; randomization; blinding;

time since stroke; selection criteria; measurement schedule; baseline arm function or score; frequency of MP sessions; duration of each MP session; the length of the entire MP intervention; number of completed sessions; total minutes of completed MP; duration and length of control intervention; baseline, post-intervention, and follow-up (when available) point estimates and measures of variability on outcome tools that measured activities or activity limitations. When the manuscript did not present data, the authors were contacted for this information.

## Risk of bias (quality) assessment

Two reviewers (R.C.S. and K.J.) independently assessed the quality of all included studies using the PEDro[36] criteria scores. When possible, published assessments on the PEDro website were used to indicate the quality of included studies. In the absence of published scores, PEDro scores were independently assigned and agreed by 2 reviewers (R.C.S. and K.J.). Scores indicated poor (<2), moderate (3-5), or high (6-10) quality trials.[36] Any discrepancies were resolved by discussion.

## Analysis

Studies were synthesized narratively and, when possible, meta-analysis of the different continuous measures of upper limb activity, presenting results as point estimates and 95% confidence intervals (CI) was also undertaken by one reviewer (A.J.C.). Funnel plots (plot of effect estimates from studies against a measure of precision) were used to judge the risk of publication bias. Weighted mean differences (WMD) were calculated when outcomes were measured on the same scale, and standardized weighted mean differences (SMD) were calculated when outcomes were measured on different scales for the same underlying construct.[34] Random-effects models were estimated where SMDs were used to pool outcomes and fixed-effect models where MD were synthesized. Heterogeneity was assessed through visual inspection of forest plots and the calculation of the chi-square and $I^2$ statistics. Subgroup analyses explored the influence of time after stroke onset (using the Stroke Recovery and Rehabilitation Roundtable classification),[37] severity of upper limb involvement at baseline (Action Research Arm Test [ARAT] score: 0-20, 21-40, 41-57), and the overall dose of MP delivered (min per day, calculated by dividing the total number of min of MP reported to be delivered by the total length of the MP intervention in d). This was categorized into low (<25th percentile), medium (25th-75th percentile), and high (>75th percentile) doses.

Results were presented according to the TIDieR framework[31] and comprised consideration of who and when (including participant sex, time since stroke using published criteria,[37] the participants' cognitive function, and arm severity at baseline) and what and how much (the viewpoint of MP, the simultaneous inclusion and the nature of other rehabilitative interventions, and the overall dose of MP provided).

# Results

Initial searches yielded 1721 articles, which were reduced to 1239 after duplicates were removed (see PRISMA diagram, fig 1). After title, abstract, and full text screening, 15 studies were selected for narrative review and are presented in table 1.[19,26,27,38-49] Four authors were contacted and asked to provide data that would allow meta-analysis.[38,40,44,46] Of these, 1 responded with data, another responded but did not provide the data, and 2 did not respond but the data for 1 of these was able to be extracted from Barclay-Goddard et al's Cochrane review.[8] This left 12 studies that were suitable for meta-analysis.[19,26,27,39-43,45-47,49] The characteristics and main findings of included studies are presented in table 1.

## Quality

PEDro scores are displayed in table 1. Seven studies were either of moderate[19,26,40,42,43,45,46] or high quality,[27,39,41,44,47-49] while 1 was of poor quality.[38]

## Outcomes

Nine[19,26,27,39,42-45,49] studies used the ARAT to indicate upper limb activity limitations as a primary or secondary outcome tool. The remaining 6 studies used either the Wolf Motor Function Test,[47,48] Jebsen-Taylor Hand Function Test,[41] Arm Functional Test-Functional Arm Ability Scale,[46] or Motor Activity Log.[38,40] As these tools captured data predominantly at the level of activities, they were collectively pooled for analysis.[19,26,27,39-43,45-47,49] Meta-analysis of these 12 studies revealed that the SMD for the overall effectiveness of MP on measures of activity limitation (fig 2) was 0.6 (95% CI, 0.32-0.88; n=328; $I^2$=29%).

## Who and when?

Fourteen of the 15 included studies presented demographic data and reported the time since stroke (see table 1).[19,26,27,39-43,45-50] There were more men than women (men, n=282; women, n=183), and the mean age of the participants was 59.2±4.9 years. Using standard criteria,[37] 8 studies were conducted in the chronic period,[26,40,42-45,47,49] 2 in the late sub-acute period,[27,49] and 4 with individuals predominantly in the early subacute period after stroke.[19,39,46,48] Meta-analysis of 12 studies showed that MP had the largest benefit on activity limitations in the early subacute period (7d-3mo) after stroke (SMD,1.01; 95% CI, 0.53-1.5; 3 studies, n=76; $I^2$=0%),[19,39,46] followed by the chronic period (≥6mo; SMD, 0.65; 95% CI, 0.32-0.99; 7 studies, n=151; $I^2$=0%)[13,26,40-42,43,47] (fig 3). Changes in activity limitation after MP during the late subacute period (3-6mo) were small and nonsignificant (SMD, 0.09; 95% CI, -0.3 to 0.48; $P$=.65; 2 studies, n=111; $I^2$=0%).[27,49]

All studies required participants to have no or very mild cognitive deficits to take part. Ten of 15 studies screened people for cognitive dysfunction before inclusion.[26,27,40-44,46,47,49] Eight used the mini or full modified mental state examination[26,40-44,46,47] with cutoffs of 24 and 70, respectively. One used the mental status questionnaire,[27] whereas another used the Wechsler Memory scale.[49]

For those 8 studies (n=226) that reported baseline arm function using the ARAT,[19,26,27,39,42,43,45,49] most included participants who had moderate arm limitations (median ARAT score, 25; range, 5-49). Only one study included participants who would be classified as having severe arm limitations on the ARAT (mean ARAT score, 5).[49] As presented in figure 4, meta-analysis showed that MP had the greatest benefit for those with the most severe upper limb limitations (ARAT scores, 0-20; WMD, 7.33; 95% CI, 0.94-13.72; 3 studies,[39,43,49] n=82; $I^2$=0%), followed by those with moderate limitations (ARAT scores, 21-40; WMD, 5.13; 95% CI, 2.88-7.39, 4 studies,[19,26,27,42] n=115; $I^2$=0%). However, MP was not effective in improving limitations in individuals with the

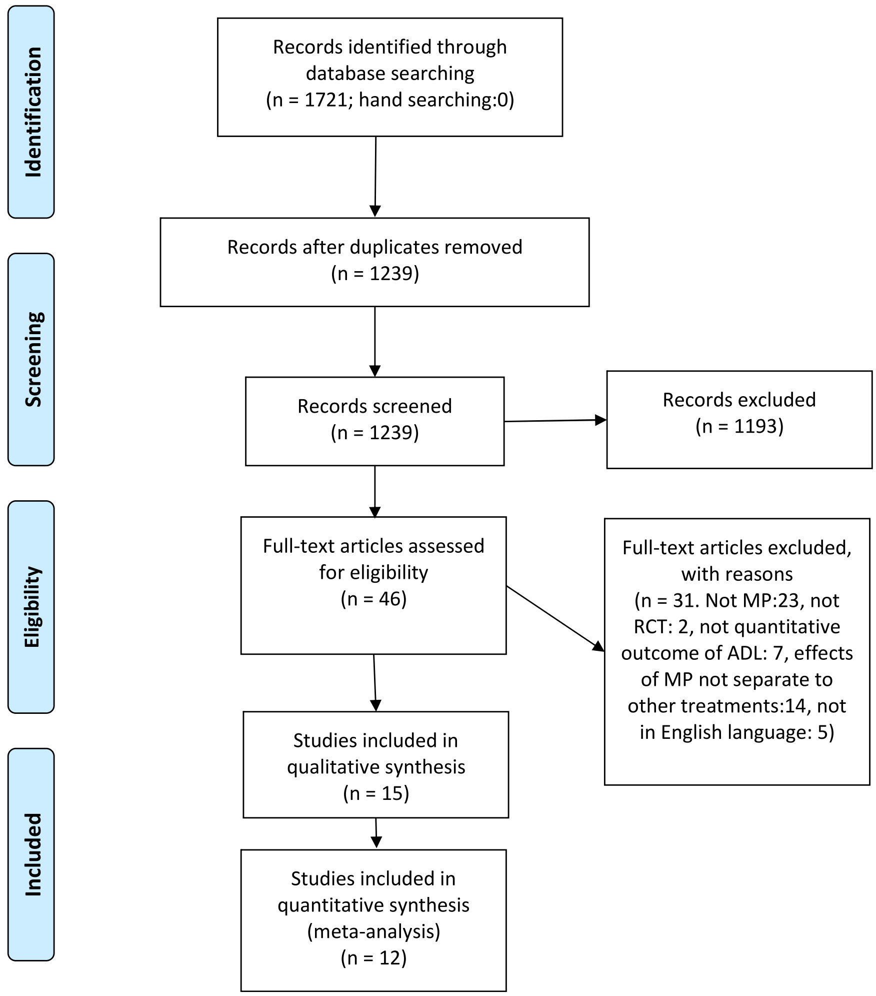


**Fig 1** PRISMA diagram showing the article flow through the review.

most mild upper limb involvement, although this was only based on 1 study (ARAT scores, 41-57; WMD, 2.50; 95% CI, -4.38 to 9.38; $P=.48$; 1 study,[45] n=29).

## What and how much?

Ten studies did not clearly specify which perspective (first or third person) was used during MP. Of the 5 studies that did, 4 used solely a first person perspective[19,43,48,49] whereas 1 used both first and third person.[41]

In 10 of the studies, MP was delivered in addition to conventional therapy or other usual rehabilitation,[13,19,26,39,41,42-44,46,47] but there was little detail included of what this comprised.

The mean length of the MP intervention was 4.7±1.9 weeks, with a median of 3 sessions (range, 2-15) provided each week. One study compared 3 different durations of MP intervention and was excluded from this analysis.[50] The mean duration of a typical MP session in the other 14 studies was 28.4±15.1 minutes.[19,26,27,38-43,45-49] Dose was calculated to indicate the average amount of MP received per day (total number of min of MP divided by the total length of the intervention in d). The mean average dose was 20.3±14 minutes per day in the 14 studies that used a single MP intervention[19,26,27,38-43,45-49] (see table 1).

For meta-analysis, the data were split into low, medium, and high doses using the method of calculation described earlier. Two studies used a low dose of MP (≤6.6min/d),[26,41] 5 used a medium dose (6.7-32min/d),[13,40,42,43,47] and 5 used a high dose (≥32.1min/d).[19,27,39,46,49] As shown in figure 5, a lower dose appeared to confer somewhat greater benefit to upper limb function (SMD, 0.89; 95% CI, 0.04-1.74; 2 studies,[26,41] n=25; $I^2=0\%$) than a medium dose (SMD, 0.61; 95% CI, 0.25-0.98; 5 studies,[13,40,42,43,47] n=126; $I^2=0\%$) or high dose (SMD, 0.57; 95% CI, 0.05-1.08; 5 studies,[19,27,39,46,49] n=177; $I^2=60\%$).

Six of the 15 studies provided control treatments to match the time and attention given the intervention group.[19,27,40-42,48] They provided additional conventional therapy,[19,40] relaxation recordings,[31,43] additional treatment based on the neurodevelopmental technique,[48] or visual imagery training.[27] The remaining 9 studies did not detail the provision of additional control treatment.

# Discussion

This systematic review evaluated the effectiveness of MP for the upper limb after stroke. It aimed to determine in whom and when MP might have benefit after stroke and to identify the dose of MP

**Table 1** Details of included studies

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/ Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Inter vention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ietswaart et al[27] | 7 | Late subacute | Intervention: 69.3±10.8<br>Attention control: 68.6±16.3<br>Usual care: 64.4±15.9 | 70/51 | Movements using different muscle groups (eg, opening and closing of the hand, wrist rotation, arm elevation), goal directed movements (eg, reaching, grasping and lifting household objects), and activities of daily living (eg, ironing, washing under the arms or doing buttons on a shirt).<br>First person perspective. Supported with presence of pictures/objects and action observation. | 3 | 45 | 4 | 12 | 12×45=900 | No differences between the MP group and attention-control placebo were found at baseline or postintervention on the ARAT or any of the secondary outcome measures. |
| Kanwar et al[38] | 2 | Not specified | Intervention: 60±10.9<br>Control: 58±11.7 | 21/8 | An audio recording including 5 minutes of relaxation followed by imagining activities in first person (eg, reaching for and grasping a cup or object, turning a page in a book, opening cork of a bottle, proper use of pencil or pen). | 2 | 30 | 4 | 8 | 8×30=240 | The mean score of Motor Activity Log Quality of Movement for all 3 groups (video MP, auditory MP, control group) were 2.15, 2.5, and 1.5, respectively, preintervention and 3.8, 3.5, and 2.2 postintervention. The mean amount of use score for all 3 groups was 1.82, 1.9, and 1.32, respectively, preintervention and 3.51, 3.200, and 1.91, respectively, postintervention. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/ Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Inter vention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Li et al[19] | 5 | Early subacute | Mean ± SD not stated<br>Range: 32-51 | 13/7 | Thumb flexion-extension movement (pronation), index finger flexion-extension (pronation), thumb circling, index finger circling, adduction and abduction of all digits, flexion and extension of all digits, making a fist and then spreading the fingers, wrist lateral movement (5 fingers unbent), wrist flexion and extension (5 fingers unbent), wrist circling, and hand flip. Supported with video before MP. First person perspective. | 5 | 45 | 4 | 20 | 20×45=900 | ARAT and Fugl-Meyer Assessment results were significantly better postintervention in the MP group compared with the traditional rehabilitation group. |
| Liu et al[39] | 6 | Early subacute | Intervention: 48.9±7.19<br>Control: 53.10±10.38 | 11/9 | MP included flexion and extension of the thumb, abduction and adduction of all digits, making a fist and spreading the hand, moving extended fingers backwards and forwards, and moving the hand between the ulnar and radial deviation.<br>First person perspective. Supported by video and practice with unaffected arm. | 5 | 45 | 4 | 20 | 20×45=900 | There was a significant difference in the<br>ARAT score between the 2 groups postintervention in favor of the intervention group. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Intervention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nayeem et al[40] | 4 | Chronic | Intervention: 47.53±5.50<br>Control: 50.13±5.09 | 20/10 | Audio recording, including 5 minutes of relaxation followed by focus on imagining activity.<br>Week 1: reaching for and grasping a glass, taking a spoon to mouth.<br>Week 2: holding a ball in hand, squeezing and releasing it, and combing hair.<br>Week 3: drawing lines/circles on a paper and drying the face with a towel.<br>Perspective not stated. | 4 | 15 | 3 | 12 | 12×15=180 | Participants who received MP performed significantly better than the control group postintervention on Fugl-Meyer Assessment scores and Motor Activity Log quality of movement scores but not on amount of use. |
| Nilsen[41] | 6 | Chronic | Control: 66.2±2.6<br>Internal MI: 46.6±5.2<br>External: 62.0±5.7 | 9/10 | Audio recording with 2 minutes of instructions and 5 minutes of relaxation. MP activities comprised drinking from a cup, donning a button-down shirt, and folding a towel.<br>One group was instructed to use first person perspective, another group to use third person perspective. | 2 | 18 | 6 | 12 | 12×18=216 | The internal and external MP groups showed statistically similar improvements on the Fugl-Meyer and Jebsen-Taylor Test of Hand Function posttest, whereas the control group did not show statistical improvement. All groups improved significantly on the Canadian Occupational Performance Measure. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Inter vention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Page et al[26] | 5 | Chronic | 64.6±8.44 | 10/3 | Audio recording including 2-3 minutes of relaxation, followed by imagining activities (eg, reaching for a cup on the table). Three scripts during the 6-week intervention. Each script focused on different functional movements: shoulder internal/external rotation, pronation/supination, shoulder flexion, and movements that facilitate/approximate grasp. First person perspective | 3 | 10 | 6 | 18 | 18×10=180 | After intervention, Fugl-Meyer and ARAT scores of patients in the therapy only group remained virtually the same. Scores in the therapy plus imagery group improved by 13.8 and 16.4 points, respectively, on the Fugl-Meyer and ARAT. |
| Page et al[42] | 5 | Chronic | 62.3±5.1 | 9/2 | Audio recording including 5 minutes of relaxation. Activities consisted of reaching for and grasping a cup or object, turning the page in a book, and use of a pencil or pen. First person perspective. | 2 | 30 | 6 | 12 | 12×30=360 | In the MP group, affected limb Motor Activity Log amount of use increased from 1.55 to 1.66, quality of movement increased from 2.33 to 2.15, and ARAT scores increased 10.7 points. In contrast, controls showed nominal increases on the Motor Activity Log. There were significantly greater changes in ARAT scores for the MP group. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Intervention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Page et al[43] | 5 | Chronic | 59.5±13.4 | 18/14 | Audio recording including 5 minutes of relaxation. Activities consisted of reaching for and grasping a cup or object, turning the page in a book, and use of a pencil or pen. First person perspective | 2 | 30 | 6 | 12 | 12×30=360 | Individuals receiving MP showed significant reductions in affected arm impairment (Fugl-Meyer Assessment) and significant increases in daily arm function (ARAT). |
| Page et al[44] | 7 | Chronic | 60.8±12.3 | 32/6 | Audio recording including 5 minutes of relaxation. Activities consisted of reaching for and grasping a cup or object, turning the page in a book, use of a pencil or pen, use of an eating utensil, and combing hair. First person perspective. | 3 | 20, 40 & 60 | 10 | 30 | MP GROUP 20: 30×20=600 MP GROUP 40: 30×40=1200 MP GROUP 60 30×60=1800 | Fugl-Meyer: mental practice duration significantly predicted pre to post change, with increasing duration related to a larger Fugl-Meyer and ARAT: a nonsignificant trend was seen, favoring the 20-minute dosing condition (4.5 point increase). Regardless of dosing condition, participants undertaking MP exhibited markedly larger score changes on both measures than those not receiving MP. |
| Park et al[45] | 4 | Chronic | Intervention: 60±10.9 Control: 58±11.7 | 21/8 | Muscle relaxation for 2 minutes, followed by MP of activities: turning a page, putting beans, and stacking plastic cups. Perspective not stated. | 5 | 10 | 2 | 10 | 10×10=100 | The MP group showed significant improvements in upper extremity function Fugl-Meyer-UL and ARAT on the affected side and activities of daily living scores (Modified Barthel Index) postintervention compared with the control group. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/ Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Inter vention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Riccio et al[46] | 5 | Early subacute | Group A: 60.17±11.69<br>Group B: 60.6±11.68 | 21/15 | Audio recording including relaxation exercises followed by MP of activities in Arm Functional Test.<br>Perspective not stated. | 5 | 60 | 3 | 15 | 15×60=900 | There were significant differences on Motricity Index and Arm Function Test between the 2 groups at 3 weeks (crossover) in favor of the MP group. At 6 weeks, the difference was not significant. |
| Seong-Sik and Byoung-Hee[47] | 6 | Chronic | Intervention: 64.2 y (SD not stated)<br>Control: 59.4 y (SD not stated) | 9/15 | 18 tasks: drinking from a cup, setting a seal, turning pages of a book, plugging a cord into an outlet, brushing their teeth, sorting chopsticks and spoons, folding a towel, tearing/folding toilet paper, making a phone call, placing a card in wallet, changing batteries, opening/closing a wallet, using scissors, using a spray bottle, turning a faucet on and off, opening/closing a container, opening a bottle top, and tightening shoelaces. Participants were asked to imagine normal motion of their nonparalyzed upper extremity. External perspective. | 3 | 20 | 4 | 12 | 12×20=240 | Post-test score of the MP group on Fugl-Meyer Assessment was significantly higher than the control group. There was no significant difference between the control and MP group on the Wolf Motor Function Test score. |

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**Table 1** (*continued*)

| Article | PEDro Score | Stage After Stroke* | Age, Mean ± SD | Sex, Male/ Female | Content of MP | Frequency of MP /Wk | Duration of Each MP Session (min) | Length of MP Inter vention (wk) | Number of Completed Sessions | Estimated Total Minutes of Completed MP | Key Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Timmermans et al[48] | 7 | Early subacute | Intervention: 59.7±7.3 Control: 58.7±9.6 | 26/16 | Six different MP training tasks were available, with gradually increasing difficulty: holding paper, grasp/hold/release of a glass, handle a pen to mark a cross on a paper, take a telephone call, bring glass to mouth, and pour water from a jar into a glass. First person perspective. | 15 | 10 | 6 | 90 | 90×10=900 | There was no improvement over time on Fugl-Meyer Assessment or Wolf Motor Function Test in either group. A significant improvement on the Frenchay Arm Test was found after training, which was maintained at 12-month follow-up, only in the experimental group. |
| Welfringer et al[49] | 7 | Late subacute | Intervention: 56.3±11.2 Control: 57.1±11.3 | 13/17 | MP included clench and release of hand and picking up objects (eg, an apple), with focus on hand and arm. First person perspective. | 10 | 30 | 3 | 28-30 | 30×30=900 | No significant changes in any group with respect to function (ARAT). Benefits specific to MP were found with respect to arm sensation within the intervention group. |

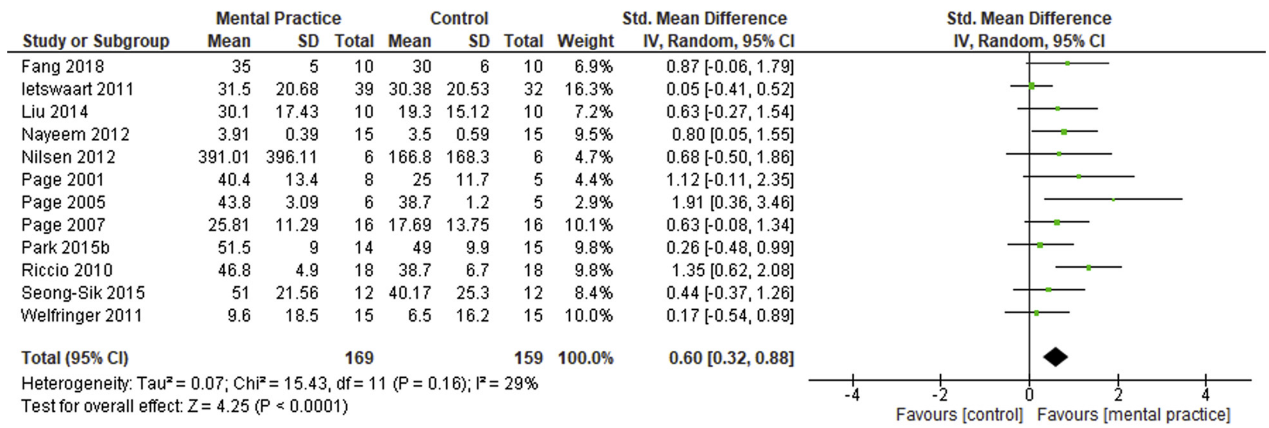


**Fig 2** Forest plot showing the overall effectiveness of mental practice on activity limitations of the upper limb. Data in Nilsen [41] are reversed so that improvement is indicated by a higher score.

that might have the greatest effect. The main results of this review were largely based on moderate to high quality trials and indicate that MP can confer significant reductions in upper limb activity limitations. Heterogeneity was low in the meta analyses (<29%), supporting the validity of these results.

An important finding was that the magnitude of reported benefit of MP on upper limb activity limitations (SMD, 0.60; 95% CI, 0.32-0.88; 12 studies, n=328) exceeded that reported for other recognized upper limb treatments in comparable studies of individuals after stroke. These include repetitive task training (SMD, 0.25; 95% CI, 0.01-0.49; 11 studies n=749)[24] and constraint-induced movement therapy (SMD, 0.24; 95% CI, -0.05 to 0.52; 42 studies, n=1453).[51] Despite the apparent superiority of MP to other upper limb interventions, MP is reported to be used much less frequently than either repetitive task training or constraint-induced movement therapy in clinical practice.[32] This indicates that further work to support the implementation of MP into routine therapy practice is clearly warranted.

The results of the current study are similar to those of the most recent Cochrane review of MP for the upper limb, which reported analogous effect sizes of the overall effectiveness of MP from 15 studies (SMD, 0.66; 95% CI, 0.39-0.94; n=397).[9] However, a larger analysis reported a smaller effect (SMD, 0.36; 95% CI, 0.16-0.55; 18 studies, n=644).[28] The disparity between these 2 reviews may be attributable to differences in the number of studies and participants included and the analytical

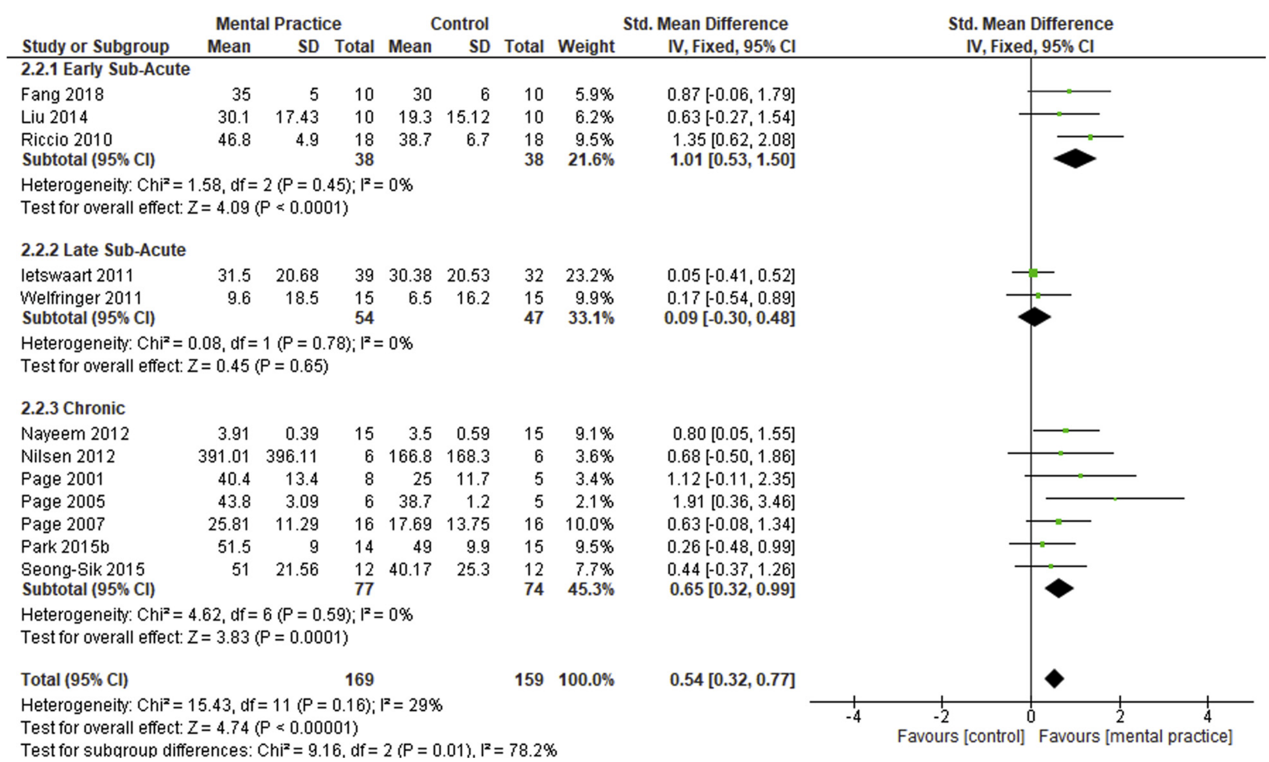


**Fig 3** Forest plot showing subgroup analysis (fixed-effects) of time after stroke and effectiveness of mental practice on upper limb activities. Data in Nilsen[41] are reversed so that improvement is indicated by a higher score.

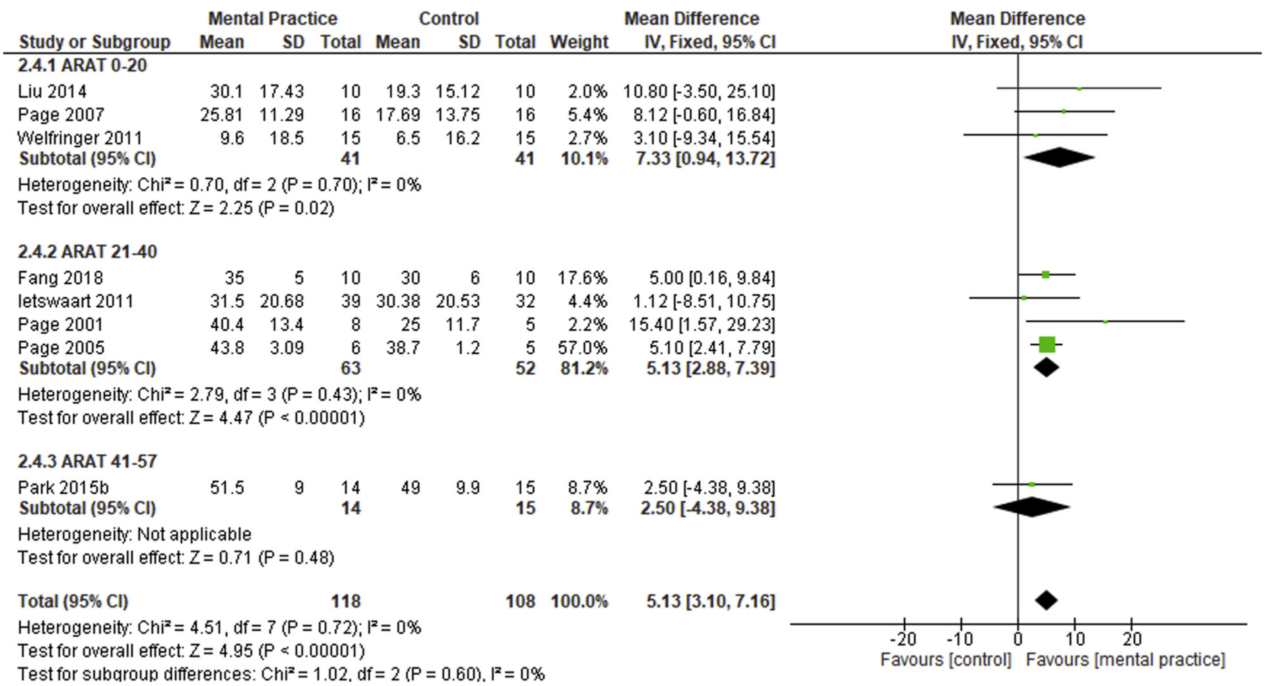


**Fig 4** Forest plot showing subgroup analysis of the effects of dose on activity limitations.

approach. Guerra et al[28] pooled data from studies measuring both impairment and activity limitations, whereas Barclay-Goddard et al[9] did not. The findings could indicate a trend for lower effectiveness of MP on impairments in comparison with activity limitations. However, this supposition is not supported in the analysis of impairment outcomes by Barclay-Goddard et al[9] (SMD, 0.59; 95% CI, 0.30-0.87; 15 studies, n=397). This warrants further investigation.

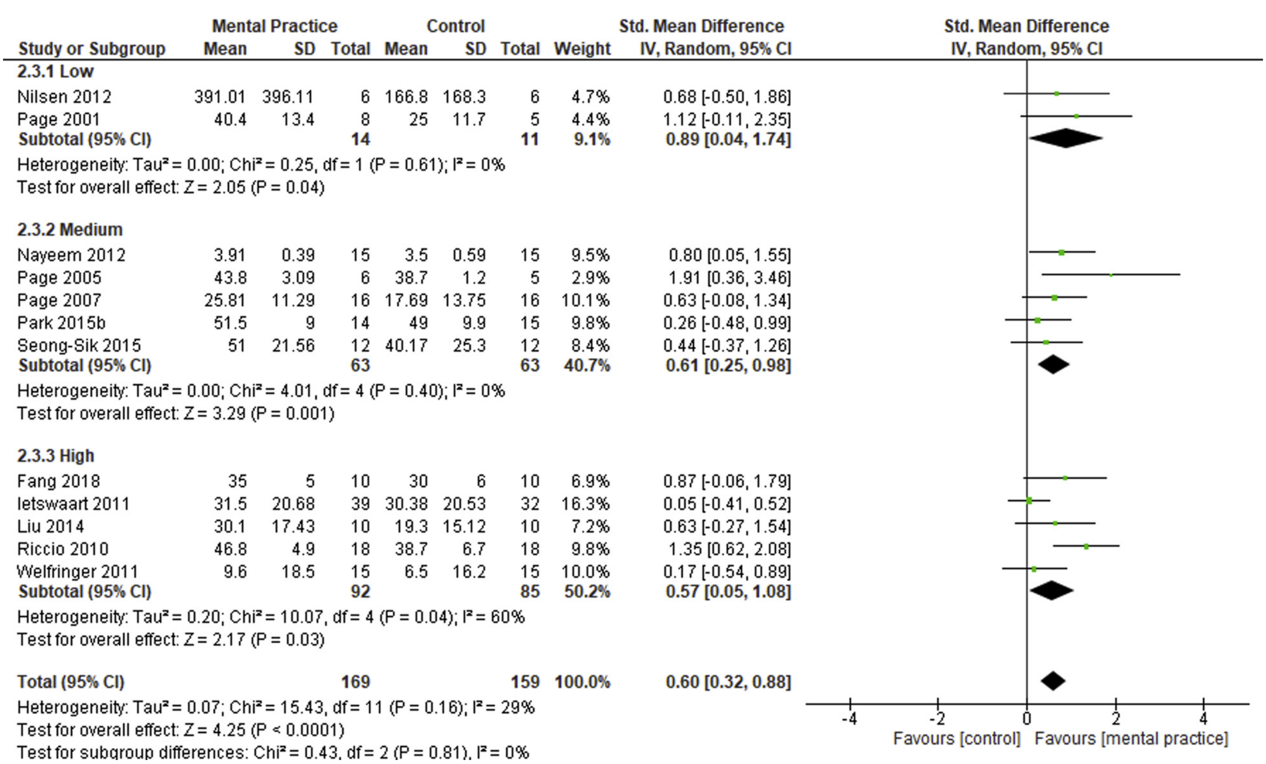


**Fig 5** Forest plot showing subgroup analysis (random-effects) of the effects of initial arm severity, measured using the ARAT, on the effectiveness of mental practice. Data in Nilsen[41] are reversed so that improvement is indicated by a higher score.

## Who? Patient selection and time since stroke

All trials selected participants who had normal or only mild cognitive dysfunction after stroke. The effect of reduced cognition on the ability to undertake MP after stroke remains uncertain. Several studies have shown that mental imagery after stroke may take longer to complete when compared with healthy or younger controls,[20,21,52,53] but no studies have provided explicit evidence of the minimal cognitive function required to successfully complete MP. Future studies should therefore consider broadening inclusion criteria to incorporate subgroups of individuals with moderate cognitive deficits after stroke to determine if they may benefit from MP.

None of the included trials stratified participants at baseline. As well as potentially attenuating the estimates of effectiveness, the absence of stratification leads to difficulty in knowing the optimal time after stroke and the severity of upper limb limitations likely to benefit most from MP. However, the subanalyses presented in this review suggest that MP delivered in the early subacute and chronic phases after stroke and to those with the most severe arm deficits (scoring 0-20 on the ARAT) may gain the most from MP.

Although others have found small differences between the effectiveness of MP provided in the first 6 months after stroke or later[9] (<6mo: SMD, 0.48; 95% CI, -0.04 to 0.99; 5 studies, n=188; ≥6mo: SMD, 0.75; 95% CI, 0.44-1.06, 8 studies, n=179),[9] our use of the Stroke Recovery and Rehabilitation Roundtable criteria allowed more detailed consideration of time periods. This revealed that the early subacute (7d-3mo after stroke) group had the largest change in activity limitations after using MP. The larger magnitude of changes during this early period is perhaps unsurprising as the most rapid and the majority of endogenous plasticity, and thus recovery of motor control, is typically observed in the first few weeks after stroke.[37,54] However, in line with the Barclay et al review,[9] a smaller but significant benefit was also seen in individuals at least 6 months after stroke, suggesting that MP may have different mechanisms of effect depending on when it is used after stroke. Collectively these results suggest that MP can improve upper limb function at multiple time points after stroke, and that work to understand the mechanism, and potential differences in mechanisms, depending on the time period in which it is applied after stroke is warranted.

Our finding that individuals with the most severe deficits exhibited substantial and significant benefit from MP is novel and is particularly noteworthy, as this benefit (WMD, 7.3; 95% CI, 0.94-13.7; $I^2=0\%$) exceeds the minimal clinically important difference for the ARAT (5.7).[55] No other reviews of MP for the upper limb have considered the severity of upper limb deficits on the effectiveness of MP.[9,28,56] Our finding indicates that MP could provide a promising treatment for individuals with severe upper limb limitations who typically cannot independently participate in other recognized treatments (such as repetitive task training), as they have little voluntary movement. The strength of this conclusion is limited by the wide CIs and relatively small number of studies in each subgroup, although heterogeneity was low, and because the cutoffs used in this analysis were arbitrarily assigned (ARAT scores: severe, 0-20; moderate, 21-40; mild, 41-57) to allow comparison. However, we chose not to use more widely recognized ARAT cutoff scores (severe, 0-10; moderate, 11-56; mild, 57),[55] as this would mean all but 1 study[49] would be considered to have moderate limitations and so any subtleties in the response to MP would be missed. Although analyzing the severity of upper limb limitations as we did is not standard, it highlights that the effect of MP on severe activity limitations after stroke is worthy of further study in this group.

## What and how much? Delivery and dose of MP after stroke

There was little indication in this review to determine which perspective (first or third person) used during MP was superior, as most studies did not indicate the perspective used. Mental imagery from a first person (egocentric) perspective is generally agreed to be more effective than that from a third person perspective and so is more widely used in published research protocols,[7] but there is little empirical evidence to support this.[11,41] Few studies also indicated if or how MP training was supervised. This is important because how MP is provided will have important time and cost implications for therapy services, significantly influencing cost effectiveness. Lack of detail regarding how MP is provided is a common criticism of studies reporting MP interventions.[57] This could be remedied by adopting recognized frameworks to deliver MP used in sport (eg, Physical, Environment, Task, Timing, Learning, Emotion, and Perspective)[11] and by the assiduous use of intervention reporting guidelines in future studies (eg, TIDieR).[31,57]

Interestingly, all but one[49] of the 15 studies included in this review delivered MP as a single massed practice session on each day it was delivered. This contrasts with the superiority of distributed over massed practice seen in motor learning[58] and the findings of a small study in which distributed MP (20min, 3 times a day, n=13) produced significantly larger gains in upper limb recovery after stroke when compared with once daily therapy for 60 minutes (n=14).[59] This suggests that future studies should consider delivering shorter but more frequent MP sessions to elicit greater gains in function.

The meta-analysis of the dose delivered in this review indicated that a low or medium total daily dose (low, <6.6min/d; medium, 6.7-32.1min/d) appeared slightly more beneficial than higher doses of MP (>32.2min). If accurate, this indicates that MP could provide an effective intervention without requiring substantial increases in therapy time and costs. However, this is perhaps unlikely as these findings contradict the accepted linear relationship between upper limb therapy dose and response,[60] and instead could be explained by the doses of MP delivered in all included studies being below the amount needed to elicit optimal benefit. Other studies indicate that therapy for the upper limb must be delivered intensively to show an optimal benefit,[61,62] which is likely to comprise several hours of intensive daily treatment.[60,63] In studies included in this review, 1 hour was the maximum daily amount of MP delivered, and this was only delivered in 2 trials.[46,49] Others have shown no significant differences in outcomes between MP delivered for an hour a day when compared with lower doses of 20 and 40 minutes per day.[44] This suggests that future trials should compare doses of a few minutes of MP to much more intensive practice akin to that in studies of upper limb rehabilitation that have shown significant benefit. It is also important to note that, both in this study and others, judgments of dose and intensity were estimated solely from the duration that MP was provided. Detailing the numbers of repetitions and the joints and movements targeted of mentally practiced movements provided by the MP script would provide a more accurate estimation of the intensity of training and should be reported in future studies, although it is recognized that an individual's adherence to imagining movements cannot be measured.

## Study limitations

Funnel plots suggest that the findings of this systematic review may be skewed by publication bias, with asymmetrical plots suggesting a lack of small studies showing no benefit from the comparator interventions. Inevitably this can lead to overestimation of the effectiveness of MP. Potential bias in the judgments of which studies were included in the review may also skew results. Although data extraction was checked, it was undertaken by 1 reviewer, which may have introduced error. Its wider validity is also restricted by the inclusion of only full-text articles available in English and exclusion of articles that did not measure changes in activity limitations of the upper limb. The exclusion of studies that measured impairment was primarily because a reduction in activity limitations is recognized to be more meaningful to individuals after stroke than alterations in impairment.[64] Taken alongside the knowledge that finding ways to effectively rehabilitate the upper limb after stroke is a recognized priority for both stroke survivors and clinicians,[30] the focus on activity limitations in this review increases its clinical validity and ultimately its usefulness to clinicians and individuals after stroke.

Interestingly, the studies included in this review did not always reflect the "typical" individual who has had a stroke, which limits the broader generalizability of the findings. Included studies had relatively young participants with a mean age of 59±5 years and preferentially recruited men (there were almost 100 more men than women). In Europe and Australasia, the average age for first stroke is markedly older (approximately 70y), stroke is more common in women than men,[65] and findings between sexes are not directly transferable as women tend to have poorer functional recovery.[66]

A further limitation to the findings of this review is that no studies comprehensively examined compliance and fidelity to the MP intervention. Others have reported low patient and therapist compliance to MP,[67] MP interventions are often not clearly defined,[57] and few therapists report using MP as part of therapy for the upper limb after stroke,[32] suggesting that the training and practical requirements of implementing MP need to be considered alongside its clinical effectiveness.

# Conclusions

The results of this systematic review and meta-analysis indicated that MP can significantly improve activity limitations of the upper limb after stroke and that it appears to be more effective than several other, more frequently used, interventions for the upper limb. This highlights that work is warranted to explore and support the successful implementation of MP into clinical practice so more people can benefit from using it as part of their rehabilitation after stroke. The finding that MP provides significant and substantial benefit that markedly exceeds the minimal clinically important difference for the ARAT in individuals with the most severe limitations of the upper limb after stroke is particularly novel and suggests that MP may constitute a promising therapy for this subgroup.

Future trials should seek to stratify individuals based on the severity of upper limb function and their potential for recovery of the upper limb to aid understanding of who may benefit the most from MP. Further work is also needed to standardize the delivery of MP, including identifying an optimal dose, standardizing exactly how MP is being used (first or third person viewpoints), and the number of repetitions of the included movements in the MP intervention. This could be done by use of a detailed intervention reporting tool[31] and established MP intervention structure.[11]

# Keywords

Stroke rehabilitation; Systematic review; Upper extremity

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