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Effectiveness of Action Observation and Motor Imagery on Relearning Upper Extremity Function After Stroke: A Systematic Review and Meta-analysis

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Abstract
The effectiveness of action observation (AO) and motor imagery (MI) in high-quality studies with less risk of bias is rarely reported together. This systematic review evaluates the effectiveness of AO and MI on improving upper extremity function among people after stroke by combining evidence of studies with high methodological quality. Randomised controlled trials, with a score of 6 or above in the PEDro Scale, that examined the effects of AO or MI for people with stroke were selected. A narrative analysis and meta-analysis were conducted using the PRISMA guidelines. Ten randomised controlled trials from 11 articles met the inclusion criteria. The results of meta-analysis showed that AO had a small to moderate statistically significant effect on improving upper extremity motor function (standardized mean difference, SMD = 0.34; confidence interval, CI = 0.08, 0.59; P = 0.35; I^2 = 0.00%) and no significant effect on MI (SMD = 0.08; CI = -0.26, 0.42; P = 0.65; I^2 = 0.00%) when compared with the control intervention. Evidence was found in support of AO and it is recommended for people with acute or sub-acute stroke.
Keywords: Motor imagery; Action observation; Stroke; Systematic review; Meta-analysis

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Introduction

Stroke is a leading cause of long-term motor disability in adults.[1,2] Approximately 85% of people with stroke experience hemiplegia and at least 69% have difficulty in regaining motor control of the affected hand.[3] Difficulty in using the affected hand may lead to a significant long-term impact on activities of daily living, leisure activities and work.

Action observation (AO) and motor imagery (MI) have been recognized as innovative techniques that may aid stroke survivors to overcome motor limitations. This is achieved by increasing the excitability of the impaired sensorimotor system and facilitation of cortical reorganization. Both AO and MI have been used for people in the acute, subacute, and chronic stages of stroke recovery and in different settings such as acute care hospitals, rehabilitation centres, homes, and community settings.[4-6]

AO is defined as a dynamic mental state during which an observer can understand what other people are doing by simulating their actions.[7] The theoretical foundation of AO is based on the mirror neuron system, consisting of the inferior parietal lobule, the premotor cortex and superior frontal gyrus. During observation of a movement, the related action representation produces similar activations in the observer's motor system. Previous studies have reported substantial evidence of the effectiveness of AO for motor skill learning and performance improvement in people with stroke.[4,7]

MI also involves a dynamic mental state during which a person mentally rehearses a physical task in the working memory without executing it. Several behavioural, psycho-physiological and neuroimaging studies have investigated the use of MI and have consistently reported comparable outcomes between MI and actual execution of the movement.[8,9,10] Neuroimaging studies have shown that MI leads to activation of regions in the brain, including the frontal, parietal, superior temporal cortices, basal ganglia and cerebellum, similar to the activations obtained in the real movement execution.[11] Recent studies have revealed that MI combined with actual practice provides improvement in upper extremity motor function of people with stroke for example.[12-15]

These approaches appear to increase the excitability of the impaired sensorimotor system and facilitate cortical reorganization[8] and thus the movement involved. Existing studies of AO and MI suggest that the mechanisms of AO and MI would share a similar excitability as the actual motor execution and, therefore, produce positive effects on facilitating movement. This view is supported by neuroimaging data showing an overlap in the activities within dorsal premotor cortex, superior parietal lobe and intraparietal sulcus during observation, execution, and imagery of reaching tasks.[8] However, AO is driven by visual stimuli of external origin (others' behaviour) and MI is driven by internal stimuli (re-activation of a motor representation stored in memory), and therefore, the main differences between AO and MI exists in the occipital regions. Although recent Cochrane Reviews reported the benefits of MI[15] and AO,[16] the reviews combined the use of MI or AO with other treatment and all the studies had different levels of quality. Further review on the use of MI or AO alone based on high quality studies with less risk of bias might be warranted.

The objective of this systematic review was to evaluate and summarize the current evidence on the effectiveness of AO and MI alone in improving upper extremity function among people with stroke by combining evidence of high-quality studies, including randomized controlled trials with high methodological quality (i.e., a Physiotherapy Evidence Database (PEDro) score ≥ 6 and least likelihood of bias).

Methods

The study was registered prospectively with the PROSPERO prior to commencement (registration number CRD42016047164).

Information Source and Search Strategy

We searched the following electronic databases: Medical Literature Analysis and Retrieval System Online (MEDLINE), Embase Biomedical Answers (Embase), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (via Ebscohost), and PsycINFO (via Ebscohost) from inception to September 2021. In addition to the studies retrieved from the above databases, reference lists of all included studies were searched to identify any additional relevant studies for inclusion.

The search strategy was derived considering the population, intervention, comparison, and outcome. The relevant Medical Subject Heading terms were combined with key words identified from related literature (e.g., cerebrovascular accident [CVA], stroke, hemiplegia, upper limb, upper extremity function, hand function, action observation, mirror, mirror therapy, motor imagery, imagery). Results from the database searches were exported and managed in Endnote, a reference management software. The search strategy is presented in Appendix 1.

Study Selection

We searched for all randomised controlled trials (RCTs) published in English and included studies that: (1) recruited adults (> 18 years) with either acute, subacute, or chronic stroke; (2) evaluated the effectiveness of AO or MI in the recovery of upper extremity function; (3) compared AO or MI with standard rehabilitation, sham therapy, or no treatment; and (4) used direct measures of upper extremity function. Studies were excluded if they were single day interventions or combined AO and MI interventions with other treatments such as brain stimulation, robotic devices, or virtual reality.

The quality of the included studies in this systematic review was assessed using the PEDro scale. The PEDro scale contains 11-items of quality assessment based on the Delphi list. The first item influences the external validity of the study. The remaining 10 items assess the characteristics pertaining to the internal validity of the study and were used to assess the quality of the studies in current systematic review. Studies which scored less than six on the PEDro scale were excluded from further analysis.

Two independent reviewers (NW and KL) were involved in the study selection. During initial screening of titles and abstracts, all papers screened as potentially eligible by at least one of the two reviewers were retained for full review. Authors were contacted when details required for screening was missing from papers. Date was included if further information was obtained. Reasons for inclusion and exclusion were recorded, and disagreements were resolved by discussion between the two reviewers to reach a consensus. A third reviewer (MB) resolved any difference in opinion between the two independent reviewers. The study selection process was in accordance with the PRISMA guidelines and is represented below in Figure 1.

Data Extraction Process

Two independent reviewers (NW and KL) were involved in the data extraction. A data extraction form was developed and piloted independently by two reviewers (NW and KL) on 10% of the identified studies prior to use. No modification was required.

Once eligible papers had been identified, data was extracted independently by the two reviewers. Disagreements relating to eligibility and differences in data extraction were resolved by discussion between the two reviewers to reach a consensus. A third reviewer was not required.

Data Extraction, Synthesis, and Analysis of Results

The data on participant information, type of interventions, outcome measures and results of the studies were extracted.

A narrative synthesis of the findings was used to report

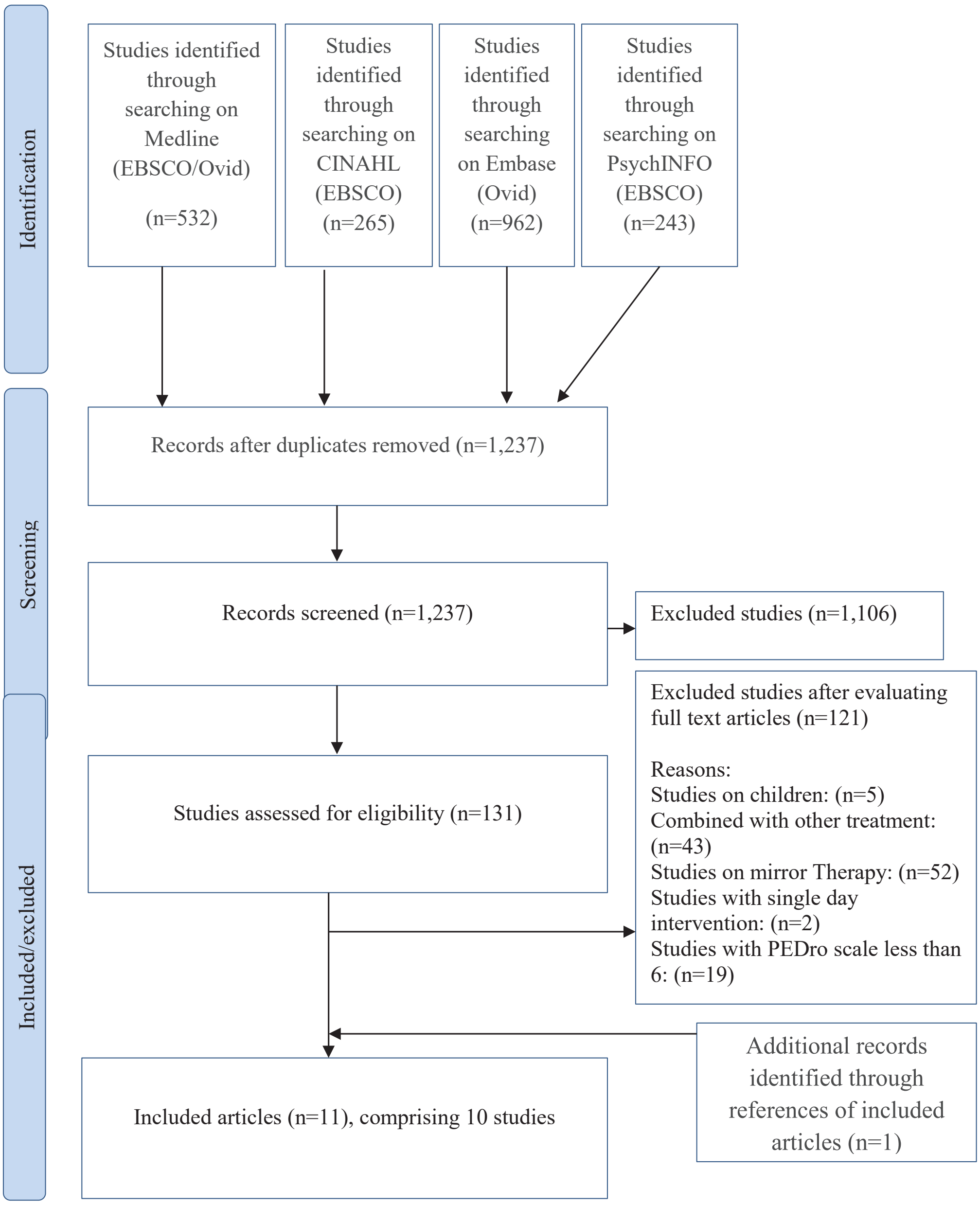

Figure 1. Flow Diagram of the Study Selection Process Based on the PRISMA Guidelines.

outcomes of all included studies. This synthesis was formatted around study type, sample size, participant characteristics, outcomes, and outcome measures. The context of intervention on type, quantity, frequency and/or duration of therapy were described.

Each study and outcome measure were assessed for suitability for meta-analysis. The treatment effects, based on pooled data from individual studies, were recorded. Means and standard deviations (SDs) or medians at pre- and post-intervention were extracted from each study. Meta-analyses were conducted using linear mixed models reporting standardized mean differences between the treatment and control group at follow-up. Where results were presented with adjustment for potential confounders, we selected results with most adjustment. Results of the meta-analysis were presented as forest plots with accompanying heterogeneity statistics I^2. We viewed $I^2 > 0.50$ as an indicator of large heterogeneity and added appropriate cautions to the interpretation of any pooled results. We also tested for heterogeneity using the Chi-square test, taking $P < 0.05$ as an indicator of statistically significant evidence of heterogeneity. The analysis will be performed using the 'metafor' package in R software, where the random effect model with 95% CI will be used.

Results

Study Selection

A total of 2002 articles were identified in the electronic search. Of these, 765 were duplicates leaving 1237 articles to undergo title and abstract review. The initial review excluded 1092 articles and ultimately, the authors reviewed the full text of 145 articles. Eleven articles comprising 10 studies met the inclusion criteria and were consequently included in this systematic review. The process of study selection is presented in Figure 1. The results of the quality analysis against the PEDro scale are presented in Appendix 2.

Participant Characteristics

The 10 studies incorporated in the review included 536 participants. Five studies examined AO[4,7,17-19] and included 291 participants. The remaining five studies (six articles) evaluated MI[6,20-24] and included 245 participants. There were 333 men and 203 women recruited in the studies. The mean age varied between 46.6[21] to 77.2[17] years. Individual study details are presented in Table 1.

Outcomes

The upper extremity function assessments reported in the selected studies were the upper extremity section of the Fugl-Meyer Assessment (F-M),[4,6,7,18,19,21-24] the Motricity Index,[17] the Action Research Arm Test (ARAT),[17,20,22] the Frenchy Arm Test,[4,6] the Box and Block Test [4, 7, 19], the Jebsen-Taylor Hand Function Test, [21] and the Wolf Motor Function Test.[6]

Study Duration

The frequency and total duration of the intervention in the selected studies was diverse. The frequency of therapy was generally higher in the studies using AO, varying from 5 times a week[4,7,17] to 6 times a week.[18] In the studies using MI, the frequency ranged from 2[21] to 7[6] times a week. The total duration of therapy for the studies using AO was 8 weeks,[18] 4 weeks[4,7,19] or 3 weeks.[17] The total duration of MI intervention varied, and was either 10 weeks,[22] 6 weeks[6, 21] or 4 weeks.[20,23,24] The total number of minutes of intervention ranged from 600 minutes[4,7] to 800 minutes[17] in the studies using AO and 240 minutes[21] to 1260 minutes[6] in the studies using MI.

Use of AO and MI

The studies exploring AO used everyday task performance for observation. As examples, participants in the Cowles and colleagues' study[17] observed everyday task performed by the research therapist and participants in one study[18] observed a video depicting daily activities.

The MI studies had greater variability in the mediums used. For example, participants in Ietswaart and colleagues' study[20] imagined daily tasks shown through pictures and verbal instructions, and in another study by Timmermans et al,[6] participants imagined daily tasks guided by a video. In two other studies, participants imagined daily tasks practiced during therapy session.[21,22]

Effects of AO and MI

Three studies on AO reported a significantly better improvement of upper extremity function in F-M in the experimental group compared with the control group.[7,18,19] This result was consistent for the MI studies with three studies (4 articles) reporting significant improvement of upper extremity function with the F-M using MI.[21-24] Results of the meta-analysis showed that the participants engaging in AO had a statistically significant small to moderate effect on improving upper extremity motor function (standardized mean difference [SMD] = 0.34; CONFIDENCE INTERVAL [CI] = 0.08, 0.59; P = 0.35; I^2 = 0.00%). For those using MI, no significant effect was found (SMD = 0.08; CI = -0.26, 0.42; P = 0.65; I^2 = 0.00%) (Figures 2 and 3).

Discussion and Implications

This systematic review reports the evidence relating to how AO and MI can enhance upper extremity function of people with stroke. The narrative analysis indicated the positive effects of both AO and MI. However, the results of the meta-analysis only showed that, in comparison with the control intervention, AO has a statistically significant small to moderate positive effect on upper extremity function. The results concur with a recent Cochrane review on the benefits of AO.[16] The therapeutic effects of AO on upper extremity function may be attributed to the promotion of motor relearning by activating the mirror neuron system and motor cortex.[2] Similar to mirror therapy, AO may exert a strong influence on the motor network, through increased cognitive control on movement. Although neuroimaging studies showed that MI involves the control mechanisms and neural substrates employed in actual movement for example,[8-10] the meta-analysis of this study did not show a positive effect on upper extremity function. Contrary to our findings, the result of a recent Cochrane review [15] showed that mental practice, a form of MI, was effective in improving upper extremity function after stroke. However, these two reviews combined the use of mental practice with other rehabilitation intervention which might result in a different finding from our review of MI alone.

The PEDro score for the included studies depicts high quality studies (PEDro ≥ 6) reducing the possible risk of bias. In all studies, the assessors were blinded. However, none of the studies included blinding of the participants and therapists and this is common among stroke rehabilitation clinical trials. For example, a systematic review on the effect of functional electrical stimulation for people with stroke also reported that none of the 18 studies included in the review had blinding of participants or therapists.[1] This is perhaps difficult to arrange in clinical studies where participants might know each other through participating in rehabilitation together and therapists are mostly conducting the intervention in an open space area within the clinic environment.

Participants were similar in sex and age in both the AO and MI studies, although Cowles et al[17] reported a much

Table 1. Summary of Included Trials (n = 10, from 11 articles)

Study	Type	Participants	Intervention	Outcome Measures	Results: Within Group Difference	Results: Between Group Difference
Cowles et al[17]	AO	n = 29 Age (y): 77.2 ± 10.4 Sex: 17 M, 12 F Time since stroke: < 1 mon	Exp: Observation of research therapist performing the functional task/physical practice 2 x 60 min x 5/wk x 3 wk Con: nil Both: conventional physical therapy	Motricity Index ARAT Timing: 0, 3 wk	Significant improvement in Exp and Con for Motricity Index ($P = 0.003$; 0.012 for Exp and Con respectively). Significant improvement in Con for ARAT ($P = 0.006$).	No significant difference found.
Franceschini et al[4]	AO	n = 102 Age (y): Exp: 65.7 ± 11.9 Con: 67.0 ± 12.4 Sex: 61M, 41 F Time since stroke: < 1.25 mon	Exp: Observation of video footage of daily routine tasks/physical practice 2 x 15 min x 5/wk x 4 wk Con: Sham 2 x 15 min x 5/wk x 4 wk Both: Standard rehabilitation	Frenchay Arm Test Fugl-Meyer Assessment Box and Block Test Timing: 0, 4, 20 wk	Significant improvement in Exp and Con for Frechay Arm Test ($P = 0.0005$;.03 for Exp and Con respectively), Fugl-Meyer Assessment ($P = 0.0008$; 0.01 for Exp and Con respectively), Box and Block Test ($P = 0.0001$; 0.03 for Exp and Con respectively).	Significant better improvement in Exp for Box and Block Test ($P = 0.003$).
Mancuso et al [19]	AO	n = 32 Age (y): Exp: 64.5 ± 15.75 Con: 76.50 ± 13.70 Sex: 20 M, 12 F Time since stroke: 15.60 ± 8.30 days	Exp: Observation of video footage 30 min x 5/wk x 4 wk plus Conventional treatment 60 min x 5/wk x 4 wk Con: Task-oriented training 30 min x 5/wk x 4 wk plus Conventional treatment 60 min x 5/wk x 4 wk	Fugl-Meyer Assessment Box and Block Test Timing: 0, 4 wk	Significant improvement in Exp and Con for Fugl-Meyer Assessment ($P < 0.001$; = 0.005 for Exp and Con respectively), Box and Block Test ($P = 0.0003$; 0.01 for Exp and Con respectively).	Significant better improvement in Exp for Fugl-Meyer Assessment ($P = 0.03$).
Sale et al [7]	AO	n = 67 Age (y): 66.5 ± 12.7 Sex: 41 M, 26 F Time since stroke: < 1 mon	Exp: Observation of video footage of daily routine tasks /physical practice 2 x 15 min x 5/wk x 4 wk Con: Sham 2 x 15 min x 5/wk x 4 wk Both: Physical exercise	Fugl-Meyer Assessment Box and Block Test Timing: 0, 4, 20 wk	Not reported.	Significant better improvement in Exp for Box and Block Test ($P = 0.012$).
Zhu et al [18]	AO	n = 61 Age (y): Exp: 57.75 ± 15.57 Con: 56.89 ± 14.93 Sex: 34 M, 27 F Time since stroke: < 6 mon	Exp: Observation of video depicting a model performing motor actions 30 min x 6/wk x 8 wk Con: nil Both: Traditional physical and occupational therapy 120-300 min x 6/wk x 8 wk	Fugl-Meyer Assessment Timing: 0, 6 wk	Significant improvement in Exp and Con for Fugl-Meyer Assessment ($P < 0.05$).	Significant better improvement in Exp for Fugl-Meyer Assessment ($P \leq 0.05$).
Ietswaart et al [20]	MI	n = 121 Age (y): Exp: 69.3 ± 10.8 Con 1: 68.6 ± 16.3 Con 2: 64.4 ± 15.9 Sex: 70 M, 51 F Time since stroke: < 3 mon	Exp: MI intervention 45 min x 3/wk x 4 wk Independent session 45min x2/wk x 4 wk Con 1: Attention-placebo control intervention 45min x 3/wk x 4 wk Con2: Normal care	ARAT Timing: 0, 5 wk	Not reported.	No significant difference found.

Table 1. Continued

Study	Type	Participants	Intervention	Outcome Measures	Results: Within Group Difference	Results: Between Group Difference
Nilsen et al [21]	MI	n = 19 Age (y): Exp 1: 46.6 (5.2) Exp 2: 62.0 (5.7) Con: 66.2 (2.6) Sex: 9 M,10 F Time since stroke: < 2.25 mon	Exp 1: Mental practice training in functional tasks using internal perspective 20 min x 2/wk x 6 wk Exp 2: Mental practice training in functional tasks using external perspective 20 min x 2/wk x 6 wk relaxation imagery training 20 min x 2/wk x 6 wk Con: nil All: Occupational Therapy 30min x 2/wk x 6 wk	Fugl-Meyer Assessment Jebsen-Taylor Hand Function Test Timing: 0, 6 wk	Significant improvements in Exp 1 and Exp 2 for Fugl-Meyer Assessment (Mean = 9.6, SEM = 1.03 for Exp 1; Mean = 10.6, SEM = 2.94 for Exp 2) and Jebsen-Taylor Hand Function Test (Mean = -83.22 s, SEM = 44.49 for Exp 1; Mean = -226.72 s, SEM = 82.94 for Exp 2). No significant improvement in Con.	Significant better improvement in Exp 1 with Con, Exp 2 with Con in Fugl-Meyer Assessment (*P* = .047); Jebsen-Taylor Hand Function Test (*P* = .036). No significant difference found between Exp 1 and Exp 2.
Page et al [22]	MI	n = 29 Age (y): 60.8 ± 12.3 Sex: 23 M, 6 F Time since stroke: 36 mon	Exp 1: Mental practice using audio tape instructions 20 min x 3/wk x 10 wk Exp 2: Mental practice 40 min x 3/wk x 10 wk Exp 3: Mental practice 60 min x 3/wk x 10 wk Con: Sham All: Reparative task practice 30 min x 3/wk x 10 wk	Fugl-Meyer Assessment ARAT Timing: 0, 1, 10 wk	Not reported.	Significant better improvement in Exp 1 and Exp 2 with Con, in ARAT (*P* = 0.07). No significant difference found between Exp 1 and Exp 2.
[Two manuscripts using the same data set] Wang et al,[23] Wang et al,[24]	MI	n = 34 Age (y): Exp: 53.38 ± 14.04 Con: 60.47 ± 7.58 Gender: 32 M, 2 F Time since stroke: 3-12 mon	Exp: MI training 30min x 5/wk x 4 wk plus conventional rehabilitation training 3 h x 5/wk x4 wk Con: conventional rehabilitation training 3 h x 5/wk x 4 wk plus health education 30 min	Fugl-Meyer Assessment Timing: 0, 4 wk	Significant improvement in Exp and Con for Fugl-Meyer Assessment (*P* < 0.000; = 0.002).	Significant better improvement in Exp with Con, in Fugl-Meyer Assessment (*P* = 0.024). .
Timmermans et al [6]	MI	n = 42 Age (y): Exp: 58.7 ± 9.6 Con: 59.7 ± 7.3 Gender: 26 M, 16 F Time since stroke: < 1.5 mon	Exp: Mental practice using video instructions 3 x 10 min x 7/wk x 6 wk Con: Exercise therapy 3 x 10 min x 7/wk x 6 wk	Frenchay Arm Test Fugl-Meyer Assessment Wolf Motor Function Test Timing: 0, 6, 24, 36, 52 wk	Significant improvement in Exp and Con for Frenchay arm test (*P* = 0.000; .037) [a clinically meaningful important difference was found in Exp only]; Fugl-Meyer Assessment (*P* = 0.000); Wolf Motor Function Test (*P* = 0.000).	No significant difference found.

Abbreviations: n = number, y = year, AO = Action observation, MI = Motor imagery; Exp = experimental group, Con = control group, M = male, F = female, wk = weeks, mon = months, SEM = Standard Error of Mean; ARAT = Action Research Arm Test.

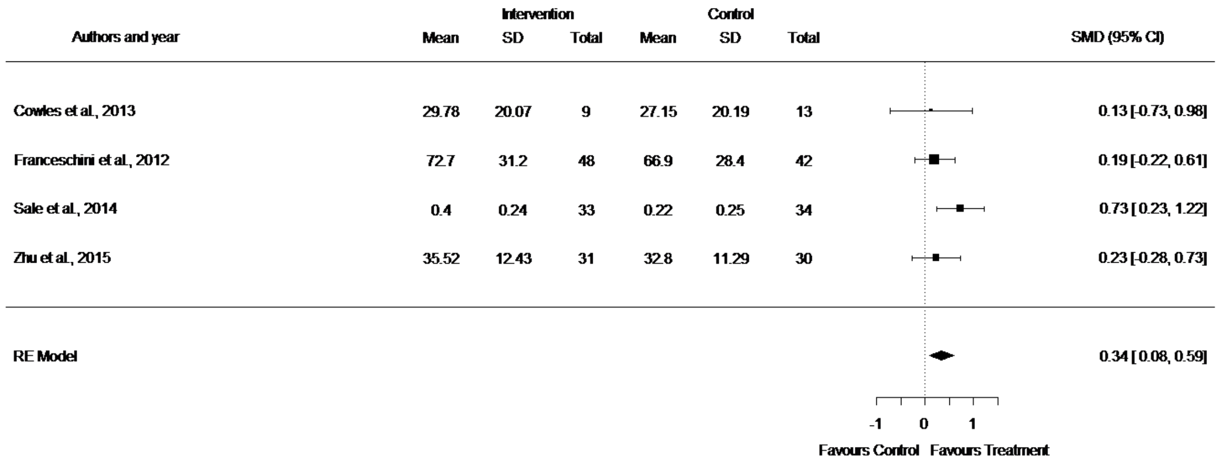

Figure 2. Meta-analysis Plots of the Effects of Action Observation (AO) on Upper Extremity Motor Function.
SMD (95% CI) of the effect of AO compared with sham/standard rehabilitation by pooling data from a total of 240 participants. Heterogeneity: $Tau^2=0.83$; $Chi^2=3.27$, df=3 ($P=0.35$); $I^2=0.00\%$; Test for overall effect: $Z=6.69$ ($P=0.009$). Abbreviations: SD=standard deviation, SMD=standardized mean differences, CI=confidence interval. Intervention refers to AO.

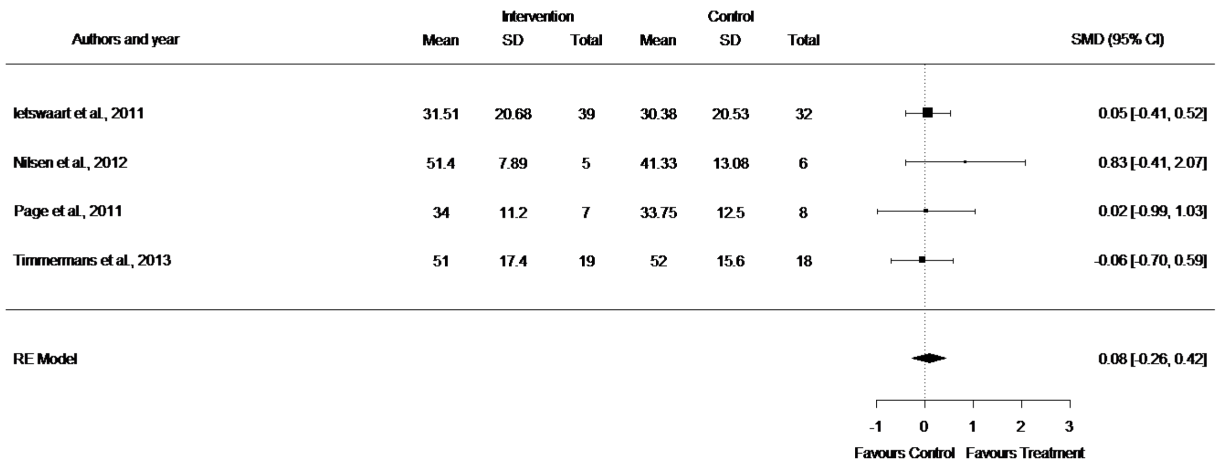

Figure 3. Meta-analysis Plots of the Effects of Motor Imagery (MI) on Upper Extremity Motor Function. Heterogeneity: $Tau^2=0.19$; $Chi^2=1.62$, df=3 ($P=0.65$); $I^2=0.00\%$; Test for overall effect: $Z=0.19$ ($P=0.655$). SMD (95% CI) of the effect of MI compared with sham/standard rehabilitation by pooling data from a total of 134 participants. Abbreviations: S=standard deviation, SMD=standardized mean differences, CI=confidence interval. Intervention refers to MI.

older participant group and Nilsen et al[21] had slightly more female participants than male participants when compared with other studies. The time following the onset of the stroke in all the four studies using AO was acute or sub-acute (<6 months after stroke), and in studies using MI, three studies were conducted in people with acute or subacute stroke period (<3 months after stroke) and one study with those in the chronic stage (36 months after stroke). This indicates that the results of this study only pertain to the acute and sub-acute phases. Further research of the chronic phase is required. A previous systematic review by Kho et al[5] recommended MI as a useful therapeutic technique for upper extremity motor rehabilitation in the sub-acute stage to further enhance neural recovery. The study using AO in facilitating motor cortical activity among patients with stroke suggests that rehabilitation is maximally beneficial during the acute and recovery stages of stroke rather than the chronic stage. These provide possible reasons why seven of the included studies in this systematic review recruited participants in the acute or sub-acute stage.

The duration of interventions, between 3 to 8 weeks in the studies using AO and 4 to 10 weeks in the studies using MI, is comparable to the findings of the systematic review examining effectiveness of the constraint-induced movement therapy following stroke in which interventions were implemented between 2-10 weeks.[25] In that systematic review, it was identified that shorter sessions with a duration of up to 10 weeks are suitable for both participants and therapists and improve upper extremity function. However, the authors did not conclude the optimal training frequency and duration.

In the studies selected in this systematic review, there were two main types of AO being practiced by the participants. They included observation of tasks performed by the therapist or video depicting daily tasks. The interventions involved imagining daily task performance guided by a video or practiced during therapy sessions. The AO involved observation only and the MI had an active imagining component. However, it is unknown if the participants performed the imagery by themselves after observing the performance during the AO. Whether performing imagery while receiving AO would induce a greater effect to the upper limb functional regain is unknown. However, the results of meta-analysis showed that AO resulted in a statistically significant improvement than the control intervention.

The most common upper extremity and hand function assessment used in the individual studies in this review were the ARAT and the F-M. This finding is consistent with other studies on upper extremity function post stroke with the range of measures of upper extremity function, being most commonly the ARAT, the F-M and the Motor Assessment Scale.

A previous systematic review analysed the effect of MI for motor rehabilitation of the upper extremity [5]. In that meta-analysis, the ARAT yielded significant results but not the F-M (with mean difference 6.39, 95% CI: 4.47–8.31; $Z=6.53$, $P<0.00001$). The authors postulated that the F-M largely measures upper extremity function compared to the ARAT which is more focused on grasp, grip, and pinch. Therefore, a ceiling effect in motor recovery could have been observed in the F-M. In our meta-analysis, we used the pooled results of the upper extremity outcome measures and this may compensate for the possible ceiling effects of a particular outcome measure.

Study Limitations

The main limitations of this study included the lack of blinding of therapists and participants in the clinical trial, this might induce certain bias. There was a lack of consistent outcome measures used, it would be possible that the pooled results of the upper extremity outcome measures in the meta-analysis might affect the outcome. In the selection of studies, we used the definitions of MI and AO with two independent reviewers, however this might potentially create errors as the reviewers could interpret the description of the studies inconsistently. In the meta-analysis, we calculated the SMD and an estimation of the benefit of AO and MI in real terms might not be expressed.

Conclusion

MI seemed to produce a beneficial effect; however, this was not supported by the results of the meta-analysis. The results of this study suggest that AO is beneficial in promoting upper extremity function in people with stroke. The results of the meta-analysis further verify the positive effects of AO on upper extremity functions for people in the acute and sub-acute period after stroke.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

Ethical Statement

Not applicable.

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Appendix 1. Search strategy

Keywords searched
1. Stroke [mh] OR Cerebrovascular accident [tw] OR CVA OR Hemiplegia [mh] OR Hemipar*[tw]
2. Upper extremity [mh] OR Upper limb [tw] OR Hand [mh] OR Hand function [tw] OR Finger dextirit* [tw] OR Agility [mh]
3. Motor imagery [tw] OR Guided imagery [mh] OR imagery [tw] OR Visualisation [tw] OR Guided imagery [tw]
4. Mirror therap* [tw] OR Mirror OR Mirror neurons [mh] OR Action observation [tw]
5. 1 AND 2 AND 3 AND 4

Abbreviation: mh, Medical Subject Headings; tw, text word; *, wildcard

Appendix 2. Physiotherapy Evidence Database (PEDro) scores for included articles (N = 11)

Author	Criteria											Total (0-10) [Item 1 is not used to calculate the total.]
	1	2	3	4	5	6	7	8	9	10	11	
Included studies												
Cowles, Clark, Mares, Peryer, Stuck and Pomeroy [17]	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Franceschini, Ceravolo, Agosti, Cavallini, Bonassi, Dall'Armi, Massucci, Schifini and Sale [4]	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Mancuso, Tondo, Costantini, Damora, Sale and Abbruzzese [19]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8
Ietswaart, Johnston, Dijkerman, Joice, Scott, MacWalter and Hamilton [20]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Nilsen, Gillen, DiRusso and Gordon [21]	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	6
Page, Dunning, Hermann, Leonard and Levine [22]	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Sale, Ceravolo and Franceschini [7]	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	7
Timmermans, Verbunt, van Woerden, Moennekens, Pernot and Seelen [6]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
* Wang, Xu, Wang, Sun, Zhu, Fan, Jia, Guo and Sun [23]	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	7
* Wang, Wang, Xiong, Sun, Zhu, Xu, Fan, Tong, Sun and Guo [24]	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	7
Zhu, Wang, Gu, Shi, Zeng, Wang, Chen and Fu [18]	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6

NOTE: 1 - Eligibility criteria; 2 - Random allocation; 3 - Concealed allocation; 4 - Baseline comparability; 5 - Participant blinding; 6 - Therapist blinding; 7 - Assessor blinding; 8 - <15% dropouts; 9 - Intention to treat; 10 - Between group difference; 11 - Point estimate and variability. Item one is not considered for calculating the total.
Abbreviations: N, no; Y, yes
* The two articles used the same data set and are considered as one study in the analysis.