Med. J. Cairo Univ., Vol. 87, No. 2, March: 1059-1076, 2019
www.medicaljournalofcairouniversity.net

Mirror Neuron Applications on Motor Recovery in Stroke Patients: A Systematic Review

AHMED A. EL-ZALABANY, M.Sc.*; GEHAN M. NOUR, Ph.D.** and MAYA G. ABD AL-WAHAB, Ph.D.***

The Department of Neuro-Rehabilitation, Faculty of Physical Therapy, Pharos University, Alexandria,
*The Departments of Physical Therapy for Neuromuscular disorder** and Physical Therapy for Pediatrics***,*
Faculty of Physical Therapy, Cairo University

Abstract

Background: Mirror neurons represent a variety of neurons that fire when the subject executes a motor act or observes others making the same action. A lot of therapeutic applications based on the existence of mirror neurons are widely used today in the field of stroke rehabilitation.

Objectives: To summarize the best evidence of the effectiveness of mirror neuron applications for improving motor function, activities of daily living, spasticity, pain, visuospatial neglect, sensation, quality of life and muscle power in the stroke patients.

Methods: We searched the following electronic databases: Pubmed (October 2017), Cochrane Library (November 2017) and PEDro (November 2017). We also checked the reference lists. We included Randomized Controlled Trials (RCTs) that compare mirror neuron applications (mirror therapy, motor imagery/mental practice, action observation therapy or virtual reality reflection therapy) with conventional physical or occupational therapy for patients after stroke. Then we selected the trials that match the inclusion criteria, and we assessed the methodological quality of studies and extracted data. Finally, we analyzed the results by pooling the data of change scores between pre- and post-intervention through calculation of the overall Standardized Mean Differences (SMDs) with 95% Confidence Interval (CI).

Results: We included 44 studies with a total of 1792 participants. Of the 44 studies, 4 interventions based on mirror neurons were studied. Firstly, mirror therapy may have a significant effect on motor function of the upper extremity; however, effects on motor function are influenced by the variation of mirror therapy, activities of the unaffected limb showed greater effect than bilateral activities. We found limited evidence for improving walking ability. Secondly, motor imagery/mental practice showed a significant improvement on the motor function specially for the lower extremity functions. Thirdly, we found limited evidence of action observation therapy in improving motor function of the upper extremity, walking ability. Finally, we included only one study that used virtual reality reflection therapy in stroke rehabilitation, so we didn't include it in the pool analysis.

Conclusion: There is an evidence from the included RCTs on the effectiveness of mirror therapy on improving motor function of the upper extremity. Additionally, we found a significant positive effect of mental practice on motor function specially the walking ability. And there was a poor evidence on the effects of action observation on motor recovery in patients after stroke. However, much more studies should be conducted to assess the benefits of virtual reality reflection therapy.

Key Words: *Action observation – Mental practice – Mirror therapy – Motor recovery – Stroke – Systematic review – Virtual reality reflection therapy.*

Correspondence to: Dr. Ahmed A. El-Zalabany,
The Department of Neuro-Rehabilitation, Faculty of Physical Therapy, Pharos University, Alexandria

Introduction

STROKE is a neurological deficit attributed to an acute focal injury of the Central Nervous System (CNS) by a vascular cause, including cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage, and it is presented as paralysis or weakness of one side of the body, disturbance of speech, impaired sensations, alterations in muscle tone and abnormal reflexes [1].

Recovery may be enhanced by intensive physical therapy aimed at the reorganization of function in damaged neural networks to minimize motor deficits and develop new strategies in motor learning by promoting adaptive plasticity of structure and function in the undamaged brain toward recovery. In patients with poor motor ability, however, participation in physical therapy may be limited, and it may be a challenge to provide relevant input for experience-dependent neural plasticity for neurorehabilitation, repair, and recovery [2].

One way to overcome these limitations is suggested by the putative mirror neuron system. Which are the neurons that fire when an animal acts or observes the same action of another thus coding the motor response. By representing observed actions in the motor cortex, the mirror system may serve as an alternative means to access the motor system after CNS injury-despite impairments-to rebuild voluntary motor function. There are many applications that are used in the neurorehabilitation such as mirror therapy, action observation and motor imagery [3,4].

Mirror therapy is based on visual stimulation. In mirror therapy, a mirror is placed in the patient's sagittal plane, thus reflecting the non-affected side as if it were the affected side, so that movements of the non-affected limb give the illusion that the affected limb is moving [5].

Motor imagery is considered the mental execution of a skilled movement without actually performing the movement. While mental practice training means the therapy task in which an internal representation of the movement is activated and the execution of the movement repeatedly mentally simulated, without physical activity [6].

Action Observation Therapy (AOT) is based on the observation of action performed by others. In this technique, participants are typically required to carefully observe videos showing actions that then they have to execute [7].

Subjects and Methods

This review was conducted through electronic and manual search, from May 2017 to May 2018, in order to provide valid evidence regarding the effectiveness of mirror neuron applications in the rehabilitation of stroke, and it followed the following steps:

Inclusion criteria for considering studies for this review:

I- *Types of studies:* This review included published Randomized Controlled Trials (RCTs) with or without blinding of participants, physiotherapists and assessors, which compare mirror therapy, action observation therapy, mental practice or virtual reality reflection therapy with any other therapy modality or sham therapy.

II- *Types of participants:*

- Adult participants (over 18 years of age) with a clinical diagnosis of stroke, either ischaemic or haemorrhagic in origin, acute, sub-acute or choronic.
- Studies on mixed populations of healthy individuals or patients with stroke, were included only if separate data for patients were available.

III- Types of interventions: Different forms of mirror neuron applications including mirror therapy, motor imagery or mental practice, action observation therapy and virtual reality reflection therapy.

IV- Control/comparator: The comparisons of interventions were control, placebo or standard care; and comparisons of different doses, intensities or timing of delivery of the same intervention.

V- Outcome: The primary outcome was motor function. Thus, some outcome measures were selected due to its variety and to facilitate quantitative pooling. For the initial analyses of motor recovery, every outcome measure was analyzed separately. Then the outcomes were reanalyzed to test the efficacy of the included intervention variations, measures were prioritized as follows:

1- Upper limb and hand function: Including measures that examine active function, dexterity, object manipulation and reach-to-grasp, grip or pinch.

- Fugl-Meyer assessment, upper limb or hand function or both; Action Research Arm Test; Wolf Motor Function Test; Manual Function Test; Box and Block Test (for dexterity).

2- *Lower limb function:* Such as walking ability, stages of motor recovery, measures of disability and temporospatial gait characteristics including the following:

- Fugl-Meyer assessment, lower limb function; Timed Get up and Go; 10 Meter Walking Test; 6-Minute Walk Test; Gait analysis (Velocity, Cadence, step length, stride length, single stance, stance phase, swing phase and step width); functional ambulation categories.

Exclusion criteria:

The studies were excluded if they were:

- Study designs other than randomized controlled trials.
- Review articles, survey, case report and case series.
- Published abstracts with no full text articles available.
- Trials that investigate one of the included interventions together with the application of other intervention.
- Studies with low methodological quality (all studies with total PEDro scores less than 5).

Search methods for identification of studies:

Electronic database search was done in:

- PubMed (Medline) at http://www.ncbi.nlm.nih.gov/pubmed.
- CENTRAL at http://www.thecochranelibrary.com.
- Physiotherapy Evidence Database (PEDro) at http://www.pedro.org.au/.

The following keywords have been used to search the electronic databases (PubMed, CEN-

TRAL (Cochrane) and PEDro): Mirror neuron, mirror therapy, motor imagery, mental practice and action observation therapy. An additional search was done using the following keywords: Stroke, Apoplexy, CVA (Cerebrovascular Accident), cerebral stroke, cerebrovascular accident, cerebrovascular accident, acute, cerebrovascular Apoplexy, cerebrovascular stroke, stroke, acute or vascular accident, brain. Databases were searched from May 2017 to May 2018, in addition to searching the database also the reference lists of relevant publications was checked.

Study selection criteria:

Titles and abstracts of records identified by the electronic searches were assessed by two independent reviewers (Ahmed Anwar and Maya Galal). Manual search was done through checking the reference lists of relevant publications and tracking the newer studies through “Scopus”. Obvious irrelevant trials were excluded. Then, the full text of the remaining studies was obtained and checked for eligibility against inclusion and exclusion criteria in order to exclude the studies that don't fulfil the inclusion criteria.

Data extraction:

A data collection form was used to extract and record the key features of each trial including details of the participants, interventions, outcomes and results. One reviewer (Ahmed Anwar) extracted data from the included studies and a second reviewer (Maya Galal) cross-checked it.

Methodological quality assessment of the studies:

The methodological quality of the full papers was assessed by using the risk of bias assessment tool according to Chapter 8 of the Cochrane Handbook for Systematic Reviews of Interventions [8]. And by applying the physical therapy evidence data base scale (PEDro) which assess the eligibility criteria, method of randomization and blinding, concealment of allocation, similarity of participants in treatment groups at baseline, whether an intention-to-treat analysis will be performed and the number of participants lost to follow-up and missing values (Appendix I). Consensus was achieved through discussion, including a third author if necessary (Prof. Gihan Mousa).

Studies that got 9-10 points on PEDro scale are considered to be excellent, studies that got 6-8 points on PEDro scale are considered to be good, studies that got 4-5 points on PEDro scale are considered to be average and studies that got 0-3 points on PEDro scale are considered to be poor.

Measures of treatment effect:

The primary and secondary outcome variables of interest were continuous outcomes. Data of change scores between pre-and post-intervention measures were evaluated and entered as means and Standard Deviations (SDs) and the Standardised Mean Difference (SMD) with 95% Confidence Intervals (CIs) for each trial was calculated. Data were pooled through calculation of the overall SMD and 95% CI.

Data analysis:

A comparison between the mirror neurons interventions and conventional therapy or placebo therapy was made, and a pooled analysis of primary and secondary outcomes was conducted as described above, using a random effects model instead of a fixed-effect model if heterogeneity of the studies was high. A subgroup analysis was performed to establish the effectiveness related to the used outcome measures, mirror therapy variation and upper or lower extremity.

Results

Results of the search:

515 studies were identified from the search of PubMed, Cochrane and PEDro databases and additional 24 studies from the other sources (screening the reference lists of all relevant articles). After excluding all duplicate studies, a total of 387 studies have been screened then, 322 studies have been excluded and the full-text articles of 65 studies which appear to meet the eligibility criteria have been assessed. Results of the search are displayed in Fig. (1).

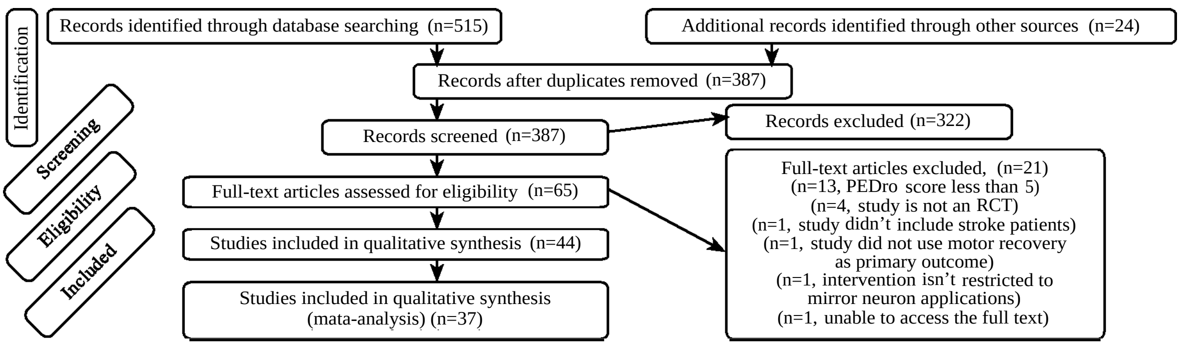


Fig. (1): Search results.

Included studies:

44 studies met the inclusion criteria of this review. Of the 44 studies, 4 interventions-based on mirror neurons-were studied. (20 studies **[9:28]** used mirror therapy, 12 studies **[29-40]** used mental practice/motor imagery, 11 studies **[41:51]** used action observation and 1 study used virtual reality reflection therapy).

Sample size and participants:

The 44 studies included a total of 1792 participants. Individual sample sizes of identified trials ranged from 13 **[37]** to 121 **[32]**. Detailed descriptions of patient characteristics are given in (Table 1). The mean age of participants in the included studies was 60 years. There were more male (60%) than female (40%) participants. Mean time post-stroke was 12.1 months.

Table (1): Participants of the included studies.

Study	Experimental group					Control group				
	N	Male	Female	Age	Duration	N	Male	Female	Age	Duration
Arya (2015)	17	15	2	48	12.88	16	10	6	42.12	12.25
Bang (2013)	15	9	6	64.1	14.10	15	8	7	58.9	12.60
Braun (2010)	18	9	9	77.9	1.12	18	5	13	77.7	1.42
Cacchio (2009)	24	13	11	57.9	5.10	24	17	7	58.8	4.90
Cho (2012)	15	9	6	53.93	44.67	13	8	5	53.85	45.54
Colomer (2016)	15	13	2	53.8	19.47	16	13	3	53.3	17.33
Cowles (2013)	15	8	7	78.8	0.65	14	9	5	75.6	0.59
Dohle (2008)	24	13	5	54.9	0.87	18	13	5	58	0.93
Ertelt (2007)	8	5	3	57.16	49.10	8	6	2	55.4	24.16
Franceschini (2012)	53	33	20	67	1.03	49	28	21	65.7	0.97
Fu (2017)	28	11	17	62.04	1.32	25	11	14	59.76	1.37
Gurbuz (2016)	16	10	6	60.9	1.54	15	7	8	60.8	1.41
Harmsen (2014)	18	9	9	57	46.00	19	13	6	60	38.00
Hosseini (2012)	15			48.4	17.60	15			47.7	21.00
Ietswaart (2011)	41	23	18	69.3	2.73	80	47	33	66.5	2.86
In (2016)	13	8	5	57.31	12.54	12	7	5	54.42	13.58
Invernizzi (2013)	13	9	4	62	0.73	13	8	5	71.1	0.80
Ji (2014)a	10	7	3	48.6	7.30	10	6	4	54.6	6.70
Ji (2014)b	17	9	8	55.2	4.30	17	10	7	54.3	4.30
Kim (2012)	15			64.1	4.60	15			65.5	4.10
Kuk (2016)	10	4	6	60	15.30	10	5	5	59.7	14.90
Kumar (2015)	20	16	4	53	6.50	20	14	6	51	5.60
Lee (2012)	13	8	5	58.8	3.50	13	7	6	55.4	3.60
Lin (2014)	14	10	4	56.01	18.50	15	11	4	53.34	17.80
Liu (2004)	26	11	15	71	0.41	20	11	9	72.7	0.51
Liu (2009)	17	9	8	70.4	0.41	17	12	5	68.1	0.41
Michielsen (2010)	20	7	13	55.3	57.18	20	13	7	58.7	54.75
Mirela Cristina (2016)	7	3	4	58.2	1.81	8	4	4	56.8	1.74
Motaqhey (2015)	12	6	6	54.8	5.25	12	6	6	54.5	5.25
Oostra (2014)	21	15	6	50.3	4.70	23	14	9	53.7	3.60
Page (2001)	8	6	2	64.37	5.80	5	4	1	65	7.60
Page (2007)	16			58.69	38.81	16			60.38	45.19
Page (2011)										
Park (2014)	11	8	3	55.91	21.09	10	7	3	54.8	25.60
Park (2015)	15	8	7	58.3	7.90	15	7	8	61.7	8.70
Pervane Vural (2016)	15	8	7	68.9	4.50	15	9	6	61.4	5.08
Sale (2014)	33					34				
Selles (2014)										
Sun (2013)	10	9	1	56.67	3.90	10	9	1	56.11	4.40
Sütbeyaz (2007)	20	10	10	62.7	3.50	20	7	13	64.7	3.90
Thieme (2012)	18	11	7	63.8	1.59	21	14	7	68.3	1.71
Tyson (2015)	62	37	25	64	0.89	31	23	8	64	1.17
Wu (2013)	16	11	5	54.77	19.31	17	12	5	53.59	21.88
Yavuzer (2008)	17	9	8	63.2	5.40	19	10	9	63.3	5.50

Interventions:

Characteristics of interventions are summarized in (Table 2).

Table (2): Characteristics of interventions of the included studies.

Study	Extremity	Frequency	Method	Control intervention	Type of activities
Mirror therapy:					
• Arya (2015)	U.L	• 5S/W for 8W 90min each.	• Unaffected limb activities.	• Conventional occupational therapy.	• Functional motor tasks.
• Cacchio (2009)	U.L	• 5S/W for 4W 60min each.	• Unaffected limb activities.	• Conventional therapy; covered mirror.	• ROM ex for shoulder, elbow, wrist and forearm.
• Colomer (2016)	U.L	• 5S/W; 60min each (conventional therapy); 3S/W for 8W 45min each.	• Unaffected limb activities.	• Conventional therapy and passive mobilization.	• ROM ex for shoulder, elbow, wrist and forearm without objects.
• Dohle (2008)	U.L	• 5S/W for 6W 30min each.	• Bilateral activities.	• Standard therapy and bilateral arm training without mirror.	
• Gurbuz (2016)	U.L	• 5S/W for 4W 60-120min each.	• Unaffected limb activities.	• Conventional therapy; ex against the non-reflecting face of the mirror.	• ROM ex for wrist and fingers.
• Invernizzi (2013)	U.L	• 5S/W for 4W 60min each; 30:60 extra min for experimental group.	• Unaffected limb activities.	• Conventional therapy; covered mirror.	• ROM ex for shoulder, elbow, wrist and forearm.
• Ji (2014)a	L.L	• 5S/W for 6W 50min each.	• Bilateral activities.	• PNF; NDT; covering the mirror.	• Dorsiflexion of the foot.
• Ji (2014)b	L.L	• 5S/W for 4W 45min each.	• Unaffected limb activities.	• Conventional therapy; covered mirror.	• Hip-knee-ankle flexion, knee extension with ankle dorsiflexion, and knee flexion beyond 90º.
• Lee (2012)	U.L	• 5S/W for 4W 105:130min each.	• Bilateral activities.	• Standard rehabilitation program.	• ROM ex for shoulder, elbow, wrist and forearm.
• Lin (2014)	U.L	• 5S/W for 4W 90min each.	• Bilateral activities.	• Task-oriented training.	• Gross motor tasks; fine motor tasks.
• Michielsen (2010)	U.L	• 6S/W for 6W 60min each. Once a week under supervision; 5 times at home.	• Bilateral activities.	• Bimanual exercises with a direct view of both hands.	• Exercises based on the Brunnstrom recovery stage; functional ex.
• Mirela Cristina (2016)	U.L	• 5S/W for 6W 30:60min each.	• Bilateral activities.	• Conventional therapy.	• ROM ex for shoulder, elbow, wrist, fingers and forearm.
• Park (2015)	U.L	• 5S/W for 6W.	• Unaffected limb activities.	• Ex against the non-reflecting face of the mirror.	• Functional training.
• Pervane Vural (2016)	U.L	• 5S/W for 4W 2:4 hours each.	• Unaffected limb activities.	• Conventional therapy.	• ROM ex for elbow, wrist, fingers and forearm.
• Selles (2014)	U.L	• 70 practice trials.	• Bilateral activities; unaffected limb activities.	• Task performance with affected hand, without mirror; task performance with unaffected side, without mirror; task performance with both sides, without mirror.	• Pointing task.
• Sütbeyaz (2007)	L.L	• 5S/W for 4W 2.5:5.5 hours each.	• Unaffected limb activities.	• Conventional therapy; ex against the non-reflecting face of the mirror.	• Ankle dorsiflexion and plantarflexion.
• Thieme (2012)	U.L	• 3:5S/W for 4W 30min each.	• Bilateral activities.	• Conventional therapy; ex against the non-reflecting face of the mirror.	• Isolated movements of U.L joints; object related movements.

• Tyson (2015)	U.L	• 30min/day, for 4W.	• Bilateral activities.	• Conventional therapy and lower-limb exercises.	• ROM ex for elbow, wrist and fingers; reaching; functional activities.
• Wu (2013)	U.L	• 5S/W for 4W 90min each.	• Bilateral activities.	• Task-oriented functional practice.	• Gross motor tasks; fine motor tasks; intransitive movements.
• Yavuzer (2008)	U.L	• 5S/W for 4W 2.5:5.5 hours each.	• Bilateral activities.	• Conventional program; the mirror reflecting the affected arm.	• ROM ex for wrist and fingers.
Mental practice/ motor imagery:					
• Braun (2010)	U.L & L.L	• 6W.	• w1: Explaining the concept, w1,2: Developing imagery techniques, w3-6: Applying mental practice, w6: Consolidating.	• Conventional rehabilitation; home practice of difficult tasks.	• Drinking; walking and 2 individually chosen activities, 1 for U.L & 1 for L.L.
• Cho (2012)	L.L	• 3S/W for 6W 30:45min each.	• Videos of normal gait, using visual and kinematic imagery separately.	• Gait training on the treadmill.	
• Hosseini (2012)	L.L	• 3S/W for 5W 45min each.		• Conventional rehabilitation program.	• Stand up and go, approaching a wall, turning in without stop and coming back to the armchair and siting on it.
• Ietswaart (2011)	U.L	• 3S/W for 4W 45min each under supervision; 2S/W for 4W 30min each independent training.		• Control group 1: Attention-placebo control (watching optical illusions; visual imagery of objects); control group 2: Standard care without additional intervention.	
• Kumar (2015)	L.L	• 4S/W for 3W 45:60min each.	• Audio tape (relaxation; cognitive visual images of L.L).	• Task specific training program.	
• Liu (2004)	U.L & L.L	• 5S/W for 3W 60min each.	• w1: Analyzing task sequences, w2: Problem identification through MI, w3: Practicing.	• Conventional therapy (OT and PT), practice to perform ADL.	
• Liu (2009)	U.L & L.L	• 5S/W for 3W 60min each.		• Conventional physical and occupational therapy, practice to perform ADL.	
• Oostra (2014)	L.L	• 5S/W for 6W 3.5 hour each.	• w1: Familiarizing with MP, w2: Focusing on gait problems, w3,4: Rehearsing gait symmetry & velocity; w5,6: Gait exercises.	• Standard rehabilitation; muscle relaxation therapy.	
• Page (2001)	U.L	• 3S/W for 6W 70min each.	• Audiotape with cognitive visual images plus using such a tape at home twice a week.	• Conventional therapy (OT and PT); sham therapy (audiotape containing stroke information).	
• Page (2007)	U.L	• 2S/W for 6W 60min each.	• Audiotape.	• Conventional therapy; sham therapy (tape of a progressive relaxation program).	
• Page (2011)	U.L	• 3S/W for 10W 50:90min each.	• Audiotape.	• Repetitive task specific training; sham therapy (tape of a stroke information and relaxation program).	

• Sun (2013)	U.L	• 5S/W for 4W 3-3.5 hours each.	• Relaxation; imagining simple ROM ex of the affected U.L; imagining complex actions of ADL; refocus onto the room.	• Conventional rehabilitation.
Action observation:				
• Bang (2013)	L.L	• 5S/W for 4W 40min each.		• Watching nature video; treadmill training.
• Cowles (2013)	U.L	• 2S/D, for 15 working days, 30min each.		• Conventional physical therapy.
• Ertelt (2007)	U.L	• 1 S/D, for 18 working days, 90min each.		• Intensive conventional physical therapy; sham therapy (watching a sequences of geometric symbols and letters).
• Franceschini (2012)	U.L	• 5S/W for 4W at least 3h/d of conventional therapy; two 15-minute daily sessions of experimental or control treatment.		• Conventional therapy; sham action (watching static images of objects).
• Fu (2017)	U.L	• 6S/W for 8W 20min each.		• Conventional physical therapy.
• Harmsen (2014)	U.L	• Single training session (30-45 minutes).		• Observation of a landscapes photographs; execution of reaching movements.
• Kim (2012)	L.L			• Watching relaxation program (stretching).
• Kuk (2016)	U.L	• 1 assessment session; 5 intervention sessions 4min. each.		• Watching video clip of landscapes pictures; perform the motor task.
• Motaqhey (2015)	L.L	• 12S, 45:60min each.		• Conventional therapy.
• Park (2014)	L.L	• 3 S/W for 4W 30min each.		• Conventional therapy; watching video clip of landscapes; walking training.
• Sale (2014)	U.L	• 5S/W for 4W 3.5 hours each.		• Standard rehabilitation; sham therapy (static images displaying objects).
Virtual reality reflection therapy:				
• In T (2016)	L.L	• 5S/W for 4W 60min each.	• Activities of the unaffected limb.	• Conventional therapy; placebo VRRT program (don't see the unaffected L.L, but saw the affected).

Outcome: Motor function:

For measure of the motor function of the upper extremity, 17 studies used Fugl-Meyer score of the upper extremity **[9,11-13,17-20,22,25,27,30,34-40,43,44,47]** 6 studies used the Action Research Arm Test **[12,14,19,25,26,32,37-39,41]** 4 studies used the Wolf Motor Function Test **[10,11,42,44]** 2 studies used the Manual Function Test **[17,21]** and 5 studies used Box and Block Test **[18,26,43,46,47]** . To analysis the motor function of the lower extremity, (walking ability) studies used Gait analysis **[15,16]**, Functional Ambulation Categories **[24]**, 10-meter walking test **[29,30,33,36]** and Timed Get up and Go **[30,31]**.

Risk of bias in included studies:

All details about the methodological quality of the included studies using the risk of bias assessment tool **[8]** and the PEDro Scale are provided in Fig. (2) and (Table 3).

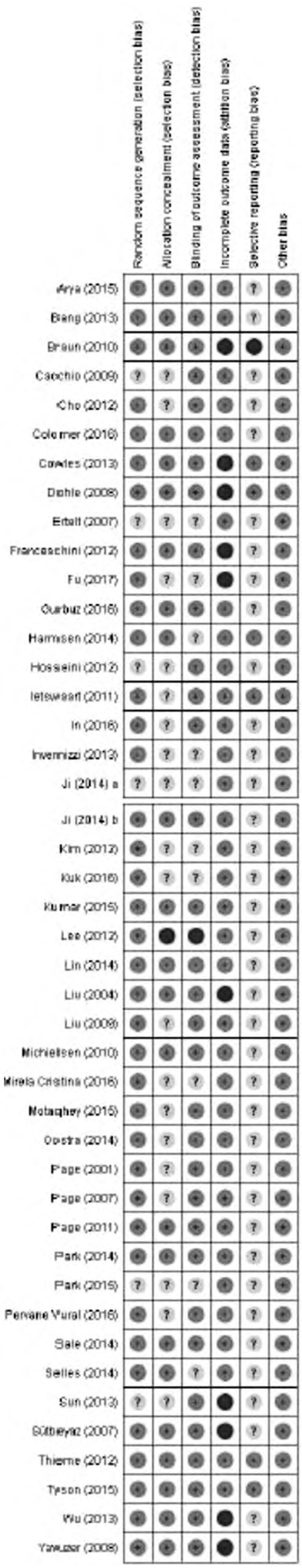


Fig. (2): Risk of bias summary.

Table (3): PEDro scale.

9-10 points excellent 4-5 points average				6-8 points good 0-3 points poor					
Article	1	2 3	4 5	6 7	8 9	10	11	To-tal	Classi-fication
Arya (2015)	Yes	1 1	1 0	0 1	1 1	1	1	8	Good
Bang (2013)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Braun (2010)	Yes	1 1	1 0	0 1	0 1	1	1	7	Good
Cacchio (2009)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
Cho (2012)	Yes	1 0	1 0	0 1	1 0	1	1	6	Good
Colomer (2016)	Yes	1 1	1 0	0 1	1 1	1	1	8	Good
Cowles (2013)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Dohle (2008)	Yes	1 1	1 0	0 1	0 0	1	1	6	Good
Ertelt (2007)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Franceschini (2012)	Yes	1 1	1 0	0 1	0 0	1	1	6	Good
Fu (2017)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Gurbuz (2016)	Yes	1 0	1 0	0 1	0 0	1	1	5	Average
Harmsen (2014)	Yes	1 1	1 0	0 0	1 0	1	1	6	Good
Hosseini (2012)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
Ietswaart (2011)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
In (2016)	Yes	1 0	1 0	0 1	0 0	1	1	5	Average
Invernizzi (2013)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Ji (2014)a	No	1 0	1 0	0 0	1 0	1	1	5	Average
Ji (2014)b	No	1 1	1 0	0 1	1 0	1	1	7	Good
Kim (2012)	Yes	1 1	1 0	0 0	0 0	1	1	5	Average
Kuk (2016)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Kumar (2015)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Lee (2012)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Lin (2014)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Liu (2004)	No	1 1	1 0	0 1	1 0	1	1	7	Good
Liu (2009)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
Michielsen (2010)	Yes	1 1	1 0	0 1	1 1	1	1	8	Good
Mirela Cristina (2016)	No	1 0	1 0	0 0	1 0	1	1	5	Average
Motaqhey (2015)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
Oostra (2014)	Yes	1 0	1 0	0 1	1 1	1	1	7	Good
Page (2001)	Yes	1 0	1 0	0 1	1 0	0	1	5	Average
Page (2007)	Yes	1 0	1 0	0 1	0 0	1	1	5	Average
Page (2011)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Park (2014)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Park (2015)	Yes	1 0	1 0	0 0	1 0	1	1	5	Average
Pervane Vural (2016)	Yes	1 0	1 0	0 1	1 0	1	1	6	Good
Sale (2014)	No	1 1	0 0	0 1	1 1	1	1	7	Good
Selles (2014)	Yes	1 1	1 0	0 0	1 0	1	1	6	Good
Sun (2013)	No	1 0	1 0	0 1	1 0	1	1	6	Good
Sütbeyaz (2007)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good
Thieme (2012)	Yes	1 1	1 0	0 1	1 1	1	1	8	Good
Tyson (2015)	Yes	1 1	1 0	0 1	1 1	1	1	8	Good
Wu (2013)	No	1 1	1 0	0 1	0 0	1	1	6	Good
Yavuzer (2008)	Yes	1 1	1 0	0 1	1 0	1	1	7	Good

Effects of interventions:

Comparison 1: Mirror therapy versus conventional therapy:

We included 15 studies in a pooled analysis on upper extremity motor function **[9-14,17-22,25-28]** we performed analysis of change scores between pre-and post-assessment. The 15 studies were divided into 5 subgroups according to the used assessment scale.

1- *Fugl-Meyer assessment:* Mirror therapy has a significant effect on Fugl-Meyer assessment scale in patients after stroke compared with conventional therapy (SMD 0.25; 95% CI 0.03 to 0.46; p=0.02; I2=0%, random-effects model).

2- *Action Research Arm test:* We found no significant effect on Action Research Arm test in patients after stroke for mirror therapy compared with conventional therapy (SMD 0.11; 95% CI –0.15 to 0.37; p=0.42; I2=0%, random-effects model).

3- *Wolf Motor Function Test:* Mirror therapy don't have a significant effect on Wolf Motor Function Test in patients after stroke compared with conventional therapy (SMD 0.94; 95% CI –1.07 to 2.95; p=0.36; I2=94%, random-effects model).

4- *Manual Function Test:* Mirror therapy has a significant effect on Manual Function Test in patients after stroke compared with conventional therapy (SMD 0.58; 95% CI 0.04 to 1.11; p= 0.04; I2=0%, random-effects model).

5- *Box and Block Test:* Mirror therapy don't have a significant effect on Box and Block Test in patients after stroke compared with conventional therapy (SMD 0.11; 95% CI –0.27 to 0.48; p= 0.58; I2=0%, random-effects model).

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.1.1 Fugi-Meyer Assessment								
Arya (2015)	10.7	15.52	17	4.75	10.66	16	9.6%	0.43 [–0.26, 1.13]
Colomer (2016)	0.1	2.22	15	0.5	2.13	16	9.2%	–0.18 [–0.89, 0.53]
Dohie (2008)	9.53	2.17	18	8.36	2.31	18	10.4%	0.51 [–0.15, 1.18]
Gurbuz (2016)	14.3	19.75	16	4.9	19.4	15	9.0%	0.47 [–0.25, 1.18]
Lee (2012)	17.2	12.12	13	7.6	15.04	13	7.3%	0.68 [–0.11, 1.48]
Lin (2014)	5.65	18.74	14	3.33	20.02	14	8.4%	0.12 [–0.63, 0.86]
Michlelsen (2010)	3.8	27.39	20	0.2	28.16	20	12.0%	0.13 [–0.49, 0.75]
Mirela Cristina (2016)	12.4	14.65	7	8.7	11.69	8	4.4%	0.27 [–0.76, 1.29]
Pervane Vural (2016)	5.75	6.09	15	0.5	6.831	15	8.3%	0.79 [0.04, 1.54]
Thleme (2012)	3.2	3.8	18	5.2	8.7	21	11.5%	–0.28 [–0.92, 0.35]
Wu (2013)	5.31	16.46	16	3.47	19.77	17	9.9%	0.10 [–0.58, 0.76]
Subtotal (95% CI)			169			173	100.0%	0.25 [0.03, 0.46]
Heterogenelty: Tau^2=0.00; Chi^2=8.97, df=10 (p=0.54); I^2=0%								
Test for overal effect Z=2.27 (p=0.02)								
1.1.2 Action Research Arm test								
Dohie (2008)	4.1	12.66	18	3.1	8.48	18	16.3%	0.09 [–0.56, 0.74]
Invernizzi (2013)	31.74	34.5	13	12.67	39.19	12	10.9%	0.50 [–0.30, 1.30]
Michieisen (2010)	1.7	32.25	20	0.6	32.94	20	18.1%	0.04 [–0.58, 0.66]
Thieme (2012)	3.4	7.1	18	1.1	3.1	21	17.2%	0.42 [–0.21, 1.06]
Tyson (2015)	6.9	13.9	62	8.3	12.1	31	37.5%	–0.10 [–0.54, 0.33]
Subtotal (95% CI)			131			102	100.0%	0.11 [–0.15, 0.37]
Heterogenelty: Tau^2=0.00; Chi^2=2.85, df=4 (p=0.58); I^2=0%								
Test for overal effect Z=0.81 (p=0.42)								
1.1.3 Wolf Motor Function Test								
Cacchio (2009)	1.5	0.9	24	–0.2	0.8	24	50.0%	1.96 [1.27, 2.66]
Colomer (2016)	1.4	3.38	15	1.7	3.38	16	50.0%	–0.09 [–0.78, 0.62]
Subtotal (95% CI)			39			40	100.0%	0.94 [–1.07, 2.95]
Heterogenelty: Tau^2=1.97; Chi^2=16.39, df=1 (p=0.0001); I^2=94%								
Test for overal effect Z=0.92 (p=0.36)								
1.1.4 Manual Function Test								
Lee (2012)	8.1	6.9	13	2.6	9.48	13	45.9%	0.64 [–0.15, 1.43]
Park (2015)	23.8	27.43	15	10.6	21.53	15	54.1%	0.52 [–0.21, 1.25]
Subtotal (95% CI)			28			28	100.0%	0.58 [0.04, 1.11]
Heterogenelty: Tau^2=0.00; Chi^2=0.05, df=1 (p=0.82); I^2=0%								
Test for overal effect Z=2.11 (p=0.04)								
1.1.5 Box and Block Test								
Lin (2014)	0.5	29.47	13	4.2	28.41	13	24.0%	–0.12 [–0.89, 0.65]
Tyson (2015)	8.2	12.7	62	6	11.1	31	76.0%	0.18 [–0.25, 0.61]
Subtotal (95% CI)			75			44	100.0%	0.11 [–0.27, 0.48]
Heterogenelty: Tau^2=0.00; Chi^2=0.45, df=1 (p=0.50); I^2=0%								
Test for overal effect Z=0.55 (p=0.58)								

Test for subgroup differences: Chi^2=3.27, df=4 (p=0.51) I^2=0%

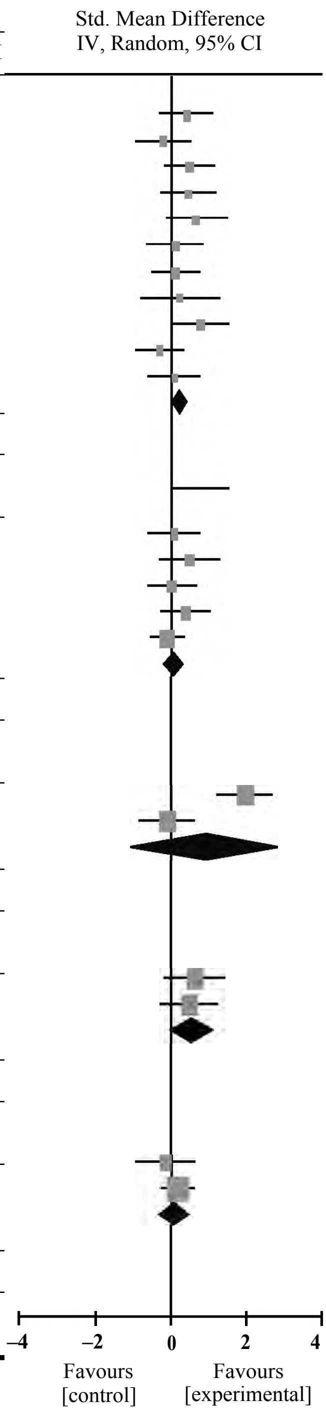


Fig. (3): Effect of mirror therapy on motor function of the upper extremity.

Motor function of the upper extremity (according to mirror therapy variation):

In this analysis we classified the 15 studies into 2 subgroups according to the used mirror therapy variation, either using mirror therapy with activities of the unaffected limb only or using bilateral actives. We performed analysis of change scores between pre-and post-assessment.

1- *Activities of the unaffected limb:* Mirror therapy with activity of the unaffected limb has a significant effect on motor function of the upper extremity in patients after stroke compared with conventional therapy (SMD 0.64; 95% CI 0.15 to 1.14; *p*=0.01; I2=70%, random-effects model).

2- *Bilateral activities:* We found no significant effect on motor function of the upper extremity in patients after stroke for mirror therapy with bilateral activities compared with conventional therapy (SMD 0.10; 95% CI –0. 13 to 0.33; *p*= 0.38; I2=0%, random-effects model). The overall effect of the mirror therapy has shown a significant difference on the motor function of the upper extremity in patients after stroke compared with conventional therapy (SMD 0.38; 95% CI 0.09 to 0.66; *p*=0.002; I2=60%, random-effects model).

Walking ability:

We included 3 studies in a pooled analysis on walking ability [15,16,24]. We performed analysis of change scores between pre-and post-assessment. We identified 9 different outcomes used in the comparison of walking ability, Velocity, cadence, step length, stride length, single stance, stance phase, swing phase, step width and Functional Ambulation Categories (FAC) mirror therapy don't show a significant effect on eny of them. The overall effect of mirror therapy on motor function of the lower extremity for patients after stroke compared with conventional therapy just reached significance (SMD 0.20; 95% CI 0.00 to 0.41; *p*= 0.05, I2=0%, fixed-effects model).

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.2.1 Activities of the unaffected limb								
Arya (2015)	10.7	15.52	17	4.75	10.66	16	6.8%	0.43 [–0.26, 1.13]
Cacchio (2009)	1.5	0.9	24	–0.2	0.8	24	6.7%	1.96 [1.27, 2.66]
Colomer (2016)	0.1	2.22	15	0.5	2.13	16	6.7%	–0.18 [–0.89, 0.53]
Gurbuz (2016)	14.3	19.75	16	4.9	19.4	15	6.6%	0.47 [–0.25, 1.18]
Invernizzi (2013)	31.74	34.5	13	12.67	39.19	12	6.0%	0.50 [–0.30, 1.30]
Park (2015)	23.8	27.43	15	10.6	21.53	15	6.5%	0.52 [–0.21, 1.25]
Pervane Vural (2016)	5.75	6.09	15	0.5	6.831	15	6.3%	0.79 [0.04, 1.54]
Subtotal (95% CI)			115			113	45.5%	0.64 [0.15, 1.14]
Heterogenelty: Tau^2=0.32; Chi^2=19.89, df=6 (*p*=0.003); I^2=70%								
Test for overal effect Z=2.53 (*p*=0.01)								
1.2.2 Bilateral activities								
Dohie (2008)	9.53	2.17	18	8.36	2.31	18	7.0%	0.51 [–0.15, 1.18]
Lee (2012)	17.2	12.12	13	7.6	15.04	13	6.0%	0.68 [–0.11, 1.48]
Lin (2014)	5.65	18.74	14	3.33	20.02	14	6.4%	0.12 [–0.63, 0.86]
Michielsen (2010)	3.8	27.39	20	0.2	28.16	20	7.4%	0.13 [–0.49, 0.75]
Mirela Cristina (2016)	12.4	14.65	7	8.7	11.69	8	4.6%	0.27 [–0.76, 1.29]
Thieme (2012)	3.2	3.8	18	5.2	8.7	21	7.3%	–0.28 [–0.92, 0.35]
Tyson (2015)	6.9	13.9	62	8.3	12.1	31	9.0%	–0.10 [–0.54, 0.33]
Wu (2013)	5.31	16.46	16	3.47	19.77	17	6.8%	0.10 [–0.58, 0.78]
Subtotal (95% CI)			168			142	54.5%	0.10 [–0.13, 0.33]
Heterogenelty: Tau^2=0.00; Chi^2=5.90, df=7 (*p*=0.55); I^2=0%								
Test for overal effect Z=0.88 (*p*=0.38)								
Total (95% CI)			283			255	100.0%	0.38 [0.09, 0.66]
Heterogenelty: Tau^2=0.18; Chi^2=34.84, df=14 (*p*=0.002); I^2=60%								
Test for overal effect Z=2.61 (*p*=0.009)								
Test for subgroup differnces: Chi^2=3.75, df=1 (*p*=0.05), I^2=73.3%								

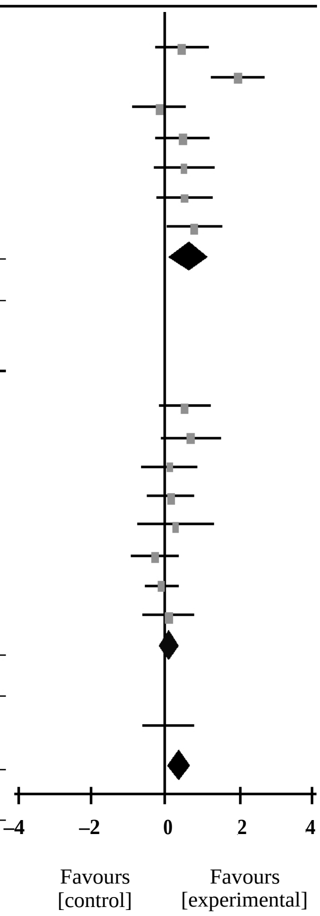


Fig. (4): Effect of mirror therapy variations on motor Function of the upper extremity.

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
1.3.1 Velootly								
Jl (2014)a	15.2	13.44	10	6.8	10.33	10	5.1%	0.67 [–0.24, 1.58]
Jl (2014)b	16.8	34.34	16	9.6	34.34	15	8.5%	0.20 [–0.50, 0.91]
Subtotal (95% CI)			28			26	18.8%	0.38 [–0.18, 0.84]
Heterogenelty: Chi^2=0.63, df=1 (*p*=0.43); l^2=0% Test for overal effect Z=1.34 (*p*=0.18)								
1.3.2 Cadence								
Jl (2014)a	7.5	17.69	10	5.8	19.73	10	5.5%	0.09 [–0.79, 0.95]
Jl (2014)b	6.5	32.6	16	3.8	30.99	15	8.5%	0.09 [–0.62, 0.79]
Subtotal (95% CI)			28			26	14.0%	0.08 [–0.48, 0.84]
Heterogenelty: Chi^2=0.00, df=1 (*p*=1.00); l^2=0% Test for overal effect Z=0.31 (*p*=0.75)								
1.3.3 Step length								
Jl (2014)a	5.5	5.94	10	3.2	7.35	10	5.4%	0.33 [–0.55,1.21]
Jl (2014)b	8.4	13.07	16	4.7	12.15	15	8.4%	0.29 [–0.42, 0.99]
Subtotal (95% CI)			28			26	13.8%	0.30 [–0.25, 0.89]
Heterogenelty: Chi^2=0.01, df=1 (*p*=0.94); l^2=0% Test for overal effect Z=1.07 (*p*=0.28)								
1.3.4 Stride length								
Jl (2014)a	12.1	13.72	10	9.9	12.6	10	5.5%	0.16 [–0.72, 1.04]
Jl (2014)b	17.3	36	16	11	29.92	15	8.5%	0.18 [–0.52, 0.99]
Subtotal (95% CI)			28			26	13.8%	0.18 [–0.38, 0.73]
Heterogenelty: Chi^2=0.00, df=1 (*p*=0.97); l^2=0% Test for overal effect Z=0.62 (*p*=0.83)								
1.3.5 Single stanoe								
Jl (2014)b	10.7	10.85	16	6.3	11	15	8.3%	0.39 [–0.32, 1.10]
Subtotal (95% CI)			18			16	8.3%	0.38 [–0.32, 1.10]
Heterogenelty: Not applicable Test for overal effect Z=1.08 (*p*=0.28)								
1.3.6 Stanoe phase								
Jl (2014)b	5	8.86	16	4	9.18	15	8.5%	0.11 [–0.60, 0.81]
Subtotal (95% CI)			16			15	8.5%	0.11 [–0.60, 0.81]
Heterogenelty: Not applicable Test for overal effect Z=0.30 (*p*=0.76)								
1.3.7 Swing phase								
Jl (2014)b	6	9.81	16	3.8	9.47	15	8.4	0.22 [–0.485, 0.93]
Subtotal (95% CI)			16			16	8.4%	0.22 [–0.485, 0.93]
Heterogenelty: Not applicable Test for overal effect Z=0.62 (*p*=0.54)								
1.3.8 Stap width								
Jl (2014)b	6.8	7.04	16	5.7	7.82	15	8.5%	0.14 [–0.56, 0.85]
Subtotal (95% CI)			16			16	8.6%	0.14 [–0.56, 0.85]
Heterogenelty: Not applicable Test for overal effect Z=0.40 (*p*=0.69)								
1.3.9 Functional Ambulation Categories								
Sutbeyaz (2007)	0.9	1.05	20	0.9	1.36	20	11.0%	0.00 [–0.62, 0.62]
Subtotal (95% CI)			20			20	11.0%	0.00 [–0.62, 0.62]
Heterogenelty: Not applicable Test for overal effect Z=0.00 (*p*=1.00)								

Std. Mean Difference
IV, Random, 95% CI

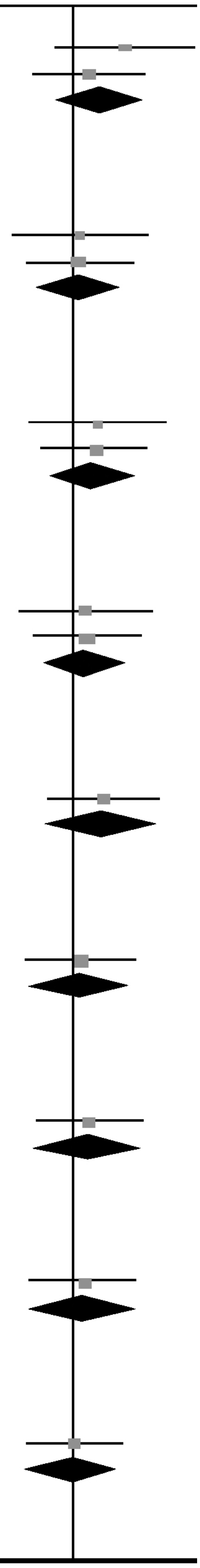


Fig. (5): Effect of mirror therapy on motor function of the lower extremity.

Comparison 2: Motor imagery/mental practice versus conventional therapy:

Motor function of the upper extremity:

We included 9 studies with a total of 354 participants in the meta-analysis [29-33,35-37,40]. All the 9 studies provided data on motor function. We performed a subgroup analysis for those studies examining mental practice for the upper extremity and lower extremity.

1- *Mental practice for the upper extremity:* We didn't find a significant effect of mental practice on motor function of the upper extremity for patients after stroke compared to conventional therapy (SMD 0.61; 95% CI 0.11 to 1.33; p= 0.1; I2=77%, random-effects model).

2- *Mental practice for the lower extremity:* We found a significant effect of mental practice on motor function of the lower extremity for patients after stroke compared to conventional therapy (SMD 0.58; 95% CI 0.06 to 1.10; p= 0.03; I2=60%, random-effects model). The overall effect of the motor imagery and mental practice has shown a significant difference on the motor function in patients after stroke compared with conventional therapy (SMD 0.58; 95% CI 0.17 to 0.99; p=0.006; I2=0%, random-effects model).

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
2.2.1 Upper Extremity								
Letswaart (2011)	5.87	38.03	39	6.64	38.52	31	12.9%	–0.02 [–0.49, 0.45]
Liu (2009)	2.5	2.4	17	3.1	5.2	17	11.0%	–0.14 [–0.82, 0.53]
Page (2001)	13.9	19.6	8	3	24.68	5	7.1%	0.47 [–0.67, 1.61]
Page (2007)	6.72	3.68	16	1	3.68	16	9.8%	1.52 [0.72, 2.31]
Sun (2013)	17.33	7.71	9	5.44	7.04	9	7.5%	1.53 [0.45, 2.62]
Subtotal (95% CI)			89			78	48.3%	0.61 [–0.11, 1.33]
Heterogenelty: Tau^2=0.49; Chi^2=17.23, df=4 (p=0.002); I^2=77%								
Test for overal effect Z=1.66 (p=0.10)								
2.2.2 Lower extremity								
Braun (2010)	5.42	15.63	12	5.17	14	13	9.9%	0.02 [–0.77, 0.80]
Cho (2012)	6.5	2.41	15	0.2	4.9	13	9.2%	1.62 [0.75, 2.50]
Hosseini (2012)	6.7	4.21	15	2.5	4.95	15	10.2%	0.89 [0.13, 1.64]
Kumar (2015)	0.14	0.15	20	0.08	0.16	20	11.4%	0.38 [–0.25, 1.01]
Liu (2009)	3.8	7.1	17	2.8	4.4	17	11.0%	0.17 [–0.51, 0.84]
Subtotal (95% CI)			79			78	5 1.7%	0.58 [0.06, 1.10]
Heterogenelty: Tau^2=0.21; Chi^2=9.88, df=4 (p=0.04); I^2=60%								
Test for overal effect Z=2.19 (p=0.03)								
Total (95% CI)			168			156	100.0%	0.58 [0.17, 0.99]
Heterogenelty: Tau^2=0.29; Chi^2=27.63, df=9 (p=0.001); I^2=67%								
Test for overal effect Z=2.76 (p=0.006)								
Test for subgroup differnces: Chi^2=0.00, df=1 (p=0.95), I^2=0%								

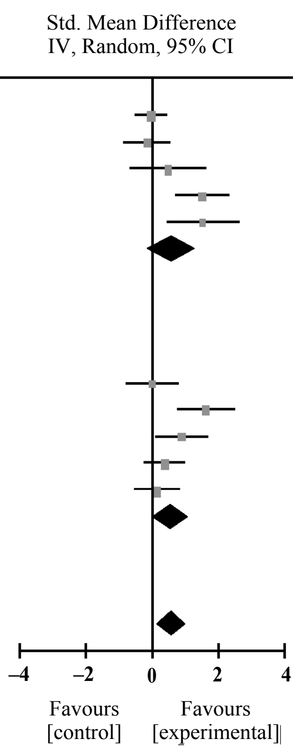


Fig. (6): Effect of motor imagery/mental practice on motor function.

Comparison 3: Action observation versus conventional therapy:

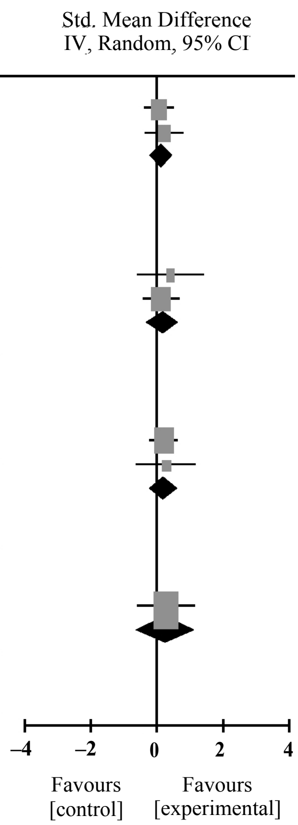
Motor function of the upper extremity:

We included 5 studies with a total of 114 participants in the experimental group and 106 participants in the control group. These studies examined the effect of action observation on upper extremity motor function. 2 of them used Fugl-Meyer Assessment [43,44], 2 studies used Wolf Motor Function Test [42,44], 2 studies used Box and Block Test [43,46] and only 1 study used Action Research Arm test [41]. We found no significant effect on upper extremity motor functions in patients after stroke for action observation compared with conventional therapy, Fugl-Meyer Assessment: (SMD 0.13; 95% CI –0.20, 0.45; p=0.46; I2=0%, fixed-effects model), Wolf Motor Function Test: (SMD 0.18; 95% CI 0.29 to 0.66; p=0.45; I2=0%, fixed-effects model), Box and Block Test: (SMD 0.21; 95% CI –0.17 to 0.59; p=0.27; I2=0%, fixed-effects model) and finally Action Research Arm test: (SMD 0.26; 95% CI –0.59 to 1.12; p=0.55).

Walking ability:

We included 4 studies with a total of 53 participants in the experimental group and 52 participants in the control group [48,49,51]. These studies examined the effect of action observation on walking ability using 10-meter walking test, timed get up and go, step length, stride length, single support time, double support time, velocity and cadence. We found no significant effect rather on walking ability nor on any used assessment test.

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
3.1.1 Fugl-Meyer assessment								
Franceschini (2012)	16.7	59.45	48	12.9	54.9	42	63.1%	0.07 [–0.35, 0.48]
Fu (2017)	10.86	22.59	28	5.48	24.23	25	36.9%	0.23 [–0.31, 0.77]
Subtotal (95% CI)			76			67	100.0%	0.13 [–0.20, 0.45]
Heterogenelty: Chi^2=0.21, df=1 (*p*=0.64); I^2=0%								
Test for overal effect Z=0.75 (*p*=0.46)								
3.1.2 Wolf motor function test								
Ertelt (2007)	15.5	33.04	8	–2.1	44.72	8	22.8%	0.42 [–0.57, 1.42]
Fu (2017)	8.64	21.82	28	6.24	19.28	25	77.2%	0.11 [–0.43, 0.65]
Subtotal (95% CI)			36			33	100.0%	0.18 [–0.29,0.66]
Heterogenelty: Chi^2=0.29, df=1 (*p*=0.59); I^2=0%								
Test for overal effect Z=0.76 (*p*=0.45)								
3.1.3 Box and block Test								
Franceschini (2012)	11.5	29.3	48	6.2	24.4	42	81.9%	0.19 [–0.22, 0.61]
Kuk (2016)	3.9	11.26	10	0.4	12.49	10	18.1%	0.28 [–0.60, 1.16]
Subtotal (95% CI)			58			52	100.0%	0.21 [–0.17, 0.59]
Heterogenelty: Chi^2=0.03, df=1 (*p*=0.86); I^2=0%								
Test for overal effect Z=1.09 (*p*=0.27)								
3.1.4 Action research arm test								
Cowles (2013)	14.11	12.08	9	11	10.93	13	100.0%	0.26 [–0.59, 1.12]
Subtotal (95% CI)			9			13	100.0%	0.26 [–0.59, 1.12]
Heterogenelty: Not applicable								
Test for overal effect Z=0.60 (*p*=0.55)								



Test for subgroup differnces: Chi^2=0.16, df=3 (*p*=0.98), I^2=0%

Fig. (7): Effect of action observation on motor function of upper extremity.

Discussion

Overall completeness and applicability of evidence:

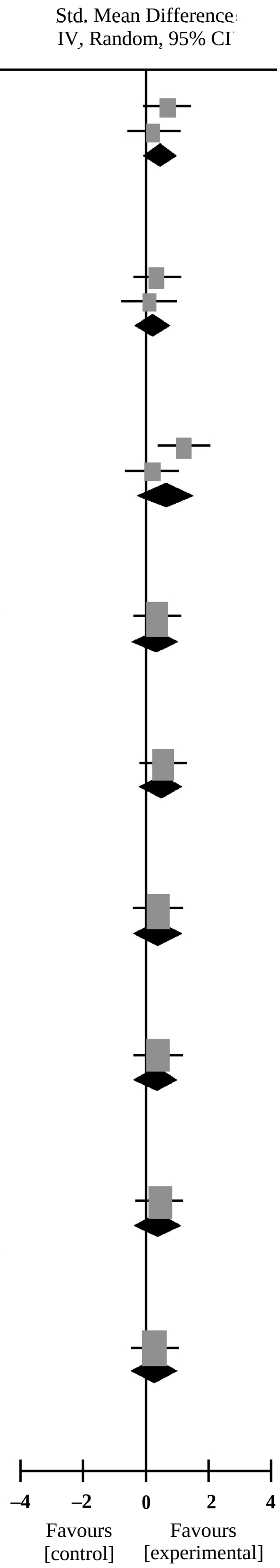
This review was able to answer the research questions, about the effect of mirror neuron applications on motor function in post stroke patients. For some outcomes, the number of studies and participants was low, so it was hard to draw a final conclusion. For example, there was only one included trial [52] that investigated the effectiveness of VRRT on motor function of patients after stroke. only 3 trials [15,16,24] specifically measured the effectiveness of mirror therapy on walking ability in stroke patients. Which downgraded the overall quality of evidence due to small sample sizes and the large heterogeneity between the measured outcomes. It is important that future research, of high methodological quality, is powered and designed to study the effects mirror therapy and action observation on walking ability.

Applicability of evidence:

The aim of this review was to synthesize best evidence on using mirror neuron applications on stroke rehabilitation, thus supporting clinicians and policy makers in clinical decision making for rehabilitation. Before any evidence is applied, it is recommended that clinicians and policy makers consider carefully the details of the trials synthesized within that review, specifically reflecting on the relevance of the participant population, trial setting, interventions delivered and outcomes assessed in relation to the clinical decision to be made.

Dose of interventions is a critical issue when assessing the potential applicability of evidence. It is likely to impact effect size, and it is likely that a specific minimum dose will be required to result in a change in outcomes. The necessary dose has not been established, and it is very difficult to be certain that the dose of intervention delivered within RCTs was sufficiently high. Consequently, evidence of 'no benefit or harm' may be a product of insufficient dose rather than of an ineffective intervention.

Study or subgroup	Experimental			Control			Std. Mean Difference	
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
3.2.1 Timed up and go test								
Bang (2013)	4.57	3.53	15	2.35	3.05	15	54.3%	0.65 [−0.08, 1.39]
Motagrey (2015)	3.4	7.1	12	1.57	7.45	12	45.7%	0.23 [−0.57, 1.03]
Subtotal (95% CI)			27			27	100.0%	0.48 [−0.08, 1.00]
Heterogenelty: Tau^2=0.00; Chi^2=0.58, df=1 (p=0.45); I^2=0% Test for overal effect Z=1.66 (p=0.10)								
3.2.2 10-3 walk test								
Bang (2013)	0.63	0.64	15	0.15	0.56	15	58.6%	0.32 [−0.40, 1.04]
Park (2014)	9.14	45.04	11	4.5	47.1	10	41.4%	0.10 [−0.76, 0.95]
Subtotal (95% CI)			26			25	100.0%	0.23 [−0.32, 0.78]
Heterogenelty: Tau^2=0.00; Chi^2=0.16, df=1 (p=0.69); I^2=0% Test for overal effect Z=0.81 (p=0.42)								
3.2.3 6-minute walk test								
Bang (2013)	89.6	39.84	15	32.81	53.19	15	50.4%	1.18 [0.39, 1.95]
Motagrey (2015)	22.45	36.48	12	14.95	41.42	12	49.6%	0.19 [−0.62, 0.99]
Subtotal (95% CI)			27			27	100.0%	0.88 [−0.29, 1.68]
Heterogenelty: Tau^2=0.33; Chi^2=3.00, df=1 (p=0.08); I^2=67% Test for overal effect Z=1.38 (p=0.17)								
3.2.4 Step length								
Kim (2012)	7.03	19.69	15	0.08	19.68	15	100.0%	0.34 [−0.38, 1.07]
Subtotal (95% CI)			15			15	100.0%	0.34 [−0.38, 1.07]
Heterogenelty: Not applicable Test for overal effect Z=0.93 (p=0.35)								
3.2.5 Stride length								
Kim (2012)	14.09	18.79	15	1.33	28.19	15	100.0%	0.52 [−0.21, 1.25]
Subtotal (95% CI)			15			15	100.0%	0.52 [−0.21, 1.25]
Heterogenelty: Not applicable Test for overal effect Z=1.39 (p=0.16)								
3.2.6 Single support time								
Kim (2012)	6.87	11.48	15	0.8	19.15	15	100.0%	0.37 [−0.35, 1.10]
Subtotal (95% CI)			15			15	100.0%	0.37 [−0.35, 1.10]
Heterogenelty: Not applicable Test for overal effect Z=1.01 (p=0.31)								
3.2.7 Double support time								
Kim (2012)	9.57	15.38	15	3.9	15.07	15	100.0%	0.36 [−0.36, 1.06]
Subtotal (95% CI)			15			15	100.0%	0.36 [−0.36, 1.06]
Heterogenelty: Not applicable Test for overal effect Z=0.98 (p=0.33)								
3.2.8 Veloothy								
Kim (2012)	0.2	0.35	15	0.05	0.37	15	100.0%	0.41 [−0.32, 1.13]
Subtotal (95% CI)			15			15	100.0%	0.41 [−0.32, 1.13]
Heterogenelty: Not applicable Test for overal effect Z=1.10 (p=0.27)								
3.2.9 Cadanoe								
Kim (2012)	16.87	25.66	15	9.22	31.02	15	100.0%	0.25 [−0.46, 0.98]
Subtotal (95% CI)			15			15	100.0%	0.25 [−0.46, 0.98]
Heterogenelty: Not applicable Test for overal effect Z=0.70 (p=0.48)								



Test for subgroup differences: Chi^2=1.01, df=8 (p=1.00), I^2=0%

Fig. (8): Effect of action observation on motor function of lower extremity.

Quality of the evidence:

This review used several methodological domains (adequate sequence generation, adequate concealment of allocation, adequate ITT analysis and blinding of assessors) to assess the risk of bias in the included studies. 6 studies were assessed as having unclear sequence generation and 21 studies were assessed as using no or unclear concealed allocation of participants to study groups, 22 studies with no or unclear use of an adequate ITT analysis, 11 studies with no or unclear use blinded assessors. And 6 studies only that have a low risk of reporting bias.

Additionally, the PEDro scale was used for evaluating the methodological quality of the studies. The median of the PEDro scale total scores was seven points, indicating overall a high quality of studies. However, 2 1 studies were classified to have a PEDro score lower than seven points. Overall limitations of the included studies were small sample sizes of most studies, very limited inclusion of control groups that used other effective interventions for the upper or lower extremity in most studies and differences in therapy delivery between the studies (i.e. amount and frequency of the treatment period).

Potential biases in the review process:

Through an extensive searching process, it is unlikely that any relevant trials have been missed. However, there is a possibility of additional (published or unpublished) studies that haven't been identified. The selection process, independent data extraction, and assessment of the risk of bias performed by the review authors did minimize errors and bias in data extraction.

There was heterogeneity between studies in trial design (duration of follow-up and selection criteria for patients), characteristics of patients (i.e. severity of motor impairment and time since stroke onset) and characteristics of interventions (i.e. total amount of time of therapy). Furthermore, there were methodological limitations of studies.

Agreements and disagreements with other studies or reviews:

This is the first time to report the effectiveness of mirror neuron applications collectively in one review. However, there were many reviews that investigated some interventions separately. For example, Rothgangel et al., 2011 and Thieme et al., 20 13 measured the effectiveness of mirror therapy on motor function after stroke, Kho et al., 2008 and Zimmermann-Schlatter et al., 2008 tested the efficacy of motor imagery in post-stroke rehabilitation. And Sarasso et al., 2015 investigated the efficacy of Action observation in the rehabilitation.

Rothgangel et al., 2011, Sarasso et al., 2015 and Zimmermann-Schlatter et al., 2008 didn't use a pooled analysis of identified studies. Rothgangel et al., 2011 included 21 studies consisted of 6 RCTs. All six RCTs investigating the effects of MT as an additional therapy involving stroke patients showed similar results in a positive direction for arm function.

Thieme et al., 2013 included 14 studies 12 of the were RCTs. It suggested that mirror therapy may improve motor function. Kho et al., 2008 included 6 studies 5 of them were RCTs. Under the qualitative analysis, 5 out of the 6 studies showed positive results in using mental imagery to promote motor recovery of the hemiplegic upper extremity function for people with stroke. The results of quantitative analysis showed statistically non-significant effect in FMAUE and significant effect in ARAT. Zimmermann-Schlatter et al., 2008 identified 4 RCTs. 3 studies showed a positive effects of motor imagery interventions on the ARAT and the FMSA and one study stated significant effects on task-related out comes, but not on the ARAT and the FMSA.

Sarasso et al., 2015 analyzed the efficacy of AOT for recovery of motor functions, regardless the kind of disease. It included 20 RCTs. 13 of them was investigating patients after stroke. Four studies showed AOT efficacy in improving upper limb functional recovery in participants with chronic stroke, two studies in sub-acute ones and one in acute ones. Six articles suggested its effectiveness on walking performance in chronic stroke individuals, and three of them also suggested an efficacy in improving balance.

Authors' conclusions:

The results of this review indicate that there is moderate evidence for the effectiveness of mirror therapy in improving motor function of upper extremity for people after stroke. It is possible to train by moving the unaffected arm, or both arms, while looking in the mirror but activities of the unaffected limb showed greater effect than bilateral activities. No clear implication could be drawn for walking ability, since the positive results just reached statistical significance.

Motor imagery and mental practice showed a moderate evidence for improvement on the motor function specially for the lower extremity functions.

Furthermore, significant effects of action observation therapy were present in heterogeneous studies that contains effect size of no difference or minimum important difference. In general, mirror neuron applications could be applied as an additional intervention in the rehabilitation of people after stroke for improving motor function, but no clear conclusion could be drawn if mirror neuron applications replaced other interventions.

The existing studies suggest an effect of most of mirror neuron applications after stroke, but they suffer from methodological problems such as small sample sizes and lack of proper reporting. There is thus an urgent need for well-designed and properly-reported multicenter RCTs with large sample sizes in order to provide a high level of evidence. Specifically, these studies should not deliver mirror neuron applications as an adjunct, but should compare it to other routinely-applied therapies. Further research should also address specific questions about the optimal dose, frequency, and duration of the interventions.

References

1- SACCO R.L., KASNER S.E., BRODERICK J.P., CAPLAN L.R., CONNORS J.J., CULEBRAS A., et al.: An updated definition of stroke for the 21 st century: A statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke, 44 (7): 2064-89. Doi: 10.1 161/STR.0b013e3 1 8296aeca, 2013.

2- DOBKIN B.H.: Training and exercise to drive poststroke recovery. Nat. Clin. Pract. Neurol., 4 (2): 76-85. Doi: 10.103 8/ncpneuro0709, 2008.

3- CARVALHO D., TEIXEIRA S., LUCAS M., YUAN T.F., CHAVES F., PERESSUTTI C., et al.: The mirror neuron system in post-stroke rehabilitation. Int. Arch. Med., 17; 6 (1): 41. Doi: 10.1186/1755-7682-6-41, 2013.

4- CATTANEO L. and RIZZOLATTI G.: The mirror neuron system. Arch. Neurol., 66 (5): 557-60. Doi: 10.1001/archneurol.2009.41, 2009.

5- MICHIELSEN M., SMITS M., RIBBERS G., STAM H., VAN DER GEEST J., BUSSMANN J., et al.: The neuronal correlates of mirror therapy: An fMRI study on mirror induced visual illusions in patients with stroke. J. Neurol. Neurosurg. Psychiatry, 82 (4): 393-8. Doi: 10.1136/jnnp.2009.194134, 2011.

6- CALIGIORE D., MUSTILE M., SPALLETTA G. and BALDASSARRE G.: Action observation and motor imagery for rehabilitation in Parkinson's disease: A systematic review and an integrative hypothesis. Neurosci. Biobehav. Rev., 72: 210-22. Doi: 10.1016/j.neubiorev.2016.11.005, 2017.

7- BUCCINO G.: Action observation treatment: A novel tool in neurorehabilitation. Philos Trans. R. Soc. Lond B. Biol. Sci., 28, 369 (1644): 20130185. Doi: 10.1098/rstb.2013.0185, 2014.

8- HIGGINS J. and GREEN S.: Cochrane Handbook for Systematic Reviews of Interventions, Cochrane Book Series. Wiley-Blackwell, 2008.

9- ARYA K.N., PANDIAN S., KUMAR D. and PURI V.: Task-Based Mirror Therapy Augmenting Motor Recovery in Poststroke Hemiparesis: A Randomized Controlled Trial. J. Stroke Cerebrovasc. Dis., 24 (8): 1738-48. Doi: 10.1016/j.jstrokecerebrovasdis.2015.03.026, 2015.

10- CACCHIO A, De BLASIS E., De BLASIS V., SANTILLI V. and SPACCA G.: Mirror therapy in complex regional pain syndrome type 1 of the upper limb in stroke patients. Neurorehabil. Neural. Repair., 23 (8): 792-9. Doi: 10.1177/1545968309335977, 2009.

11- COLOMER C., NOÉ E. and LLORENS R.: Mirror therapy in chronic stroke survivors with severely impaired upper limb function: A randomized controlled trial. Eur. J. Phys. Rehabil. Med., 52 (3): 271-8, 2016.

12- DOHLE C., PÜLLEN J., NAKATEN A., KÜST J., RIETZ C. and KARBE H.: Mirror therapy promotes recovery from severe hemiparesis: A randomized controlled trial. Neurorehabil. Neural. Repair., 23 (3): 209-17. Doi: 10.1177/1545968308324786, 2009.

13- GURBUZ N., AFSAR S.I., AYAŞ S. and COSAR S.N.: Effect of mirror therapy on upper extremity motor function in stroke patients: A randomized controlled trial. J. Phys. Ther. Sci., 28 (9): 2501-6, 2016.

14- INVERNIZZI M., NEGRINI S., CARDA S., LANZOTTI L., CISARI C. and BARICICH A.: The value of adding mirror therapy for upper limb motor recovery of subacute stroke patients: A randomized controlled trial. Eur. J. Phys. Rehabil. Med., 49 (3): 311-7, 2013.

15- JI S.G., CHA H.G., KIM M.K. and LEE C.R.: The effect of mirror therapy integrating functional electrical stimulation on the gait of stroke patients. J. Phys. Ther. Sci., 26 (4): 497-9. Doi: 10.1589/jpts.26.497, 2014.

16- JI S.G. and KIM M.K.: The effects of mirror therapy on the gait of subacute stroke patients: A randomized controlled trial. Clin. Rehabil., 29 (4): 348-54. Doi: 10.1177/02692155 14542356, 2015.

17- LEE M.M., CHO H.Y. and SONG C.H.: The mirror therapy program enhances upper-limb motor recovery and motor function in acute stroke patients. Am. J. Phys. Med. Rehabil., 91 (8): 689-96, quiz 697-700. Doi: 10.1097/PHM.0b013e31824fa86d, 2012.

18- LIN K.C., HUANG P.C., CHEN Y.T., WU C.Y. and HUANG W.L.: Combining afferent stimulation and mirror therapy for rehabilitating motor function, motor control, ambulation, and daily functions after stroke. Neurorehabil. Neural. Repair., 28 (2): 153-62. Doi: 10.1177/15459683 13508468, 2014.

19- MICHIELSEN M.E., SELLES R.W., VAN DER GEEST J.N., ECKHARDT M., YAVUZER G., STAM H.J., SMITS M., RIBBERS G.M. and BUSSMANN J.B.: Motor recovery and cortical reorganization after mirror therapy in chronic stroke patients: A phase II randomized controlled trial. Neurorehabil. Neural. Repair., 25 (3): 223-33. Doi: 10.1177/1545968310385127", 2011.

20- MIRELA CRISTINA L., MATEI D., IGNAT B. and POPESCU C.D.: Mirror therapy enhances upper extremity motor recovery in stroke patients. Acta Neurol. Belg., 115 (4): 597-603. Doi: 10.1007/s13760-015-0465-5, 2015.

21- PARK Y., CHANG M., KIM K.M. and AN D.H.: The effects of mirror therapy with tasks on upper extremity function and self-care in stroke patients. J. Phys. Ther. Sci., 27 (5): 1499-501. Doi: 10.1589/jpts.27.1499, 2015.

22- PERVANE VURAL S., NAKIPOGLU YUZER G.F., SEZGIN OZCAN D., DEMIR OZBUDAK S. and OZGIRGIN N.: Effects of Mirror Therapy in Stroke Patients With Complex Regional Pain Syndrome Type 1: A Randomized Controlled Study. Arch. Phys. Med. Rehabil., 97 (4): 575-81. Doi: 10.1016/j.apmr.2015.12.008, 2016.

23- SELLES R.W., MICHIELSEN M.E., BUSSMANN J.B., STAM H.J., HURKMANS H.L., HEIJNEN I., De GROOT D. and RIBBERS G.M.: Effects of a mirror-induced visual illusion on a reaching task in stroke patients: Implications for mirror therapy training. Neurorehabil. Neural. Repair., 28 (7): 652-9. Doi: 10.1177/1545968314521005, 2014.

24- SÜTBEYAZ S., YAVUZER G., SEZER N. and KOSEOGLU B.F.: Mirror therapy enhances lower-extremity motor recovery and motor functioning after stroke: A randomized controlled trial. Arch. Phys. Med. Rehabil., 88 (5): 555-9, 2007.

25- THIEME H., BAYN M., WURG M., ZANGE C., POHL M. and BEHRENS J.: Mirror therapy for patients with severe arm paresis after stroke--a randomized controlled trial. Clin. Rehabil., 27 (4): 314-24. Doi: 10.1177/0269215512455651, 2013.

26- TYSON S., WILKINSON J., THOMAS N., SELLES R., McCABE C., TYRRELL P. and VAIL A.: Phase II Pragmatic Randomized Controlled Trial of Patient-Led Therapies (Mirror Therapy and Lower-Limb Exercises) During Inpatient Stroke Rehabilitation. Neurorehabil. Neural. Repair., 29 (9): 818-26. Doi: 10.1177/1545968314565513, 2015.

27- WU C.Y., HUANG P.C., CHEN Y.T., LIN K.C. and YANG H.W.: Effects of mirror therapy on motor and sensory recovery in chronic stroke: A randomized controlled trial. Arch. Phys. Med. Rehabil., 94 (6): 1023-30. Doi: 10.1016/j.apmr.2013.02.007, 2013.

28- YAVUZER G., SELLES R., SEZER N., SÜTBEYAZ S., BUSSMANN J.B., KÖSEOGLU F., ATAY M.B. and STAM H.J.: Mirror therapy improves hand function in subacute stroke: A randomized controlled trial. Arch. Phys. Med. Rehabil., 89 (3): 393-8. Doi: 10.1016/j.apmr.2007.08.162, 2008.

29- BRAUN S.M., BEURSKENS A.J., KLEYNEN M., OUDELAAR B., SCHOLS J.M. and WADE D.T.: A multicenter randomized controlled trial to compare subacute 'treatment as usual' with and without mental practice among persons with stroke in Dutch nursing homes. J. Am. Med. Dir. Assoc., 13 (1): 85.e1-7. Doi: 10.1016/j.jamda.2010.07.009, 2012.

30- CHO H.Y., KIM J.S. and LEE G.C.: Effects of motor imagery training on balance and gait abilities in post-stroke patients: A randomized controlled trial. Clin. Rehabil., 27 (8): 675-80. doi: 10.1177/0269215512464702, 2013.

31- HOSSEINI S.A., FALLAHPOUR M., SAYADI M., GHARIB M. and HAGHGOO H.: The impact of mental practice on stroke patients' postural balance. J. Neurol. Sci., 322 (1-2): 263-7. Doi: 10.1016/j.jns.2012.07.030, 2012.

32- IETSWAART M., JOHNSTON M., DIJKERMAN H.C., JOICE S., SCOTT C..L, MacWALTER R.S., HAMILTON S.J.: Mental practice with motor imagery in stroke recovery: Randomized controlled trial of efficacy. Brain, 134 (Pt 5): 1373-86. Doi: 10.1093/brain/awr077, 2011.

33- KUMAR V.K., CHAKRAPANI M. and KEDAMBADI R.: Motor Imagery Training on Muscle Strength and Gait Performance in Ambulant Stroke Subjects-A Randomized Clinical Trial. J. Clin. Diagn. Res., 10 (3): YC01-4. Doi: 10.7860/JCDR/2016/16254.7358, 2016.

34- LIU K.P., CHAN C.C., LEE T.M. and HUI-CHAN C.W.: Mental imagery for promoting relearning for people after stroke: A randomized controlled trial. Arch. Phys. Med. Rehabil., 85 (9): 1403-8, 2004.

35- LIU K.P.: Use of mental imagery to improve task generalisation after a stroke. Hong Kong Med. J., 15 (3 Suppl 4): 37-41, 2009.

36- OOSTRA K.M., OOMEN A., VANDERSTRAETEN G. and VINGERHOETS G.: Influence of motor imagery training on gait rehabilitation in sub-acute stroke: A randomized controlled trial. J. Rehabil. Med., 47 (3): 204-9. Doi: 10.2340/16501977-1908, 2015.

37- PAGE S.J., LEVINE P., SISTO S. and JOHNSTON M.V.: A randomized efficacy and feasibility study of imagery in acute stroke. Clin. Rehabil., 15 (3): 233-40, 2001.

38- PAGE S.J., LEVINE P. and LEONARD A.: Mental practice in chronic stroke: Results of a randomized, placebo-controlled trial. Stroke, 38 (4): 1293-7, 2007.

39- PAGE S.J., DUNNING K., HERMANN V., LEONARD A. and LEVINE P.: Longer versus shorter mental practice sessions for affected upper extremity movement after stroke: A randomized controlled trial. Clin. Rehabil., 25 (7): 627-37. Doi: 10.1177/0269215510395793, 2011.

40- SUN L., YIN D., ZHU Y., FAN M., ZANG L., WU Y., JIA J., BAI Y., ZHU B. and HU Y.: Cortical reorganization after motor imagery training in chronic stroke patients with severe motor impairment: A longitudinal fMRI study. Neuroradiology, 55 (7): 913-25. Doi: 10.1007/s00234-013-1188-z, 2013.

41- COWLES T., CLARK A., MARES K., PERYER G., STUCK R. and POMEROY V.: Observation-to-imitate plus practice could add little to physical therapy benefits within 31 days of stroke: Translational randomized controlled trial. Neurorehabil Neural. Repair., 27 (2): 173-82. Doi: 10.1177/1545968312452470, 2013.

42- ERTELT D., SMALL S., SOLODKIN A., DETTMERS C., McNAMARA A., BINKOFSKI F. and BUCCINO G.: Action observation has a positive impact on rehabilitation of motor deficits after stroke. Neuroimage, 36 Suppl 2: T164-73, 2007.

43- FRANCESCHINI M., CERAVOLO M.G., AGOSTI M., CAVALLINI P., BONASSI S., DALL'ARMI V., MASSUCCI M., SCHIFINI F. and SALE P.: Clinical relevance of action observation in upper-limb stroke rehabilitation: A possible role in recovery of functional dexterity. A randomized clinical trial. Neurorehabil. Neural. Repair., 26 (5): 456-62. Doi: 10.1177/1545968311427406, 2012.

44- FU J., ZENG M., SHEN F., CUI Y., ZHU M., GU X. and SUN Y.: Effects of action observation therapy on upper extremity function, daily activities and motion evoked potential in cerebral infarction patients. Medicine (Baltimore), 96 (42): e8080. Doi: 10.1097/MD. 00000 00000008080, 2017.

45- HARMSEN W.J., BUSSMANN J.B., SELLES R.W., HURKMANS H.L. and RIBBERS G.M.: A Mirror Therapy-Based Action Observation Protocol to Improve Motor Learning After Stroke. Neurorehabil. Neural. Repair., 29 (6): 509-16. Doi: 10.1177/1545968314558598, 2015.

46- KUK E.J., KIM J.M., OH D.W. and HWANG H.J.: Effects of action observation therapy on hand dexterity and EEG-based cortical activation patterns in patients with post-stroke hemiparesis. Top Stroke Rehabil., 23 (5): 318-25. Doi: 10.1080/10749357.2016.1157972, 2016.

47- SALE P., CERAVOLO M.G. and FRANCESCHINI M.: Action observation therapy in the subacute phase promotes dexterity recovery in right-hemisphere stroke patients. Biomed. Res. Int., 2014: 457538. Doi: 10.1155/2014/457538, 2014.

48- BANG D.H., SHIN W.S., KIM S.Y. and CHOI J.D.: The effects of action observational training on walking ability in chronic stroke patients: A double-blind randomized controlled trial. Clin. Rehabil., 27 (12): 1118-25. Doi: 10.1177/0269215513501528, 2013.

49- KIM J. and KIM K.: Clinical feasibility of action observation based on mirror neuron system on walking performance in post stroke patients. J. Phys. Ther. Sci., 24 (7): 597-9, 2012.

50- MOTAQHEY M., GHANJAL A., MASTRI FARAHANI R., GHABAEE M., KAKA G., NOROZIYAN M. and FADAEE FATHABADI F.: Sex Differences in Neuroanatomy of the Human Mirror Neuron System: Impact on Functional Recovery of Ischemic Hemiparetic Patients. Iran Red. Crescent. Med. J., 17 (8): e28363. Doi: 10.5812/ircmj.28363, 2015.

51- PARK H.R., KIM J.M., LEE M.K. and OH D.W.: Clinical feasibility of action observation training for walking function of patients with post-stroke hemiparesis: A randomized controlled trial. Clin. Rehabil., 28 (8): 794-803, 2014.

52- IN T., LEE K. and SONG C.: Virtual Reality Reflection Therapy Improves Balance and Gait in Patients with Chronic Stroke: Randomized Controlled Trials. Med. Sci. Monit., 22: 4046-53, 2016.

53- IN T., LEE K. and SONG C.: Virtual Reality Reflection Therapy Improves Balance and Gait in Patients with Chronic Stroke: Randomized Controlled Trials. Med. Sci. Monit., 22: 4046-53, 2016.

54- ROTHGANGEL A.S., BRAUN S.M., BEURSKENS A.J., SEITZ R.J. and WADE D.T.: The clinical aspects of mirror therapy in rehabilitation: A systematic review of the literature. International Journal of Rehabilitation Research, 34 (1): 1-13, 2011.

55- THIEME H., MEHRHOLZ J., POHL M., BEHRENS J. and DOHLE C.: Mirror therapy for improving motor function after stroke. Stroke, 44 (1): e1-2, 2013.

56- KHO A.Y., LIU K.P. and CHUNG R.C.: Meta-analysis on the effect of mental imagery on motor recovery of the hemiplegic upper extremity function. Aust. Occup. Ther. J., 61 (2): 38-48. Doi: 10.1111/1440-1630.12084, 2014.

57- ZIMMERMANN-SCHLATTER A., SCHUSTER C., PUHAN M.A., SIEKIERKA E. and STEURER J.: Efficacy of motor imagery in post-stroke rehabilitation: A systematic review. J. Neuroeng. Rehabil., 5: 8. Doi: 10.1186/1743-0003-5-8, 2008.

58- SARASSO E., GEMMA M., AGOSTA F., FILIPPI M. and GATTI R.: Action observation training to improve motor function recovery: A systematic review. Arch. Physiother., 5: 14. Doi: 10.1186/s40945-015-0013-x, 2015.

تطبيقات الخلايا العصبية المرآتية لإستعادة الوظائف الحركية لدى مرضى السكتة الدماغية: مراجعة منهجية

نتيجة هذا البحث تشير إلى وجود دليل متوسط على فاعلية إستخدام تطبيقات الخلايا العصبية المراتية لتآهيل مرضى السكتة الدماغية حيث يمكن إستخدام العلاج بالمرآة لتحخسين وظائف الطرف العلوى بالآخص. وتشير الآبحاث إلى آن آفضل نتائج يمكن الحصول عليها عندما يقوم المريض بالنظر إلى إنعكاس يده السليمة فى المرآه بينما يقوم بتحريكها. بالرغم من هذا لا يوجد دليل على تآثير العلاج بإستخدام المرآه على تحسين مستوى المشى لدى مرضى السكتة الدماغية.

ومن تطبيقات الخلايا العصبية المرآتية آيضا محاولة تخيل الحركة قبل تنفيذها. وقد آظهر هذاالإسلوب من العلاج دليلا متوسطا آيضا على فاعليته فى إستعادة الوظايف الحركية عند مرضى السكتة الدماغية وبخاصة المشى. ومن جهة آخرى يعد مشاهدة آفعال الآخرين آحد تطبيقات الخلايا العصبية المرآتية ولكن هذا البحث لم يجد الدليل الكافى على فاعلية هذاالإسلوب العلاجى. وبصفة عامة يوصى هذا البحث بإستخدام تلك التطبيقات كعامل مساعد آثناء تآهيل المصابين بالسكتة الدماغية وليس كبديلا لآحد آساليب العلاج الآخرى.