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REVIEW ARTICLE

The Effects of Mirror Therapy on Outcomes in the Upper Extremity Post-Stroke

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ABSTRACT: Stroke is the leading cause of disability for adults worldwide, resulting in motor impairments, pain, spasticity, sensory loss, and reduced activities of daily life (ADLs). Mirror therapy (MT) promotes motor function and sensory recovery in patients across stroke acuity. This study analyzes the effects of MT on different levels of impairment in the upper extremities caused by stroke compared to other conventional treatments and other interventions. Sixteen studies (ten RCTs and five systematic reviews, and one metanalysis) were included, consisting of chronic or acute/subacute patients with paresis in their upper extremities. Studies were extracted from PubMed using various keywords: stroke, upper extremity, mirror therapy. MT was significantly more effective than control therapy in motor function and sensory recovery across stroke acuity. No significant differences were found between MT and control treatment in pain, spasticity, and ADLs. MT is associated with improved motor function and sensory recovery in patients with paresis across all stroke acuity.
KEYWORDS: Behavioral and Social Sciences; Neuroscience; Stroke; mirror therapy; upper extremity.

Introduction

Background:

Strokes, or cerebrovascular accidents, are a leading cause of death and long-term disability in adults worldwide.[1,2] In the United States, 795,000 individuals experience a stroke each year.[1] Worldwide, strokes affect 15 million individuals.[2] Strokes result from the obstruction or burst of a vessel to the brain, resulting in necrosis, or cell death, in the affected area of the brain.[1-3] Though the effects of a stroke are variable, 85% of stroke survivors experience hemiparesis, or one-sided weakness, in their upper extremities contralateral to the area in which the stroke occurred.[3,4] This can result in movement dysfunction, motor impairments, sensory loss, and reduced quality of life.[2,4] According to the Centers for Disease Control and Prevention, 25% of stroke survivors require assistance or use assistive devices in day-to-day tasks.[1] As a result, it is crucial to research different interventions that affect stroke rehabilitation.

Mirror therapy (MT) is an intervention whose initial purpose was to help amputees recover from phantom limb pain.[4-9] In MT, a mirror is placed in the patient's mid-sagittal plane, reflecting the movements of the non-paretic arm, with the paretic arm being obstructed by the mirror (shown on the figure on the right).[4,6] When the patient watches the mirror, there is a visual illusion that their paretic arm is fully functional, hypothesized to reverse learned nonuse.[5,6] MT has been reported to be effective in patients across stroke acuity with hemiparesis by immediately promoting motor function, motor recovery, and quality of life.[6,9-10]

(Source: EBRSR.org)

The patient observes the mirror reflecting the movements with the non-paretic hand, producing the illusion that the paretic arm is functional:

The purported mechanism behind MT is the activation of the mirror neuron system.[4,6,7,9] During MT, fMRIs have found increased activity in the superior temporal sulcus due to stimulation of the mirror neuron system.[4,7,9] When the patient is directly observing movements, the increased activity in this region causes activation of the primary motor cortex on the lesioned side, resulting in the recovery and activation of motor neurons.[4,7,9] The activation of the primary motor cortex region results in a more significant improvement of motor function and recovery for the patient.[4,7,9]

MT is performed using one of the following three methods:[5]

i) Patients watch the movements made by the non-paretic arm in the mirror while simultaneously imitating movements with the paretic arm.

ii) Patients watch the movements made by the non-paretic arm in the mirror while imagining the actions of their affected limb.

iii) Patients watch the movements made by the non-paretic arm in the mirror while being assisted in moving their paretic arm to imitate the actions of the non-paretic arm.

In short, MT might be a simple, cost-effective treatment that patients can receive at home or in a clinical setting to achieve improved arm function.[4,7] New types of MT are being studied, including task-based MT, gesture-recognition MT, and combined MT.[4,11-13]

This review will be utilizing the World Health Organization's International Classification of Function, Disability, and Health, or ICF, model. In this model, the functional abilities of an individual post-disability are assessed mainly in terms of bodily impairments and activities. In the discussion section of this review, the effect of MT on the outcomes of the upper extremities post-stroke will be organized via the ICF model. Ultimately, the objective of this review is to analyze the effects of MT on different levels of impairment in patients' upper extremities post-stroke compared to other stroke interventions and techniques.

Discussion

This section will present the evidence for MT following the ICF model, where outcomes will be divided into impairments, such as motor function loss, pain, spasticity, and somatosensation, as well as activities, such as independence in activities of daily life, in the upper extremities of stroke patients. The section will also discuss variables that may affect MT outcomes, such as dosage and acuity, and introduce variations of MT. Finally, the section will assess the appropriate and inappropriate patients for MT and present several unanswered questions about MT that future studies should address.

Impairments:

Motor function is the speed and excursion of a movement stimulated by the activity of motor neurons.[14] Motor function is usually affected by stroke, resulting in motor impairments in stroke survivors. MT has been reported to be effective in improving motor function in patients compared to control therapy. Five randomized controlled trials (RCTs) examined the effect of MT on motor function and found that there were statistically significant results in the MT group compared to the control group when assessed by the Fugl-Meyer Assessment.[7,10,15-17] This finding was in agreement with one systematic review and one meta-analysis with a total of 73 studies, which found that MT significantly improved motor function immediately after the intervention period compared to control therapy and other interventions.[6,9] Moreover, hemiparesis is a frequent consequence of a stroke associated with functional loss of the upper extremity. There is evidence that MT can improve motor function assessed by the Fugl-Meyer Assessment compared to control therapy in patients with severe hemiparesis.[5,17] In a review examining 15 studies, the authors concluded MT had significant effects on motor function in patients with hemiparesis compared to traditional therapy.[13] These findings suggest that MT possibly enhances motor function in stroke patients with severe motor impairments and hemiparesis.

Pain in the upper extremity post-stroke is also a common symptom for stroke patients. However, MT was found to be ineffective in reducing pain. Compared to control therapy, researchers in one RCT found that patients with severe hemiparesis treated with MT did not have statistically significant outcomes in pain reduction.[5] This finding is consistent with the conclusions of a systematic review including 15 studies that there were no intergroup differences between the MT and control group on pain.[13] The collective results from both the RCT and the review suggest that MT is unlikely to improve pain reduction more significantly than control therapy. However, reduced pain following MT was reported by two systematic reviews for stroke patients with complex regional pain syndrome I (CRPS-I).[6,8] A systematic review examining 62 MT studies with 1,983 patients evaluated pain, measured by the Numerical Rating Scales and the pain section of the Fugl-Meyer Assessment, and found reduced pain for those with CRPS-I post-stroke.[6] Two studies included in the other review found that MT had significant effects on pain for CRPS-I patients.[8] These suggest that MT may be effective in reducing pain in CRPS-I patients post-stroke. Collectively, these results suggest that MT compared to conventional treatment is not effective in pain reduction in stroke patients that are diagnosed with CRPS-I.

Spasticity is another consequence of stroke caused by damage to the upper motor neurons causing increased resistance to passive movement.[18] MT has been reported to be ineffective on spasticity.[4-5,8,15,16] One RCT reported that patients performing MT reported a difference in elbow flexion, wrist flexion, wrist extension, and finger extension between pre-treatment and post-treatment results when measured by the Modified Ashworth Scale.[4] However, there was no statistically significant difference in spasticity scores between the MT and control therapy groups.[4] These findings aligned with the conclusions made in a systematic review containing five RCTs, where it was concluded that groups of patients that performed MT did not demonstrate substantial benefits on spasticity compared to conventional rehabilitation.[8] The use of MT poststroke, therefore, seems to yield no significant improvements in spasticity compared to conventional therapy.

Along with stimulating the primary motor cortex, MT modulates the primary sensory cortex, therefore, somatosensory recovery can occur in the upper extremity.[10] Two RCTs were conducted and examined the effect of MT on promoting somatosensation in the upper extremities. Patients in the first RCT receiving MT had significantly improved temperature and pain sensation versus conventional rehabilitation.[10] In the second RCT, which enrolled severe hemiparetic patients, significant improvement in tactile sensation was observed compared to the control group, but no statistically significant differences were demonstrated between groups when assessed by the Ottingham Sensory Assessment.[17] One RCT in a systematic review evaluating interventions for upper limb sensation recovery post-stroke found that MT where patients experienced improved light touch, thermal, and pressure sensation compared to sham therapy when measured by Quantitative Sensory Testing, largely agreeing with the findings reported by the two RCTs.[20] With these conclusions, it is possible for MT to improve aspects of sensation in the upper extremities post-stroke.

Activities:

Activities of daily life (ADLs) are a patient's ability to perform activities related to personal care including bathing, grooming, eating, and toileting.[19] When a patient suffers a stroke, functional loss affects their upper extremities, reducing their ability to be independent in their lives.[1] As a result, recovering the ability to perform ADLs in stroke patients is a primary concern. Three RCTs evaluated the effectiveness of MT on ADLs and found no significant differences between MT and conventional therapy.[5,7,10] Patients enrolled in the MT group only demonstrated pre-post within-group differences measured by the Modified Barthel Index.[5,7,10] However, there were no significant differences between the MT and control groups for ADLs.[5,7,10] Two recent systematic reviews arrived at different conclusions. A 2019 systematic review reviewing fifteen RCTs had similar results to those of the three RCTs, finding no significant differences between the MT group and the control group.[13] However, a 2018 systematic review concluded that MT had produced a significant effect on ADLs compared to all other interventions.[6] To explain these contrasting findings, the 2018 systematic review included studies in which patients in the experimental group performed task-based MT, which has been concluded to significantly improve ADLs. These results suggest that MT, without modifications, is unlikely to show significant intergroup differences in ADLs compared to control therapy or other interventions.

Dosage:

The dosage of MT reported in various RCTs included in this review ranged from 20 to 90 minutes per session over three to six weeks.[4,5,7,10,11,15-17,21,22] In a systematic review examining 15 studies it was concluded that MT in shorter doses of 30 minutes was more effective in motor function than prolonged doses when compared to conventional therapy.[13] The same systematic review found that the total intervention period also influences the effectiveness of MT in motor recovery of the arm.[13] The review authors concluded that RCTs with an intervention period longer than four weeks were less effective than RCTs that included an intervention period shorter than four weeks.[13] These results suggest that MT should be implemented in shorter doses and intervention periods to improve motor function and recovery.

Acuity:

MT has been reported to be effective on motor function across stroke acuity. In four RCTs, patients who were either chronic or acute/subacute and treated with MT had statistically significant effects on motor function compared to the control group therapy, therefore, concluding that MT can enhance motor function across stroke acuity.[5,7,10,15] Three systematic reviews evaluating studies including patients across stroke acuity also concluded that MT significantly improved motor function measured by the Fugl-Meyer Assessment.[6,9,13] Collectively, the findings suggest that MT can enhance motor function across stroke acuity.

Conversely, reports of the effect of MT on pain differ based on stroke acuity. Patients with chronic stroke who received MT did not experience significant effects on pain compared to control therapy.[5] A systematic review examining fifteen RCTs (fourteen RCTs with chronic subjects) concluded no significant differences in pain between the MT and conventional therapy groups.[13] The remaining RCT enrolled acute patients and reported improved pain in MT compared to conventional therapy.[13] These findings suggest that MT may effectively treat pain in acute but not in chronic or subacute stroke.

Stroke acuity also plays a role in the effectiveness of MT in sensory recovery. One RCT that enrolled chronic patients found improved temperature, tactile, and pain sensation in the MT group compared to the control group.[10] One RCT in a 2010 systematic review that enrolled acute patients found the same improvements in pressure, tactile, and thermal sensation as the RCTs which enrolled chronic patients.[20] These findings suggest that MT can improve aspects of sensory recovery in both acute and chronic stroke.

Patient Appropriateness/Inappropriateness:

To treat patients with MT, it is essential to understand whether MT is a suitable treatment for each patient. Cost, travel, and the necessity for sophisticated, state-of-the-art equipment are not significant issues, as MT utilizes cost-effective, accessible equipment that can be implemented in any setting.[4,7,11] As a result, patients with cost barriers will still be able to perform MT.

To perform MT, patients must follow directions from clinicians and complete the actions/tasks they are prescribed. As a result, patients with receptive aphasia, severe attention deficits, and cognitive impairments may be inappropriate to receive MT as these conditions may interfere with their ability to understand and follow instructions.[4,6-8,11] The Mini-Mental State Exam was utilized in studies to determine whether a patient was likely to participate in MT successfully.[5,6,10,11,15-17,22]

In addition, patients with severe visuospatial neglect and visual impairments may not be successful with MT treatments.[4,6] Since MT requires patients to look at a mirror to perform actions and tasks, patients who cannot clearly see their surroundings will be unable to see the mirror. As a result, these patients are unsuitable to receive MT.

Variations of MT:

New versions of MT are being developed to increase the effectiveness of MT. One such development is task-based MT.[4,21,22] Task-based MT requires the patient to perform goal-oriented practices and functional tasks using the mirror.[4,21,22] These practices require the patient to manipulate everyday objects such as chopsticks or a ball to perform various actions such as wrist extension and elbow flexion.[4,21,22] Two RCTs reported improved motor function and motor recovery of the hand compared to conventional treatment in patients with severe hemiparesis and upper limb impairment.[4,21] One RCT reported task-based MT had statistically significant improvement in ADLs than sham therapy when assessed by the Modified Barthel Index.[22] These results suggest that task-based MT effectively improves motor function and ADLs.

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Likewise, another development of MT is gesture-recognition MT. Patients performing gesture-recognition MT use a Leap Motion controller, a device that detects motion, and observe at a mirror reflecting the screen of a monitor.[11] Patients in gesture-recognition MT play various game programs that require them to perform multiple actions such as lifting their hands and picking up objects.[11] Gesture-recognition MT was reported to significantly affect motor function and quality of life in an RCT that included chronic patients compared to MT and control therapy.[11]

Collectively, these variations of MT have positive effects on different areas in the upper extremity post-stroke. Task-based MT was found to affect motor function, recovery, and ADLs positively compared to other interventions. Likewise, gesture-based MT also had positive effects on motor function and quality of life.

Unanswered Questions:

Due to its maneuverability, MT can be utilized in any setting, such as at a patient's home or in a clinician's office.[4,7] Multiple systematic reviews have identified this fact and used studies that included at-home MT.[6,13] However, no differences between at-home MT compared to MT in a clinical setting were studied. A possible hypothesis would be that clinical MT under a therapist's supervision will be more effective in improving impairment levels than at-home MT. Future studies should assess the difference between both methods of MT, by separating two groups based on clinical MT and at-home MT. Measuring the patients at baseline, post-intervention, and follow-up, studies should observe differences in motor function, spasticity, ADLs, and somatosensation to determine any intergroup differences and sustained effects of the treatment. Finding any significant differences would determine the setting that will allow stroke patients to receive the most benefit from MT.

Determining an optimal dosage for MT that provides the maximum benefit is a limitation in studies, as multiple studies use different dosage amounts.[5,13] In a systematic review, it was found that the longer the dosage of MT, the effectiveness of MT is reduced.[13] Regarding the conclusions made in the systematic review, it could be hypothesized that shorter doses of MT increase the effectiveness of the treatment. Future studies should research the dosage of MT that should be administered to stroke patients to determine the dosage that will result in the maximum efficacy of MT. Studies should separate patients into groups, each performing at different dosage amounts, and then measure each group at baseline and post-intervention on a variety of outcomes such as motor function, spasticity, ADLs, and sensation recovery. Obtaining any statistically significant differences between all three groups can aid clinicians in determining an optimal dosage amount for MT, which will produce the maximum rehabilitation effect for a patient post-stroke.

Usually, stroke patients seek rehabilitation services to enable them to complete basic day-to-day activities.[1,19] Earlier in this review, it was noted that MT has a possibility of improving different impairment levels such as motor function and somatosensation in the upper extremities. However, MT did not yield significant improvements in an individual's ability to partake in ADLs.[5-10,15-17,20] As a result, future studies should answer whether MT is an intervention that should be recommended by clinicians to use for the general stroke patient population. Future studies should also research variations of MT such as task-based MT as it has been shown to improve both impairment and activity, particularly motor function, somatosensation, and ADLs, in the upper extremities of stroke patients.[4,21,22] Future studies should further study these variations by comparing groups with task-based MT, MT, and conventional treatments in outcomes such as motor function, spasticity, somatosensation, and ADLs, observing for any statistically significant intergroup differences post-intervention. This will allow clinicians to recommend MT to stroke patients and expect positive results in the upper extremities of their patients because of the treatment.

Conclusion

MT has been shown to improve motor function and aspects of sensorimotor recovery compared to conventional therapy across all stroke acuity.[5-7,9,10,13,15-17] No significant differences were reported between conventional treatment and MT in pain, spasticity, or ADLs post-intervention.[4-8,10,13,15-16] However, acute patients and patients with CRPS-I reported less pain than conventional therapy.[6,8,13] It is also important to note that patients with severe hemiparesis had improved motor function and sensory recovery from MT.[5,17] These results suggest that patients with motor impairments, sensory loss, and hemiparesis across all acuity can benefit from MT and, therefore, have it prescribed by a physical therapist.

This review also analyzed several variations of MT, such as task-based MT and gesture-recognition MT. Increased ability to perform ADLs assessed by the Modified Barthel Index, were found in patients performing task-based MT compared to sham therapy.[22] In addition, task-based MT was found to improve motor function compared to conventional treatment more effectively.[21,22] Gesture-recognition MT also had improved motor function compared to traditional MT and conventional therapy.[11] Furthermore, improved quality of life was reported in patients performing gesture-recognition MT compared to conventional treatment.[11] These findings suggest that new developments of MT are also viable options for stroke patients.

Future studies should address the limitations found in this review. Studies should compare at-home MT to clinic MT to determine which form of MT is more effective. If a future study found that MT performed in a home setting is more effective than at a clinic, the impact would be significant. Patients will not need to pay for a therapist and can experience improved results in various outcomes at home compared to being in a clinic. As a result, future studies in this area are crucial due to their immense impact on patients. In terms of dosage, studies should research an optimal dosage of MT that produces the maximum efficacy for a patient. This study showed that shorter doses increase the effectiveness of MT, however, researchers should further study if this conclusion is valid. This would help future clinicians determine the proper dosage of MT to help more patients affected by stroke.

Lastly, studies should definitively conclude the worth of MT as a rehabilitation method for stroke patients by further studying developments of MT that provide positive results in both impairment and activity measures. This would ultimately help clinicians recommend MT to a broader scope of stroke patients and expect positive results in improving impairment levels and activity independence, allowing patients to lead functional lives post-stroke. Moreover, more rigorous, multi-site RCTs with large sample sizes should be conducted to definitively conclude the effectiveness of MT for stroke patients.

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