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ORIGINAL ARTICLE

Effect of mirror therapy combined with somatosensory stimulation on motor recovery and daily function in stroke patients: A pilot study

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Background/Purpose: Mirror therapy (MT) has been recommended as a simple, inexpensive approach to treat motor dysfunction. The use of a mesh glove (MG) was suggested to normalize muscle tone that ameliorates motor impairment. Combining two efficient treatment protocols might maximize the benefits from training. This study investigated the effects of MT combined with MG (MG + MT) versus MT alone on motor performance and daily function after stroke.
Methods: Sixteen patients with chronic unilateral stroke were recruited. A randomized two-group pretest and posttest design was used to randomly assign participants to MG + MT or MT groups. MT involves repetitive bimanual, symmetrical movement practice in which the

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individual moves the affected limb as much as she/he could while watching the reflective illusion of the unaffected limb's movements from a mirror. The MG + MT group wore a MG on the affected hand during the MT. The Modified Ashworth scale of muscle spasticity (MAS), Action Research Arm Test (ARAT), Box and Block Test (BBT), and Functional Independence Measure (FIM) were administered to evaluate spasticity, and motor and daily function.
Results: The results for the BBT ($p = 0.013$), total scores ($p = 0.031$), grasping subscales ($p = 0.036$) of ARAT, and FIM transfer scores ($p = 0.013$) presented significantly large effects in favor of the MG + MT group.
Conclusion: Combining MG with MT significantly improves manual dexterity, grasping, and transfer performance. Adding the MG component into the MT likely increased the richness of sensory input and improved the movement performance more than MT alone.

Introduction

The hemiparetic arm is one of the most devastating consequences after stroke.[1] Approximately 30-66% of patients with stroke never regain motor function of the affected hand for the rest of their lives, which seriously affects their performance of daily functions.[2] Several treatment techniques have been developed to improve motor control and function of the affected upper extremity for stroke patients, including, for example, robotic-assisted training[3] and constraint-induced movement therapy.[4–6] These treatment protocols involve significant equipment costs and/or continuous monitoring from therapists to closely guide the therapy.

Mirror therapy (MT) has been recommended as a simple, inexpensive alternative to treat motor function.[7,8] MT involves repetitive bimanual, symmetrical movement practice in which the patient moves the affected limb as much as she/he could while watching the reflective illusion of the unaffected limb from a mirror.[9] Although the underlying mechanism remains uncertain, the studies of neural activities found that MT might activate areas within the premotor and somatosensory cortex and/or the mirror neuron system consisting of the frontotemporal region and superior temporal gyrus. This cortical activation might facilitate motor output in patients with hemiparesis.[10,11]

The effects of MT on motor and daily function have been studied in patients with stroke.[7,8,12] The findings of these clinical trials suggested positive effects of MT on reducing motor impairment as measured by the Brunnstrom stages of recovery and Fugl-Meyer assessment (FMA)[7,8,12] and daily function as examined by the Functional Independence Measure (FIM).[7] However, findings that MT modulated muscle tone and motor function (action research arm test, ARAT) were inconsistent and not significant.[8,12]

The mesh glove (MG) is a two-channel electrical stimulator composed of two independent cathodes over the dorsal and volar side of the forearm and a common anode inside the glove that provides synchronous or reciprocal tonic sensory stimulation with different amplitudes. The MG was suggested to normalize muscle tone that ameliorates motor impairment in patients with stroke.[13–15] Research showed that MG stimulation on the affected hand modulated the polarization and depolarization of the ascending afferent fibers. The damaged hemisphere received the controlled kinesthetic input from the spinal, subcortical level, changed the blood-oxygen level-dependent response in the sensorimotor cortex,[16,17] and induced a long-lasting modulated effect on motor cortical excitability.[18]

Combining two efficient treatment protocols to maximize the benefits from training has been advocated.[19,20] The key concept of both MT and MG is sensory manipulation (i.e., visual illusion and kinesthetic input),[21,22] and these two approaches share the same cortical reorganization mechanism to a certain degree. Combining both approaches might facilitate the sensorimotor cortex that controls movement and might augment somatosensory input and further treatment efficacy. In other words, MG functions to modulate sensory input to control the spasticity, and combining MG with MT may complement the insufficiency of MT to acquire better outcomes in motor or functional performance.

Considering that these two approaches share a similar cortical mechanism, this study combined MG with MT to investigate its possible effects on motor performance and daily function. We hypothesized that patients who received MG therapy coupled with MT would gain a larger effect in motor recovery and muscle tone than patients receiving MT alone and that daily function would be enhanced.

Methods

Participants

Sixteen patients who experienced unilateral stroke (13 men and 3 women; mean age, 55.64 years; range 31-78 years), identified by brain imaging, were recruited from medical hospitals. Participants signed informed consent forms approved by the respective Institutional Review Boards.

Participants received independent examinations to determine their eligibility for the following inclusion criteria: (1) more than 6 months after onset of an ischemic or hemorrhage stroke; (2) Brunnstrom stage[23] higher than III for the proximal and distal upper extremity; (3) no excessive spasticity on all joints of the affected arm (Modified Ashworth Scale (MAS)[24] <3); (4) no serious cognitive deficits (Mini-Mental Status Examination score[25] >24); and (5) no serious vision or visual perception deficits (the best gaze and visual subtest in National Institutes of Health Stroke

Scale[26] = 0). Exclusion criteria were (1) history of stroke or other neurologic, neuromuscular, or orthopedic disease; (2) participation in other experimental rehabilitation or drug studies concurrent with this study; and (3) recurrence of stroke or documented seizure during the intervention.

Design

The study was a randomized two-group pretest and posttest design. Participants were randomly assigned to MG + MT or MT groups by a research assistant. All groups received training for 1.5 hours/day, 5 days/week, for 4 weeks. Training sessions were conducted by four trained occupational therapists during regularly scheduled occupational therapy sessions. All other routine interdisciplinary stroke rehabilitation was continued as usual, including physical therapy or acupuncture treatment. The treating therapists were trained in the administration of these two protocols by the investigators to conduct consistent intervention protocols. Pretest and posttest clinical evaluations were conducted by two occupational therapists blinded to the participant group. Raters were trained to administer the outcome measures, and their competence was assessed by a senior occupational therapist.

Interventions

Mirror therapy

MT included mirror box training for 1 hour and functional training with warm-up for 30 minutes. During the mirror box training, the mirror box was placed in the patient's sagittal plane. The affected arm was placed and obscured behind the mirror. Participants were required to perform symmetrical bilateral arm movements as simultaneously as possible while looking at the reflection of the unaffected hand in the mirror as if it were the affected one. Activities included transitive movements, such as stacking blocks or flipping a card, and intransitive movements, such as forearm pronation/supination or finger opponent. Both transitive and intransitive movements included gross motor (e.g., reaching tasks) and fine motor activities (e.g., grasp and grip tasks). Ten minutes of warm-up (i.e., stretching and passive range of motion exercises) was conducted before the mirror box training. Functional training, providing traditional therapeutic activities based on task-oriented treatment principles, was administered immediately after the mirror box training for about 20 minutes.

Combined MG with MT, MG + MT groups

Participants in the MG + MT group wore the Electro-Mesh glove (Prizm Medical Inc. Oakwood, GA, USA) on the affected hand during the 1-hour mirror box training. For safety purposes, the conscious sensory threshold was first set using the unaffected hand with a feeling of tingling on both the palmar and dorsal sides. Then, the MG was applied to the affected hand. If the muscle tone tested by MAS exceeded two points in any joints of the affected hand, the participant received a two-step electrical stimulation during the treatment session: the first step was a subthreshold electrical level defined by 80% of the conscious sensory threshold, and the second step was the conscious sensory threshold. Each step lasted 30 minutes. If the MAS score was lower than two points in all joints of the affected hand, a third step of 120% of the conscious sensory threshold was added, and each step took 20 minutes.[21] We applied continuous-synchronous subthreshold stimulation first and then provided continuous-synchronous stimulation equal to and/or higher than the threshold because the subthreshold one could decrease spasticity and the equal to / higher than threshold one could improve awareness of the hand and enhance volitional activity.[13,21,27]

Outcome measures

MAS, Box and Block Test (BBT), ARAT, and FIM were administered to evaluate spasticity and motor and daily function. The MAS assesses the muscle tone of the shoulder, elbow, wrist, and finger by using a scale of zero to four points. A higher score represents more severe spasticity. We used the mean scores of the 14 upper extremity items including the shoulder, elbow, wrist, and finger muscle tone in MAS to indicate the overall level of upper extremity spasticity. The Spearman ρ showed the interrater reliability of MAS was 0.56-0.90.[28]

The BBT tests manual dexterity. A box, which is separated into two equal sides by a partition, was placed in front of the patients. Patients were asked to bring one block at a time from one side to the other as soon as possible in 60 seconds. The number of blocks that were transported was counted. Only the performance of the affected hand was reported. The BBT also has good validity and reliability.[29]

The ARAT is a 19-item observational test that evaluates upper extremity motor function by grasping, grip, pinch, and gross motor subtests. Each motor task is rated on a four-point scale, ranging from zero (no movements) to three (complete the total movement). The total score is 57 points. The ARAT has high validity and reliability.[30,31]

Although both BBT and ARAT measure motor performance, BBT represents manual dexterity and is regarded as the level of body function.[32,33] On the other hand, ARAT includes diverse functional tasks[34] and might be related to the activity level.[33] Use of these two measures might help interpret effects at different performance levels of outcomes.[35]

The FIM measures independent functioning. A total of 18 items grouped into six subscales evaluate self-care, sphincter control, transfers, locomotion, communication, and social cognition ability. The score ranges from one (total assistance) to seven (complete independence), and the maximum total score is 126. The FIM has good interrater reliability, construct validity, and discriminate validity.[36–38]

Data analysis

Data were analyzed with SPSS 19.0 software (SPSS Inc, Chicago, IL, USA). Analysis of covariance (ANCOVA) was used to examine whether the effects of MG + MT were greater than MT alone on the outcome measures. The pretest performance was used as the covariate, group as the independent variable, and posttest performances as the dependent variable. Separate tests for individual endpoint help us understand and interpret the effects on specific motor skills and the overall motor performance to establish a knowledge base for developing a new intervention. It could also help explore whether there was an endpoint that might have been more beneficial. The effect size, η^2, was calculated for each outcome measure to index the magnitude of group differences in performance. According to Cohen,[39] a large effect size was represented by η^2 larger than 0.14, a moderate effect by η^2 between 0.06 and 0.14, and a small effect by η^2 smaller than 0.06.

Results

Each group consisted of eight patients. There were no significant differences between the two groups in their demographic data (Table 1); however, they differed significantly in the pretest performance on the total scores, and sphincter, transfer, and motor subscales of the FIM. We addressed the difference between the groups by treating the pretest score as a covariate in the comparison of posttest performance by the two groups.

The ANCOVA showed that the mean score of MAS was not significantly different between the two groups. However, the distal part score of the upper extremity in MAS ($p = 0.095$, $\eta^2 = 0.128$) demonstrated a moderate and nonsignificant effect in favor of the MG + MT group.

In the BBT, the MG + MT group improved better than the MT group, with a large and significant effect ($p = 0.013$, $\eta^2 = 0.331$). For the ARAT, large and significant effects between the two groups were found for results on total score ($p = 0.031$, $\eta^2 = 0.224$) and grasp ($p = 0.036$, $\eta^2 = 0.229$). Other subtests obtained moderate to large and nonsignificant effects ($p = 0.075$–0.165, $\eta^2 = 0.073$–0.152) favoring the MG + MT group over the MT group.

The MG + MT and MT groups did not differ significantly in the outcome of the FIM total score ($p = 0.141$, $\eta^2 = 0.089$). Further analyses revealed that the subscale of transfer reached a significant and large difference ($p = 0.013$, $\eta^2 = 0.326$) that favored the MG + MT group over the MT group. In addition, the MG + MT group outperformed the MT group on the motor subscale with a large and marginally significant effect ($p = 0.076$, $\eta^2 = 0.149$; Table 2).

Discussion

This study demonstrated that combining MG with MT significantly improved manual dexterity measured by the BBT and motor performance measured by the ARAT. Despite the limited sample size of 16 individuals, these impressive effects may shed light on continued research. Combining MG and MT treatment also significantly improved transfer performance measured by the FIM subscale. The results provided preliminary evidence that partially supports our hypothesis that the addition of MG to MT may increase treatment benefits.

To our knowledge, this study is among the first to report the efficacy of combining MG with MT. Our study found positive effects in manual dexterity and upper extremity motor performance (especially in grasping tasks). There are several possible reasons. First, studies have suggested MG stimulation reduces muscle tone in people with stroke.[13–15] Muscle tone is related to movement control. Abnormal muscle tone may prevent voluntary movements. For example, co-contraction of forearm flexor and extensor muscles may interfere with voluntary finger extension and prevent relaxation of grip.[40,41] A reduction of spasticity in the hand might promote grip release and improve manual dexterity. Although our findings of MAS scores did not show a statistical significance between groups, the results revealed a trend that distal part spasticity in the MT + MG group was lower to a large magnitude ($\eta^2 = 0.13$). To confirm the possible effects on both spasticity and upper extremity performance, future studies should recruit more than 30 patients in each group.[42] Second, the theoretic bases of MG stimulation and MT

Table 1 Demographic and clinical characteristics of study participants.

Characteristics[a]	MG + MT ($n = 8$)	MT ($n = 8$)	Statistic [b]		
			$F_{1,14}$	χ^2	p
Age, yr	56.31 ± 14.79	54.97 ± 14.10	0.035		0.855
Sex					
Male	6	7		0.522	1.000
Female	2	1			
Side of lesion					
Left	4	4		0.000	1.000
Right	4	4			
Onset, months after stroke	18.88 ± 14.78	23.38 ± 10.86	0.482		0.499
MMSE	27.00 ± 2.89	28.14 ± 2.19	0.696		0.421
Years of education	8.29 ± 6.21	13.63 ± 4.03	4.007		0.067
NIHSS score	1.75 ± 1.39	1.43 ± 1.40	0.199		0.663
FMA pretest score – UE part	45.38 ± 9.40	44.25 ± 11.61	0.045		0.834

FMA = Fugl-Meyer Assessment; MG = Mesh Glove; MMSE = Mini-Mental State Examination; MT = mirror therapy; NIHSS = National Institutes of Health Stroke Scale; UE = upper extremity.

[a] Continuous variables are shown as the mean ± standard deviation; categoric variables are shown as number.

[b] Statistic associated with χ^2 test for categoric variables, one-way analysis of variance for continuous variables, and nonparametric test for ordinal variables.

Table 2 Results of muscle tone, motor function, and functional independence.

Assessments	Pretest scores		Posttest scores		ANCOVA		
	MG + MT (n = 8)	MT (n = 8)	MG + MT (n = 8)	MT (n = 8)	$F_{1,14}$	p	η^2
MAS							
Proximal part	0.33 ± 0.24	0.29 ± 0.20	0.28 ± 0.23	0.26 ± 0.18	0.015	0.453	0.001
Distal part	0.55 ± 0.31	0.52 ± 0.09	0.49 ± 0.37	0.52 ± 0.17	1.913	0.095	0.128
Total	0.43 ± 0.26	0.39 ± 0.12	0.37 ± 0.29	0.37 ± 0.12	0.737	0.203	0.054
ARAT							
Grasp	8.50 ± 4.66	8.38 ± 6.14	12.00 ± 3.70	9.88 ± 6.10	3.858	0.036	0.229
Grip	5.25 ± 4.10	5.75 ± 4.03	7.38 ± 3.34	6.75 ± 4.56	1.025	0.165	0.073
Pinch	7.00 ± 5.24	8.38 ± 6.41	9.38 ± 5.29	9.00 ± 6.93	2.335	0.075	0.152
Gross motor	5.25 ± 1.16	5.13 ± 1.25	6.75 ± 1.39	5.88 ± 1.81	1.874	0.097	0.126
Total	26.00 ± 14.35	27.63 ± 17.17	35.50 ± 12.49	31.50 ± 18.52	4.204	0.031	0.224
BBT							
Affected side	10.38 ± 9.59	13.13 ± 12.19	15.63 ± 13.23	14.13 ± 12.79	6.429	0.013	0.331
FIM							
Self care	29.63 ± 7.61	35.25 ± 3.33	31.38 ± 5.71	36.25 ± 2.50	1.327	0.135	0.093
Sphincter	11.88 ± 2.47	14.00 ± 0.00	12.25 ± 1.98	14.00 ± 0.00	0.720	0.206	0.052
Transfer	16.75 ± 2.82	19.13 ± 1.13	17.00 ± 2.14	19.25 ± 1.04	6.288	0.013	0.326

ANCOVA = analysis of covariance; ARAT = Action Research Arm Test; BBT = Box and Block Test; FIM = Functional Independence Measure; MAS = Modified Ashworth Scale; MG = Mesh Glove; MT = mirror therapy.

treatment have a common ground: both use sensory manipulation, involving sensory and kinesthetic inputs as well as visual illusion. Studies have shown that MT might activate the premotor and somatosensory cortex,[43,44] and MG stimulation might induce rapid plastic change in sensorimotor regions of the cortex.[18,21,45] Therefore, it is likely that supplementing MG stimulation with MT provides cross-modal inputs that link to the modulation of somatosensory cortex, which might further positive effects of MT on movement control recovery.[22,46,47] However, we did not assess brain excitability in the study. Conclusive statements require further research on brain reorganization after intervention.

Although the study findings on pinch, grip, and gross motor subscales in ARAT were not significant, they demonstrated moderate to large effects, suggesting we may not have had enough statistical power to detect existing true effects. Such findings hold promise that their effects may be better demonstrated in an investigation with a large sample size. We suggest future studies to recruit approximately 35 participants in each group.[42]

In addition to sample size, another possibility is that the benefits of the combined treatment in our study are more focal. The training tasks in our MT protocol largely involved prehension movements that closely relate to the tasks in BBT and grasping tasks in ARAT. With some degree of improvement in prehension control, the speed of moving the blocks could increase, resulting in significant improvements in the BBT score and in grasping performance in ARAT. In contrast, the rest of the ARAT subcategories not only require grasping but also heavily involve shoulder, elbow, and dexterous motor control.

At the level of daily function outcomes, we found improvements in transfer subscales in FIM were significantly greater by adding MG stimulation ($\eta^2 = 0.326$, $p = 0.013$). One explanation could be that an increase in distal motor control might provide more assistance such as holding an armrest during performing transfer tasks, decreasing the risk of falling and facilitating mobility capability. However, we found no significant benefits in the total score and other subscales. This finding might indicate that the treatment effects of our specific intervention protocol might not transfer to these remote tasks as measured by the FIM. Future research might incorporate more functional training into MT + MG to enhance possible effects on daily function.

Other reasons for the nonsignificant findings could be the intensity of MG stimulation and the timing of providing MG stimulation. Our participants were recovering after a stroke, unlike the healthy participants studied by Golaszewski et al.[21] Setting the conscious sensory threshold by using the unaffected hand for people with sensory impairments after stroke presents a risk of underestimating the necessary intensity of stimulation. The low intensity of MG stimulation might fall into subthreshold category for the affected hand, and thus would relax the muscle. Whether this would interfere with the muscle activation required to perform actions is unclear. Future studies could use the affected hand to set the conscious sensory threshold while carefully monitoring side effects, such as pain, due to possible overstimulation.

Regarding the timing of wearing the MG, our participants wore it during the MT treatment. The sensory stimulation from the glove could interfere with true tactile sensory feedback, which could contradict with the online-correction process of movement, especially while MT is blocking the visual feedback. Moreover, Golaszewski et al.[21] found that the changes in cortex excitability outlasted the actual somatosensory stimulation by at least 1 hour.[21] A valuable area of investigation for future studies would be to apply MG stimulation before MT and assess its possible effects when compared with applying MG and MT concurrently.

Future studies may require follow-up measures and experimentation with a larger sample. The immediate effects on BBT and grasp in ARAT may need more time to transfer these skills to day-to-day activities. It is worthwhile to monitor participants for a longer period of time to examine long-lasting effects. Second, our nonsignificant findings favoring MG + MT hold promise to use a large sample size to detect existing true effects in future studies.

In summary, this pilot study found impressive positive effects of combined MG with MT on motor recovery, especially manual dexterity and grasping performance as well as functional transfer ability. Nonsignificant findings with moderate to large effects on grip, pinch, and gross motor recoveries, and self-care and mobility daily functions hold promise for further studies.

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