Mirror therapy in chronic stroke survivors with severely impaired upper limb function: A randomized controlled trial

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Congresses

This study has never been presented in any congress

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Conflicts of interest

The authors have no conflict of interest to declare.

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Abstract

Background

Mirror therapy has been proposed to improve the motor function of chronic individuals with stroke with mild to moderate impairment. With regards to severe upper limb paresis, mirror therapy has shown to provide limited motor improvement in the acute or sub-acute phase. However, no previous research has described the effects of MT in chronic individuals with stroke with severely impaired upper limb function.

Aim

To determine the effectiveness of mirror therapy on chronic stroke survivors with severe upper-limb impairment in comparison with passive mobilization.

Design

A randomized controlled trial

Setting

Outpatient

Population

A total of 31 chronic subjects post-stroke with severely impaired upper limb function were randomly assigned to either an experimental group (n=15), or a control group (n=16).

Methods

Twenty-four intervention sessions were performed for both groups. Each session included 45-minute period of mirror therapy (experimental group) or passive mobilization (control group), administered three days a week. Participants were assessed before and after the intervention with the Wolf Motor Function Test, the Fugl-Meyer Assessment, and the Nottingham Sensory Assessment.

Results

Improvement in motor function was observed in both groups on the time (p=0.002) and ability (p=0.001) subscales of the Wolf Motor Function Test. No differences were detected in kinesthesis or stereognosis. However, the experimental group showed a significant improvement in tactile sensation that was mainly observed as an increased sensitivity to light touches.

Conclusions

In comparison with passive mobilization, mirror therapy in chronic stroke survivors with severely impaired upper-limb function may provide a limited but positive effect on light touch sensitivity while providing similar motor improvement.

Clinical rehabilitation impact

Mirror therapy is a therapeutic approach that can be used in the rehabilitation of severely impaired upper limb in chronic stroke survivors, specifically to address light touch sensitivity deficits.

Keywords

Stroke; Upper Extremity; Hemiparesis; Chronic Brain Injury

Introduction

Functional impairment of the upper limb is reported in approximately 85% of stroke survivors[1] and affects participation in daily living activities and quality of life.[2] Six months after onset, 30-60% of individuals do not regain functional use, and only 5-20% will achieve full recovery of arm function.[3] Rehabilitation of severe arm paresis in chronic stroke survivors is, therefore, especially challenging.[4] Useful reorganization of cortical areas involved in arm function occurs in response to active exercise and to motor and attentional inclusion of the affected arm in task oriented movements.[4,5] Because severe paresis impedes active training of the hand, traditionally, rehabilitation strategies in these subjects have almost exclusively aimed to compensate for the deficit by training the opposite limb in daily tasks.[4,6] As synaptic connectivity is highly use dependent, this absence of stimulation on the chronic paretic arm results in reduced sensorimotor representation in the available neural circuits over time[7] and consequently diminishes the possibilities for sensorimotor clinical progress.[6] Accordingly, a reduction in sensorimotor abilities might partly be an effect of non-use of the affected limb.[7] In fact, lack of movement has been considered to be a form of "learned paralysis".[8,9]

Mirror therapy (MT) could address these issues because it does not require active movements of the affected arm. A mirror is placed along the midsagittal plane between the two limbs, and the subject is encouraged to move the less affected limb while watching its reflection in the mirror, thus providing the visual illusion that the affected limb mirrors the movement of the other limb. Neuroimaging techniques have revealed the capacity of MT to elicit cortical activation in the hemisphere contralateral to the mirrored arm (ipsilateral to the moving arm), even in absence of movement,[10] and have found evidence of interesting and varied cortical changes induced by MT.[11-13] These results have motivated the application of MT to sensorimotor rehabilitation after

stroke. Previous research has shown that MT can improve the motor function of chronic individuals with stroke with mild to moderate impairment.[14,15] Moreover, interventions involving stroke survivors with severe upper limb paresis have been shown to provide limited motor improvement in the acute[10,16] or sub-acute phase.[16] However, no previous research has described the effects of MT in chronic individuals with stroke with severely impaired upper limb function. We hypothesize that MT can be beneficial for sensorimotor function of severely affected upper limbs of chronic stroke survivors.

The objective of the present study was to determine the effectiveness of MT in chronic stroke survivors with severe upper-limb impairment in comparison to a passive mobilization intervention.

Materials and methods

Participants

Participants were recruited from the chronic stroke outpatient management program that was run by a specialized neurorehabilitation center. The inclusion criteria for the current study were: 1) chronicity > six months; 2) severe paresis of the upper limb, as defined by the Brunnstrom Approach[17] as stages I or II) and by the Upper Extremity subscale of the Fugl-Meyer Assessment (FMA)[18] as scores below 19; 3) sensory impairment in the affected upper limb, as assessed by clinical examination; 4) ability to maintain a sitting position for at least 60 minutes; 5) a fairly good cognitive condition, as defined by scores on the Mini-Mental State Examination[19] above 23. Participants were excluded if they had: 1) impaired comprehension that hindered sufficient understanding of the instructions, as defined by Mississippi Aphasia Screening Test[20] scores below 45; 2) severe visual impairments; 3) upper limb pain that limited participation in the rehabilitation protocol; 4) spatial neglect; 5) self-awareness disorders; and 6) emotional

circumstances that impeded adequate collaboration. Sample size was calculated for a two-sample t test assuming 75% power, a common standard deviation of 50, a mean difference between groups on the Wolf Motor Function Test (WMFT) of 50 seconds, and a loss rate of 10%.

The study was approved by the Institutional Review Board of the specialized neurorehabilitation center. Written consent was obtained from all of the subjects who satisfied the inclusion criteria and accepted the offer to participate in the study. Participants were randomly assigned to an experimental or a control group. The allocation sequence was concealed from an independent researcher. A sealed envelope identifying the group of each participant was given to the therapists to inform them of the allocation. Randomization was computer-generated using a basic random number generator in a ratio of 1:1.

Intervention protocol

All of the participants were undergoing a long-term care physical therapy program consisting of five one-hour sessions a week that focused on balance and gait training. During this clinical trial, participants underwent 24 sessions, each 45-minutes long, and administered three days a week in addition to the physical therapy. Subjects belonging to the experimental group underwent a MT program and those belonging to the control group received passive mobilization of the affected upper limb. Treatment intensity was dose-matched for both groups, allowing 60-second breaks every five minutes. All of the participants trained in a dedicated area of the physical therapy unit free of distractors. For the MT, a triangular prism-shaped device with a mirror on one side was fixed on a conventional table. Participants sat down close to the table in chairs with a back and without armrests. Participants hid the affected arm inside the device and the mirror was

oriented so that they were able to see the reflection of their other arm. Participants were encouraged to observe the mirror while executing different movements with their less affected limb. Exercises were indicated verbally and consisted of a series of flexo-extension and prono-supination movements of the shoulder and forearm and gross and fine movements of the wrist, hand, and fingers, with and without objects (balls, cups, and other). These activities included transitive movements, gross motor tasks, and intransitive movements.[14] Participants in the control group received passive mobilization of the paretic upper limb. Passive range of motion exercises were provided in those segments where no active movement was detected to meticulously reproduce a range of articular movements and muscle and soft tissue elongation. In case of residual active movement capability, participants were encouraged to perform the movements with the assistance of the therapists.

Assessment

All of the participants were assessed by a physical therapist, blind to the treatment, the day before the intervention and the day after the intervention. The primary outcome measure was the WMFT. Both time and ability subscales were considered. Secondary outcome measures assessed the upper limb motor function using the FMA, and the sensory impairment of the hemiparetic upper extremity using the tactile, kinaesthetic, and stereognosis subscales of the Nottingham Sensory Assessment (NSA).[21] The tactile subscale assessed light touch, pressure, pinprick, temperature, tactile localization, and bilateral simultaneous touch. Scores in the NSA ranged from 0 to 48 in the tactile subscale, from 0 to 12 in the kinesthetic subscale, and from 0 to 22 in the stereognosis subscale. Higher scores represent more preserved sensory sensation.

Statistical analysis

Demographical and clinical comparisons between the control and the experimental groups were performed with independent sample t-tests and Chi-squared or Fisher exact tests, as appropriate. Repeated measures analyses of variance (ANOVA) with time as the within-subjects factor and treatment option (control versus experimental) as the between-subjects factor were performed for the FMA and the subscales of the WFMT and NSA. The main effects were evaluated for time, treatment option, and the time-treatment option interaction. ANOVA findings that violated the sphericity assumption were accommodated by Greenhouse and Geisser's conservative degrees of freedom adjustment. For each repeated-measures ANOVA, we present the partial eta squared (η^2_p) as a measure of effect size; values may range between 0 and 1, with higher values representing higher proportions of variance explained by the independent variable.

The α level was set at 0.05 for all analyses (two-sided). All analyses were computed with SPSS for Mac, version 15 (IBM, Armonk, NY, USA). Investigators performing the data analysis were blinded.

Results

A total pool of 97 outpatients attended the long-term care program during the recruitment. Of those, 34 subjects (35.1%) met inclusion criteria. None of them refused to participate in the study, and consequently all of them were randomized. Each group consisted of 17 participants. Two participants of the experimental group were discharged, and one participant of the control group suffered a cardiac arrest. Consequently, these participants discontinued the program and were excluded from the study. Their data were, therefore, not included in the study. Finally, data from 31 participants, 16 in the control group and 15 in the experimental group, were included in this study (Figure 1). The final sample consisted of 26 males and 5 females, with a

mean age of 53.6±8.4 years, and a mean chronicity of 551.1±377.5 days. A total of 23 participants presented an ischemic stroke, and eight participants presented a hemorrhagic stroke (Table 1). No significant differences in demographical (gender and age) or clinical (etiology, hemiparetic side, chronicity, Brunnstrom, and FMA) data at inclusion were detected between the groups. All of the participants were right-handed.

With regards to the primary outcome measure, scores in the time and ability subscales of the WMFT significantly improved after the treatment period in each group, but this improvement failed to reach a significant difference between groups (Table 2). The percentage of change was 5.8% in the control group and 4.7% in the experimental group for the time subscale, and 15.6% in the control group and 18.9% in the experimental group for the ability subscale.

Regarding to secondary outcomes, no differences were found in motor performance after the treatment, as measured by the FMA, neither within any group nor between the two groups (Table 2). Regarding sensory assessment, the kinesthetic and the stereognosis subscales of the NSA showed no significant difference (Table 2). However, the results in the tactile subscale revealed a statistically significant improvement after treatment for both groups. Interestingly, the improvement experienced by the experimental group was significantly higher than that experienced by the control group ($p<0.01$). A more in-depth analysis of the tactile subscales found that scores in the light touch test promoted this result (Table 3). No significant differences were detected in any subscale of the NSA between subjects with left or right hemiparesis, neither at the beginning nor at the end of the intervention.

Discussion

This paper describes the effectiveness of a MT intervention in chronic stroke survivors with severe hemiparesis in comparison with passive mobilization. Although the MT intervention provided similar results to mobilization interventions in motor performance, the experimental intervention could promote greater changes in the tactile sensation, specifically regarding light touch.

Motor function

The improvement provided by MT for motor function was similar to the improvement provided by the mobilization intervention. Significant changes were detected in both groups by the WMFT, but not the FMA. Changes detected in the time subscale of the WMFT for both groups were lower than the Minimally Clinically Important Difference (MCID),[22] and more importantly, final timed scores, though lower than initial scores, were still very high, as expected for subjects with such severe motor impairment. Changes in the ability subscale in the control group were slightly inferior to the MCID, which was previously established as 17% for the acute phase,[22] but were higher than the MCID in the experimental group. The general nature of the FMA could explain the inability of this scale to detect changes as subtle as those detected in our study. The characteristics of our sample could have prevented greater improvement. First, all of the participants were chronic stroke survivors. Although chronicity is not believed to be an excluding factor, less recovery is expected as time since injury increases and endogenous recovery mechanisms diminish.[23] Second, all of the participants presented a severe upper limb motor impairment, evidenced by a baseline FMA score below 19. Initial severity of motor impairment has been considered the most important prognostic variable of upper limb recovery after stroke.[24-26] Specifically, an FMA above 18 points

at four weeks after onset is an independent predictor of dexterity within six months.[24] More importantly, initial FMA scores between 21 and 35 can predict improvement after a MT intervention.[27] Finally, somatosensory impairment, which was present in all of our participants as well, has also been found to be a predictor of the absence of limb dexterity one year after the injury,[25] and has been related to poorer functional ability.[28,29] Previous research with similar interventions involving stroke survivors in the acute[10] or sub-acute phase[16] with severe upper limb paresis reported no significant differences between groups in the motor domain, except for individuals with plegic fingers.[10] The combination of MT with bilateral arm training in an acute population was reported to increase the effectiveness of the intervention.[30] In contrast, positive effects were found in motor performance and motor control after MT in chronic individuals with mild to moderate hemiparesis.[14,15] All of these results suggest that the severity of the impairment, rather than the chronicity, could determine the effects of the MT in the motor impairment.

Sensory function

Although no significant improvement was detected in any group regarding kinesthesia and stereognosis, the MT provided a statistically significant improvement in the tactile sensation to participants in the experimental group, mainly promoted by an improvement in the ability to sense light touches. Despite the chronicity and the limited duration of the treatment, the effect size of the difference between groups for the tactile sensation subscale was moderate. Furthermore, a detailed analysis of its items showed a considerable effect size for light touch sensitivity. The authors hypothesize that these improvements can be related to the visual enhancement of touch, which suggests that tactile perception could be augmented by viewing the stimulated parts.[31] Visual

feedback can exert a strong modulatory influence over the motor system when there is a conflict, which can, in turn, override other modalities, such as proprioception.[32] Neuroimaging techniques have shown the dominance of vision over proprioception during motor programming.[32] Interestingly, this mechanism has previously been confirmed in healthy and brain damaged individuals with lower somatosensory sensitivity,[31] as is the case in the present study. The participants were required to pay special attention to the intervention task, which could have been another factor that contributed to the improvement in tactile sensitivity. Attention to touch could have led to increased activation in somatosensory cortical areas, including the primary somatosensory cortex.[33] Interestingly, the role of attention in MT has been previously reported to have a positive impact on heminegligence.[10,16,34]

An improvement in temperature sensation was also detected in our study but without showing differences between groups, and a similar result had been previously reported in a stroke population with mild to moderate paresis after MT.[14] This change may have been attributed to multimodal neurons in the posterior parietal and premotor cortical areas that respond to sensory stimuli, which modulate the somatosensory cortex network and contribute to the recovery of the somatosensory system. The severity of the impairment could have influenced the different results.

Limitations

The limitations of this study must be taken into account when analyzing the results. First, the sample size, which consisted of 31 participants, can be considered small even though it is similar to other studies.[10,14] Second, the chronicity and the severity of the motor impairment restricts the extrapolation of the results to other population, because these factors seem to determine the effects of the MT, as described throughout the text.

Third, the progress of the participants was not determined in a follow-up assessment. Finally, the MCID of the NSA scale has not been validated, which complicates the evaluation of the functional impact of the significant changes detected in this scale.

Nonetheless, the improvement in light touch sensitivity after the MT intervention may be relevant, because somatosensory deficits occur in approximately 50% of stroke survivors and can limit functional recovery.[31] MT could therefore be a tool to enhance sensory function in very chronic individuals with severely affected upper limb function.

Conclusions

Our results suggest that MT can provide limited but positive effects in light touch sensitivity in chronic stroke survivors with severely impaired upper limb function while providing similar motor improvement. Our results and previous research in the field suggest that MT may be more effective for motor improvement in mild to moderate hemiparesis, even at chronic stages, rather than in severe paresis, where MT may provide benefits to tactile sensitivity.

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Tables

Table 1. Characteristics of the participants.

Characteristic	Control group (n=16)	Experimental group (n=15)	Significance
Gender (n, %)			NS (p=0.532)
Male	13 (81.2%	13 (86.7%)	
Female	3 (18.8%)	2 (13.3%)	
Age (years)	53.3±10.5	53.8±5.5	NS (p=0.891)
Etiology (n, %)			NS (p=0.352)
Ischemic stroke	13 (81.2%)	10 (66.7%)	
Hemorrhagic stroke	3 (18.8%)	5 (33.3%)	
Hemiparesis (n, %)			NS (p=0.173)
Left	14 (87.5%)	10 (66.7%)	
Right	2 (12.5%)	5 (33.3%)	
Chronicity (days)	520.0±262.5	584.2±478.7	NS (p=0.601)
Brunnstrom (n, %)			NS
Stage I	0	0	
Stage II	16	15	
Flugl-Meyer Assessment	9.0±4.4	8.5±4.7	NS (p=0.803)

Age and chronicity are defined in terms of mean and standard deviation. Etiology and gender are expressed as a percentage of the total number of participants. NS: non-significant.

Table 2. Clinical data.

	Initial assessment	Final assessment	Significance (p, effect size)
WMF-time			T** (p=0.002, η^2_p =0.29)
Control	1492.7±65.1	1405.8±70.8	
Experimental	1615.2±67.2	1539.8±72.8	
WMF-ability			T** (p=0.001, η^2_p =0.31)
Control	10.9±1.7	12.6±1.8	
Experimental	8.7±1.7	10.1±1.8	
FMA			NS
Control	9.0±1.1	9.5±1.1	
Experimental	8.5±1.2	8.6±1.1	
NSA-tactile			T** (p=0.001, η^2_p =0.38); GxT* (p=0.027, η^2_p=0.16)
Control	23.9±4.5	25.1±4.3	
Experimental	17.8±4.7	21.9±4.4	
NSA-kinaesthetic			NS
Control	4.7±0.8	5.0±0.9	
Experimental	6.6±0.8	6.3±1.0	
NSA-stereognosis			NS
Control	5.2±1.8	5.3±1.8	
Experimental	4.2±1.8	4.4±1.8	

Results are given in terms of mean and standard deviation. T: time effect. GxT: group by time effect. *: $p<0.05$, **: $p<0.01$. NS: non-significant.

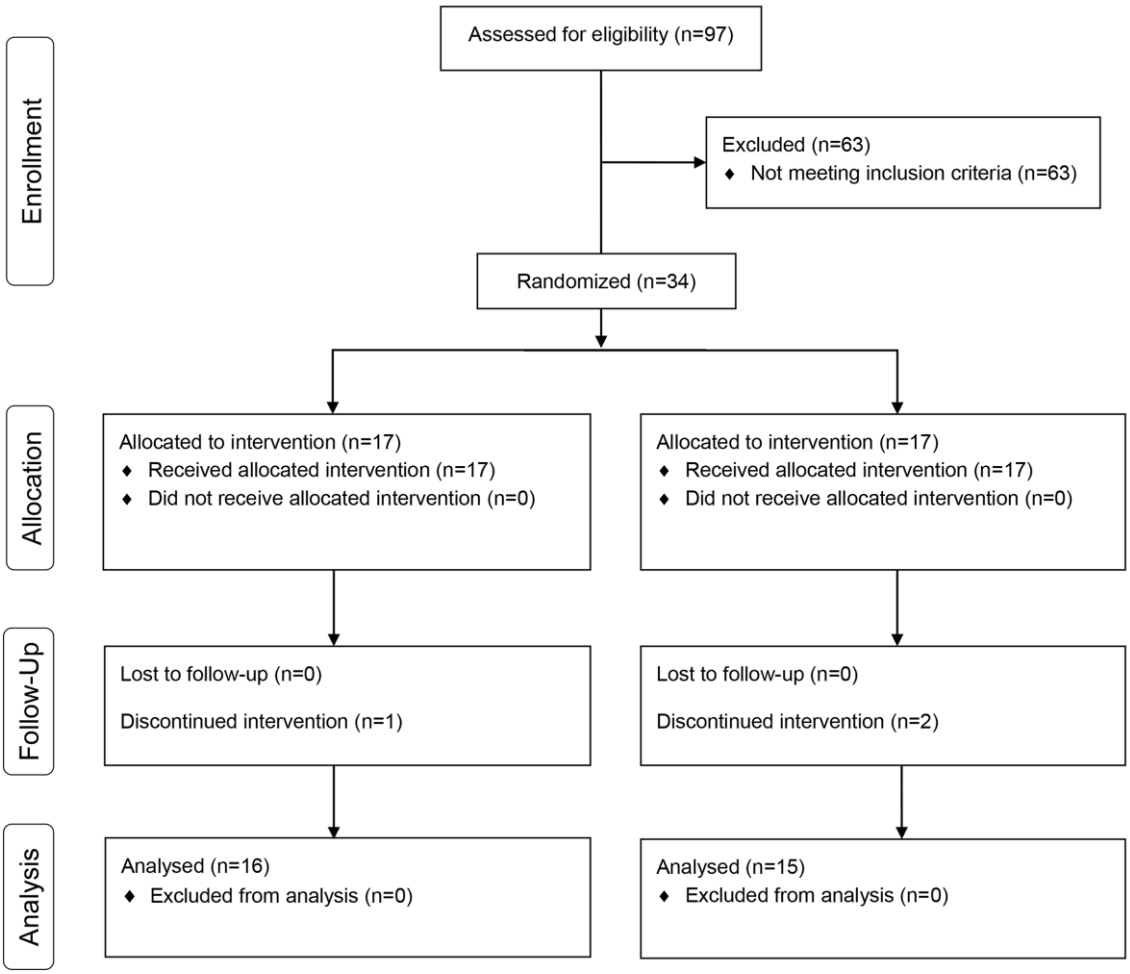
Table 3. Results in the tactile subscale of the Nottingham Sensory Assessment

	Initial assessment	Final assessment	Significance (p, effect size)
Light touch			T** (p=0.000, η^2_p =0.43); GxT** (p=0.000, η^2_p =0.36)
Control	4.2±0.8	4.3±0.7	
Experimental	3.5±0.8	4.3±0.7	
Pressure			NS
Control	4.4±0.8	4.5±0.7	
Experimental	4.2±0.8	4.3±0.8	
Pinprick			T** (p=0.001, η^2_p=0.34)
Control	4.3±0.8	4.6±0.7	
Experimental	3.8±0.9	4.3±0.7	
Temperature			T* (p=0.023, η^2_p =0.17)
Control	4.2±0.8	4.5±0.7	
Experimental	3.3±0.8	4.0±0.8	
Tactile localisation			NS
Control	4.8±0.8	5.6±0.8	
Experimental	3.8±1.2	4.0±1.1	
Bilateral simultaneous touch			NS
Control	6.1±0.9	6.0±0.9	
Experimental	5.2±1.3	5.6±1.3	

Results are given in terms of mean and standard deviation. T: time effect. GxT: group by time effect. *: p<0.05, **: p<0.01. NS: non-significant.

Figures

Figure 1– CONSORT flow diagram



Progress through the phases of the parallel randomized trial of both groups.