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W. B. SAUNDERS

ORIGINAL ARTICLE

# Mirror Therapy Improves Hand Function in Subacute Stroke: A Randomized Controlled Trial

*Gunes Yavuzer, MD, PhD, Ruud Selles, PhD, Nebahat Sezer, MD, Serap Sütbeyaz, MD, Johannes B. Bussmann, PhD, Füsun Köseoğlu, MD, Mesut B. Atay, MD, Henk J. Stam, MD, PhD*

ABSTRACT. Yavuzer G, Selles R, Sezer N, Sütbeyaz S, Bussmann JB, Köseoğlu F, Atay MB, Stam HJ. Mirror therapy improves hand function in subacute stroke: a randomized controlled trial. Arch Phys Med Rehabil 2008;89:393-8.

**Objective:** To evaluate the effects of mirror therapy on upper-extremity motor recovery, spasticity, and hand-related functioning of inpatients with subacute stroke.

**Design:** Randomized, controlled, assessor-blinded, 4-week trial, with follow-up at 6 months.

**Setting:** Rehabilitation education and research hospital.

**Participants:** A total of 40 inpatients with stroke (mean age, 63.2y), all within 12 months poststroke.

**Interventions:** Thirty minutes of mirror therapy program a day consisting of wrist and finger flexion and extension movements or sham therapy in addition to conventional stroke rehabilitation program, 5 days a week, 2 to 5 hours a day, for 4 weeks.

**Main Outcome Measures:** The Brunnstrom stages of motor recovery, spasticity assessed by the Modified Ashworth Scale (MAS), and hand-related functioning (self-care items of the FIM instrument).

**Results:** The scores of the Brunnstrom stages for the hand and upper extremity and the FIM self-care score improved more in the mirror group than in the control group after 4 weeks of treatment (by 0.83, 0.89, and 4.10, respectively; all $P<.01$) and at the 6-month follow-up (by 0.16, 0.43, and 2.34, respectively; all $P<.05$). No significant differences were found between the groups for the MAS.

**Conclusions:** In our group of subacute stroke patients, hand functioning improved more after mirror therapy in addition to a conventional rehabilitation program compared with a control treatment immediately after 4 weeks of treatment and at the 6-month follow-up, whereas mirror therapy did not affect spasticity.

**Key Words:** Cerebrovascular accident; Feedback; Imagery (psychotherapy); Motor skills; Rehabilitation.



From the Department of Physical Medicine and Rehabilitation, Ankara University Faculty of Medicine, Ankara, Turkey (Yavuzer, Atay); Departments of Rehabilitation Medicine (Yavuzer, Selles, Bussmann, Stam) and Plastic and Reconstructive Surgery (Selles), Erasmus University Medical Center, Rotterdam, The Netherlands; and IVth Physical Medicine and Rehabilitation Clinic, Ankara Physical Medicine and Rehabilitation Education and Research Hospital, Ankara, Turkey (Sezer, Sütbeyaz, Köseoğlu).

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Reprint requests to Gunes Yavuzer, MD, PhD, Mustafa Kemal Mahallesi, Baris Sitesi 87, sokak No 24, 06800 Ankara, Turkey, e-mail: *gyavuzer@medicine.ankara.edu.tr*.

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THE PARETIC UPPER LIMB is a common and undesirable consequence of stroke that increases activity limitation. It has been reported that up to 85% of stroke survivors experience hemiparesis and that 55% to 75% of stroke survivors have continued to have limitations in upper-extremity functioning.[1] A number of interventions have been published evaluating the effect of various rehabilitation methods in improving upper-extremity motor control and functioning, such as exercise training of the paretic arm,[2] impairment-oriented training of the arm,[3] functional electric stimulation,[4] robotic-assisted rehabilitation,[5] and bilateral arm training.[6] However, most of the treatment protocols for the paretic upper extremity are labor intensive and require 1-to-1 manual interaction with therapists for several weeks, which makes the provision of intensive treatment for all patients difficult.[7]

It has been suggested that mirror therapy is a simple, inexpensive and, most importantly, patient-directed treatment that may improve upper-extremity function.

Ramachandran and Rogers-Ramachandran[8] were the first to introduce the use of these visual illusions created by a mirror for treatment of phantom limb pain. By superimposing the intact arm on the phantom limb using a mirror reflection, patients reported the sensation that they could move and relax the often-cramped phantom limb and experienced pain relief.[9] Since this initial report, successful use of mirror therapy has been reported in patients with other pain syndromes, such as complex regional pain syndrome,[10,11] and in sensory re-education of severe hyperesthesia after hand injuries.[12]

Previous studies in stroke, although undersized and not sufficiently controlled, suggested that mirror therapy may be beneficial for motor function recovery in the paretic hand.[13-15] In a randomized crossover study of 9 chronic stroke patients, Altschuler et al[13] reported that range of motion (ROM), speed, and accuracy of arm movement were more improved after mirror therapy. Stevens and Stoykov[15] also reported that their 2 stroke patients trained with mirror therapy for 3 to 4 weeks and had an increase in Fugl-Meyer Assessment score, active ROM, movement speed, and hand dexterity after mirror therapy. Similarly, Sathian et al[14] found that 2 weeks of intense mirror therapy in a chronic stroke patient resulted in a strong recovery of grip strength and hand movement in the paretic arm. In a recent randomized controlled trial, Sütbeyaz et al[16] showed an improved lower-extremity motor recovery and motor functioning in subacute stroke patients after 4 weeks of mirror therapy.

We hypothesized that congruent visual feedback from the moving nonparetic hand, as provided by a mirror, would restore function of the affected hand. Our aim was to investigate whether mirror therapy is more effective than sham therapy at short-term (at 4wk) and long-term (at 6mo) intervals on motor recovery, spasticity, and hand-related functioning of patients with subacute stroke.

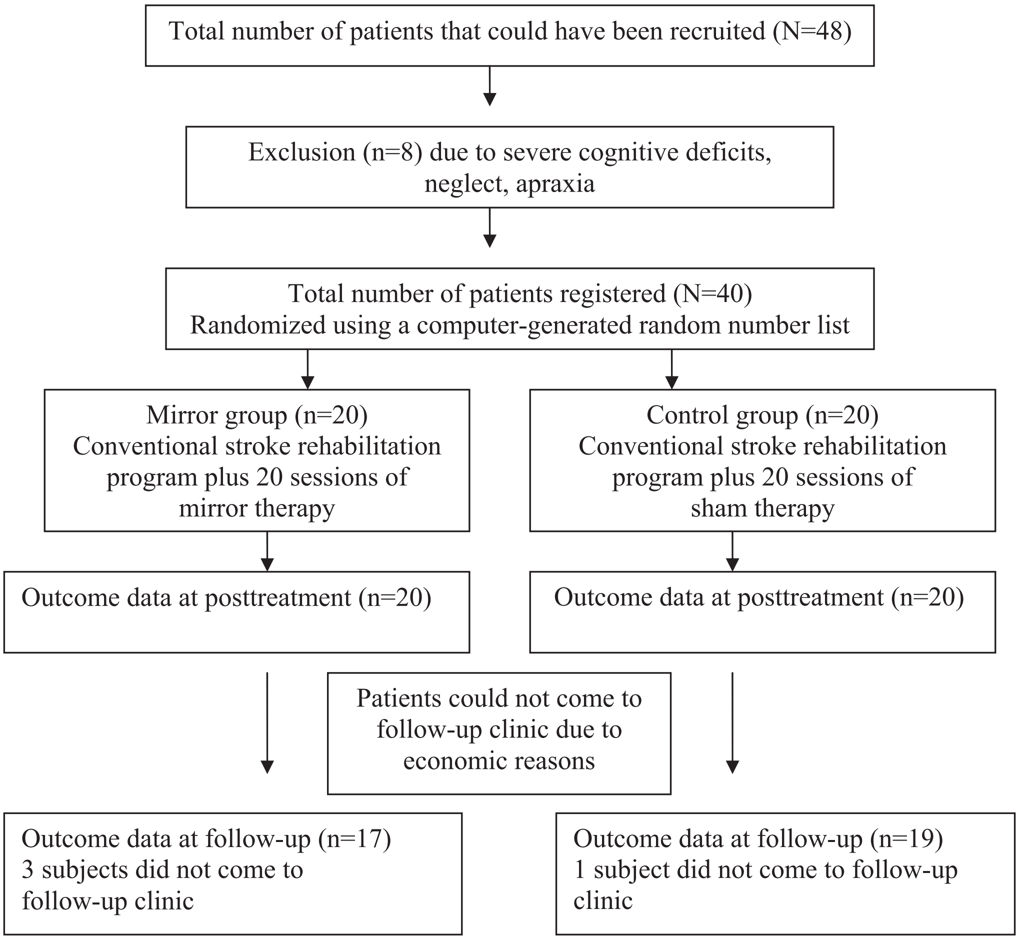


**Fig 1. Flow diagram for randomized subject assignment in this study.**

## METHODS

### Participants

Patients recruited in this study were referred from all over Turkey for inpatient rehabilitation. Generally, in Turkey, an estimated 50% of the stroke population is referred to a rehabilitation center if they cannot return home directly after discharge from the hospital. Two physiatrists (SS, NS) assessed potential participants to determine eligibility and to collect written informed consent. The trial included 40 inpatients with hemiparesis after stroke (mean age, 63.2y; mean time since stroke, 5.5mo) from February 2006 to April 2006, all of whom met the study criteria. Stroke was defined as an acute event of cerebrovascular origin causing focal or global neurologic dysfunction lasting more than 24 hours,[17] as diagnosed by a neurologist and confirmed by computed tomography or magnetic resonance imaging. Patients were included in the study if they (1) had a first episode of unilateral stroke with hemiparesis during the previous 12 months, (2) had a Brunnstrom score between stages I and IV for the upper extremity, (3) were able to understand and follow simple verbal instructions, and (4) had no severe cognitive disorders that would have interfered with the study's purpose (Mini-Mental State Examination score >24).[18] The protocol was approved by the Ankara University Ethics Committee.

### Sample Size

The required sample size was determined by using the pooled estimate of within-group standard deviations obtained from pilot data. Power calculations indicated that detecting a 20% difference in improvement in FIM self-care score between groups (with $\beta$=.20 and $\alpha$=.05) would require a sample of 15 subjects for each group.

### Study Design

We used a randomized controlled design in which the assessor was blinded to the group allocation of each subject. All assessments were performed by the same investigator (SS), who was blinded to the treatment assignment. Blinding of the patients or physical therapist was not possible because of the nature of the treatment. After signing informed consent and baseline measurements, patients were randomly assigned to either the mirror group (n=20) or the control group (n=20) using a computer-generated random number (fig 1). Blocks were numbered, and then a random-number generator program was used to select numbers that established the sequence in which blocks were allocated to one or the other group. A medical doctor who was blinded to the research protocol and was not otherwise involved in the trial operated the random-number program.

### Intervention

Both the mirror group and control group participated in a conventional stroke rehabilitation program, 5 days a week, 2 to 5 hours a day, for 4 weeks. The conventional program is patient-specific and consists of neurodevelopmental facilitation techniques, physiotherapy, occupational therapy, and speech therapy (if needed). For the same period, the mirror group

Fig 2. Mirror therapy.

received an additional 30 minutes of mirror therapy program. During the mirror practices, patients were seated close to a table on which a mirror (35×35cm) was placed vertically (fig 2). The involved hand was placed behind the mirror and the noninvolved hand in front of the mirror. The practice consisted of nonparetic-side wrist and finger flexion and extension movements while patients looked into the mirror, watching the image of their noninvolved hand, thus seeing the reflection of the hand movement projected over the involved hand. Patients could see only the noninvolved hand in the mirror; otherwise, the noninvolved hand was hidden from sight. During the session patients were asked to try to do the same movements with the paretic hand while they were moving the nonparetic hand. The control group performed the same exercises for the same duration but used the nonreflecting side of the mirror in such a way that the paretic hand was hidden from sight (fig 3). The same therapist delivered the mirror or sham treatment to the patients.

### Outcome Measures

Outcome was measured in terms of motor recovery (Brunnstrom stages), spasticity (Modified Ashworth Scale [MAS]), and the self-care items of the FIM instrument. Outcome measures were performed at 0 months (pretreatment), 4 weeks (posttreatment), and 6 months (follow-up). Pretreatment and posttreatment assessments were performed while patients were in the rehabilitation ward, whereas follow-up assessments were performed in the outpatient clinic. We called every participant by phone after discharge and invited them to our outpatient clinic to minimize loss to follow-up.

### Motor Recovery

Brunnstrom defined 6 sequential stages of motor recovery and described how the hemiplegic arm and hand progress through these stages as a method for assessing recovery.[19] The 6 stages of Brunnstrom for the hand are (1) flaccidity; (2) little or no active finger flexion; (3) mass grasp, use of hook grasp but no release, no voluntary finger extension, and possibly reflex extension of digits; (4) lateral prehension, release by thumb movement, semivoluntary finger extension, with small range; (5) palmar prehension, possibly cylindric and spheric grasp, awkwardly performed and with limited functional use, voluntary mass extension of digits, with variable range; and (6) all prehensile types under control, skills improving, full-range voluntary extension of digits, individual finger movements present but less accurate than on the opposite side. Despite some reports about its low responsiveness to change, we preferred the Brunnstrom staging system because it reflects underlying motor control based on clinical assessment of movement quality. Higher Brunnstrom scores indicate better motor recovery.

### Spasticity

The MAS was used to grade the spasticity of the wrist flexor muscles. The MAS is a 5-point ordinal rating scale with good interrater reliability designed to measure muscle tone.[20] MAS scores range from 0 to 4: a MAS score of 0 represents "no increase in muscle tone," and a score of 4 is "limb rigid in flexion or extension."

### Hand-Related Motor Functioning

The FIM is the functional status component of the Uniform Data System for Medical Rehabilitation. It contains 18 items that measure independent performance in self-care, sphincter control, transfers, locomotion, communication, and social cognition. The FIM scores range from 1 to 7: a score of 7 represents "complete independence," and a score of 1 is "complete dependence" (performs less than 25% of task).[21,22] The FIM self-care subscale[23] was used in the present study; the total score ranges from 6 (lowest) to 42 (highest). The reliability and validity of the Turkish version of the FIM has been documented.[24]

### Statistical Analysis

We analyzed data using SPSS[a] for Windows. All statistical analysis was performed on the final 36 patients, and there were no missing data. Groups were compared at baseline using the *t* test for independent samples for the continuous variables and the chi-square test or Fisher exact test for categoric data. To investigate whether the mirror group changed by more than the control group at posttreatment and at follow-up, we calculated change scores for each group and compared them by using an independent samples *t* test. To test the study hypothesis, we also used analyses of variance (ANOVAs) with repeated measures with a between-subject factor at 2 levels (2 groups) and a within-subject factor at 3 levels (time: baseline, posttreatment, follow-up). The interaction of group and time served to

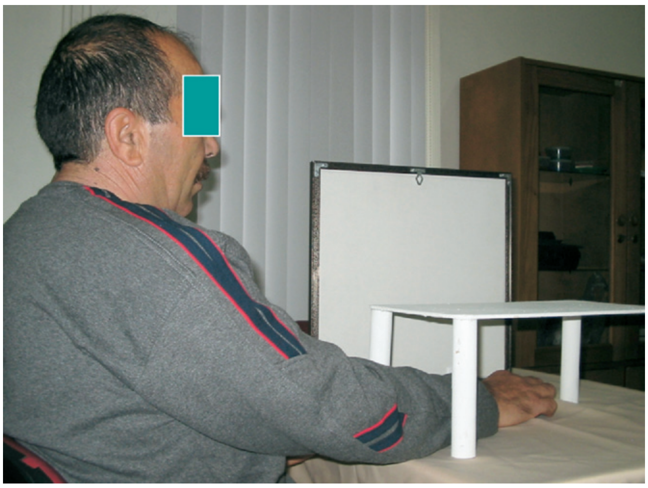

Fig 3. Sham therapy.

**Table 1: Demographic Characteristics of the Mirror and Control Groups and Baseline Measurements**

| Characteristic | Mirror Group | Control Group | P* |
|---|---|---|---|
| No. of patients | 17 | 19 | |
| Age (y) | 63.2±9.2 (49–80) | 63.3±9.5 (43–79) | .991† |
| Time since stroke (mo) | 5.4±2.9 (3–12) | 5.5±2.5 (3–12) | .928† |
| Female/male | 8/9 | 9/10 | .624‡ |
| Paretic side (right/left) | 7/10 | 8/11 | .611† |
| Dominant (right/left) | 17/0 | 19/0 | .799† |
| Lesion type (ischemic/hemorrhagic) | 14/3 | 15/4 | .566† |
| Brunnstrom stage (hand) | 2.59±0.90 (1–4) | 2.63±0.90 (1–4) | .785§ |
| Brunnstrom stage (UE) | 2.71±0.90 (1–4) | 2.74±0.80 (1–4) | .793§ |
| MAS score | 1.4±0.5 (1–2) | 1.7±0.6 (1–3) | .314§ |
| FIM self-care score | 23.7±7.0 (11–36) | 21.1±5.0 (11–31) | .207† |

NOTE. Values are n or mean ± standard deviation (SD). Ranges in parentheses are provided for continuous variables.
Abbreviation: UE, upper extremity.
*P value of difference at baseline.
†Student t test.
‡Fisher exact test.
§Chi-square test.

determine the efficacy of the mirror therapy on the outcome measures. Significance was set at .05.

## RESULTS

Initial and final evaluations were made 1 to 3 days before and 1 to 3 days after the treatment period. None of the patients missed more than 1 scheduled session during the study, and all of them finished the treatment period. However, 3 patients from the mirror group and 1 patient from the control group could not come to the follow-up clinic for final evaluation because of economic reasons. We did not observe any adverse events.

Demographic and clinical characteristics of the 2 groups are presented in table 1. Baseline comparisons showed that age, sex, injury characteristics, time since stroke, Brunnstrom stages, MAS of wrist flexor muscles, and FIM self-care scores did not differ between the groups ($P>.05$).

Table 2 presents the between-group comparisons of the change score for motor recovery, spasticity, and hand-related functioning both from baseline to posttreatment and posttreatment to follow-up. Between-group differences were significant for motor recovery and functioning scores not only at posttreatment but at the 6-month follow-up as well. Table 3 presents the motor recovery, spasticity, and hand-related functioning scores of patients at baseline, posttreatment, and follow-up. The mean change scores and 95% confidence intervals (CIs) of the Brunnstrom stages for the hand (mean change, 1.5; 95% CI, 1.1–1.9 vs mean change, 0.4; 95% CI, 0.1–0.8; $P=.001$) and upper extremity (mean change, 1.6; 95% CI, 1.3–1.9 vs mean change, 0.3; 95% CI, 0.1–0.6; $P=.001$) and the FIM self-care score (mean change, 8.3; 95% CI, 6.5–10.1 vs mean change, 1.8; 95% CI, 0.3–3.2; $P=.001$) showed significantly more improvement at follow-up in the mirror group compared with the control group. No significant differences were found between the groups for the MAS (mean change, 0.3; 95% CI, 0.0–0.6 vs mean change, 0.3; 95% CI, 0.1–0.6; $P=.904$).

## DISCUSSION

This study shows that mirror therapy in addition to a conventional rehabilitation program was more beneficial in terms of motor recovery and hand-related functioning than a similar treatment without mirroring. The beneficial effect on hand functioning started at posttreatment and continued during the 6-month follow-up evaluation. However, we found no effect on spasticity.

Several underlying mechanisms for the effect of mirror therapy on motor recovery after stroke have been proposed. For example, Altschuler et al[13] suggested that the mirror illusion of a normal movement of the affected hand may substitute for decreased proprioceptive information, thereby helping to recruit the premotor cortex and assisting rehabilitation through an intimate connection between visual input and premotor areas. Stevens and Stoykov[15] suggested that mirror therapy related to motor imagery and that the mirror creates visual feedback of successful performance of the imagined action with the impaired limb. Motor imagery itself, the mental performance of a movement without overt execution of this movement, has proven to be potentially beneficial in the rehabilitation of hemiparesis.[25]

The effect of mirror visual illusions on brain activity has been investigated in a number of studies. Garry et al[26] performed transcranial magnetic stimulation during mirror illusions in healthy subjects and showed increased excitability of

**Table 2: Between-Group Differences in Change Scores for Motor Recovery, Spasticity, and Hand-Related Functioning**

| Parameter | Baseline to Posttreatment | | | Posttreatment to Follow-Up | | |
|---|---|---|---|---|---|---|
| | Mirror Group | Control Group | Mean Difference (P)* | Mirror Group | Control Group | Mean Difference (P)* |
| Brunnstrom stage (hand) | 0.94±0.60 | 0.11±0.30 | 0.83 (.001) | 0.53±0.51 | 0.39±0.5 | 0.16 (.048) |
| Brunnstrom stage (UE) | 1.00±0.50 | 0.11±0.30 | 0.89 (.001) | 0.59±0.50 | 0.16±0.3 | 0.43 (.006) |
| MAS score | 0.12±0.40 | 0.11±0.30 | 0.01 (.925) | 0.18±0.39 | 0.21±0.4 | 0.03 (.876) |
| FIM self-care score | 5.20±3.90 | 1.10±2.60 | 4.10 (.001) | 3.00±2.5 | 0.68±1.3 | 2.34 (.001) |

NOTE. Values are mean ± SD.
*Independent samples t test.

Table 3: Motor Recovery, Spasticity, and Hand-Related Functioning Scores of Patients at Baseline, Posttreatment, and Follow-Up (n=36)

| Parameter | Group | Baseline | Posttreatment | Follow-Up | Δ (95% CI) | P* |
|---|---|---|---|---|---|---|
| Brunnstrom stage (hand) | | | | | | .001 |
| | Mirror | 2.6±0.8 | 3.5±1.3 | 4.0±1.4 | 1.5 (1.1–1.9) | |
| | Control | 2.6±0.8 | 2.7±1.0 | 3.1±1.2 | 0.4 (0.1–0.8) | |
| Brunnstrom stage (UE) | | | | | | .001 |
| | Mirror | 2.7±0.9 | 3.7±1.2 | 4.2±1.3 | 1.6 (1.3–1.9) | |
| | Control | 2.7±0.8 | 2.8±0.9 | 3.0±1.1 | 0.3 (0.1–0.6) | |
| MAS score | | | | | | .904 |
| | Mirror | 1.4±0.5 | 1.3±0.5 | 1.1±0.3 | 0.3 (0.0–0.6) | |
| | Control | 1.7±0.6 | 1.6±0.6 | 1.4±0.5 | 0.3 (0.1–0.6) | |
| FIM self-care score | | | | | | .001 |
| | Mirror | 23.7±7.0 | 28.9±10.0 | 32.0±9.5 | 8.3 (6.5–10.1) | |
| | Control | 21.1±5.0 | 22.2±6.3 | 22.9±6.3 | 1.8 (0.3–3.2) | |

NOTE. Values are mean ± SD.
Abbreviations: CI, confidence interval; Δ, mean change at follow-up from baseline.
*ANOVA for repeated measures.

primary motor cortex (M1) of the hand behind the mirror. Mirror neurons are bimodal visuomotor neurons that are active during action observation, mental stimulation (imagery), and action execution. For example, it has been shown that passive observation of an action facilitates M1 excitability of the muscles used in that specific action.[27] Mirror neurons are now generally understood to be the system underlying the learning of new skills by visual inspection of the skill. In 3 patients with brachial plexus avulsion, Giraux and Sirigu[28] used a virtual reality system displaying prerecorded movements of a hand to create the illusion of normal hand movement. During an 8-week training program, patients were asked to try to match the movement of the unseen involved hand with the displayed hand movements. After the training period an increased activity in M1 corresponding with the affected limb was found using functional magnetic resonance imaging.

In addition to previously reported "observation with intent to initiate"[29] or "stimulation through simulation"[30] mechanisms based on increased visual or mental imagery feedback, another possible mechanism for the effectiveness of the mirror therapy might be bilateral arm training. In this study we asked patients to move the paretic hand as much as they could while moving the nonparetic hand and watching the image in the mirror in a bilateral training approach. Summers et al[6] investigated the effectiveness of bilateral arm training and reported that compared with unilateral training, bilateral training intervention was more effective in facilitating upper-limb motor function in chronic stroke patients. In a recent review, Carson[31] explored the potential for bilateral interactions to occur in various brain regions, giving rise to functional improvements in the control of the paretic limb when movements are performed in a bimanual context. He suggested that when the nonparetic limb engaged during motor training, crossed facilitatory drive from the intact hemisphere will give rise to increased excitability in the homologous motor pathways of the paretic limb, facilitating recovery of function.

### Study Limitations

A potential limitation of this study is the generalizability of the results. According to our inclusion criteria, our findings and conclusions are based on the population of subacute stroke inpatients (all within 12 months poststroke) who survived from first stroke without severe cognitive deficits but with severe motor impairment of the hand and upper extremity. Because of our exclusion criteria none of our patients had apraxia or neglect. Future studies may investigate the effectiveness of mirror therapy on stroke patients with apraxia or neglect.

Because few studies have investigated mirror therapy for patients with stroke, there is no agreement on aspects such as optimal patient selection or duration and intensity of training of this new therapeutic approach. Incorporating mirror therapy into the conventional program at the early stages of treatment and applying it for a long period might be even more beneficial to improving hand function. Future studies may investigate the effectiveness of mirror therapy as a home treatment or perform functional brain imaging studies on the underlying mechanism of motor recovery after mirror therapy in patients with stroke.

## CONCLUSIONS

In our group of subacute stroke patients, hand function improved more after mirror therapy in addition to a conventional rehabilitation program compared with a control treatment directly after 4 weeks of treatment and at the 6-month follow-up, whereas mirror therapy does not affect spasticity.

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## Supplier

a. Version 11.5; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.