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Original Article

The addition of mirror therapy improved upper limb motor recovery and level of independence after stroke: a randomized controlled trial

A terapia do espelho melhora a recuperação motora do membro superior e o nível de independência após AVC: um ensaio clínico randomizado

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Abstract

Introduction: In stroke survivors, the prevalence of upper motor disability remains high. There has not been much report on the success of post-stroke mirror therapy, especially in developing countries. **Objective:** The focus of this research is to see how mirror therapy, in addition to standard rehabilitation for hand paresis, affects upper limb motor recovery and level of independence in self-care after stroke at an Indonesian teaching hospital. **Method:** This was a randomized controlled trial with no assessor blinding. The study included 18 subacute stroke patients who did not have cognitive or visual impairment. The mirror group received a 20-minute mirror therapy session in addition to conventional rehabilitation, while the control group received only the standard program for 5 weeks (2 times per week). The Brunnstrom score and self-care level of independence elements of the Functional Independence Measure (FIM) were used as outcome measures. **Results:** Baseline comparisons of lesion type and Brunnstrom score showed significant between-group differences. The ANACOVA test showed the difference had no effect on the FIM change in scores ($P > 0.05$). One patient (mirror group) was dropped out from the study. After 5 weeks (n=17), the mirror group showed improvement in both the Brunnstrom and FIM scores ($P < 0.05$) compared to the control group. **Conclusions:** Mirror treatment improves upper limb motor recovery and level of independence in self-care after stroke when combined with standard hand paresis rehabilitation 2 times a week for 5 weeks.

Keywords: Outcome Assessment, Health Care, Motor Activity, Quality-Adjusted Life Year, Rehabilitation, Stroke, Therapeutics.

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Resumo

Introdução: Em sobreviventes de AVC, a prevalência de deficiência motora nos membros superiores permanece alta. Não há muitos relatos sobre o sucesso da terapia do espelho pós-AVC, especialmente em países em desenvolvimento. **Objetivo:** O foco desta pesquisa é ver como a terapia do espelho, além da reabilitação padrão para paresia da mão, afeta a recuperação motora do membro superior e o nível de independência no autocuidado após o AVC em um hospital universitário da Indonésia. **Método:** Ensaio clínico randomizado sem cegamento do avaliador. O estudo incluiu 18 pacientes com AVC subagudo que não tinham deficiência cognitiva ou visual. O grupo de espelho recebeu uma sessão de terapia de espelho de 20 minutos além da reabilitação convencional, enquanto o grupo de controle recebeu apenas o programa padrão por 5 semanas (2 vezes por semana). O escore de Brunnstrom e os elementos do nível de independência do autocuidado da Medida de Independência Funcional (MIF) foram usados como medidas de desfecho. **Resultados:** As comparações da linha de base do tipo de lesão e do escore de Brunnstrom mostraram diferenças significativas entre os grupos. O teste ANACOVA mostrou que a diferença não teve efeito na mudança da MIF nos escores (P> 0,05). Um paciente (grupo espelho) foi retirado do estudo. Após 5 semanas (n = 17), o grupo espelho mostrou melhora em ambos os escores de Brunnstrom e FIM (P <0,05) em comparação com o grupo de controle. **Conclusão:** O tratamento com espelho melhora a recuperação motora dos membros superiores e o nível de independência no autocuidado após o AVC quando combinado com a reabilitação de paresia de mão padrão 2 vezes por semana durante 5 semanas.

Palavras-chave: Avaliação de Resultados em Cuidados de Saúde, Atividade Motora, Ano de vida ajustado pela qualidade, Reabilitação, Acidente Vascular Cerebral, Terapêutica.

Introduction

Stroke is one of the diseases that can cause severe disability (Caro et al., 2018; Thieme et al., 2018). The prevalence of upper or lower limb motor impairment is still high in stroke survivors (Hayward et al., 2019; Pan et al., 2021). Where only 30-60% gain some dexterity after 6 months, paralysis of the arm frequently causes problems with activities of daily living (Hatem et al., 2016; Rössler et al., 2020; Thieme et al., 2018). According to preliminary research, data from stroke patients admitted to Dr. Soetomo General Hospital's rehabilitation outpatient clinic in 2009 revealed that 114 out of 240 patients had upper limb disability and received occupational therapy.

Standard rehabilitation of post-stroke hemiparesis focuses on motor and sensory re-education as well as task-specific and functional exercises of the affected limb with an electroencephalogram (EEG) examination that can be used to monitor the progress of stroke rehabilitation (Novitasari et al., 2020; Winstein et al., 2016). Mirror therapy focuses on moving and observing the non-paretic side in front of a mirror (Figure 1). As a result, the illusion of normal movement of the paretic hand in the mirror as well as motor imagery of moving the paretic hand is created. Feedback from the affected side prevents or decreases learned nonuse phenomena and also promotes neural plasticity (Gandhi et al., 2020; Thieme et al., 2018). Ramachandran and Roger-Ramachandran pioneered this therapy

method for the treatment of phantom limb pain (Ramachandran & Hirstein, 1998; Ramachandran & Rogers-Ramachandran, 1996; Stoykov & Corcos, 2009; Yavuzer et al., 2008). This first report served as the foundation for further studies of mirror therapy in patients with pain syndrome, peripheral nerve damage, and stroke (Corbetta et al., 2018; Meng et al., 2018; Singh & Pawar, 2019; Wittkopf & Johnson, 2017).

Previous studies of additional mirror therapy to standard rehabilitation after stroke suggest that mirror therapy can be used and has the advantage of improving recovery of motor function in the affected lower and upper limbs. (Luo et al., 2020; Stoykov & Corcos, 2009; Thieme et al., 2018; Yavuzer et al., 2008). Even so, so far there have been no reports stating the results of mirror therapy in developing countries, while in developing countries, such as Indonesia, several factors can limit adherence of patients and effectiveness of the rehabilitation program, especially in an outpatient clinic. These factors are socio-economic status, educational status, and the national insurance coverage system (Harms & Kobusingye, 2003; Rhoda et al., 2014). So, the objective of this study is to assess upper limb motor recovery and level of independence in stroke patients who received mirror therapy in addition to a standard rehabilitation program at an Indonesian teaching hospital.

Methods

Ethics

This study was conducted in compliance with the Helsinski's Declaration to experiment with humans. This study protocol was approved by The Ethical Committee of Dr. Soetomo General Academic Hospital Surabaya, Indonesia (245/ Panke. KKE/ XII/ 2010). As previously mentioned, participants will be informed about the study procedures and will agree to consent before participating. Each participant will be identified by a code when collecting demographic and clinical variables and outcomes.

Figure 1. The Mirror Therapy Process.

Design

This research was conducted at the rehabilitation outpatient clinic, Dr. Soetomo Surabaya, Indonesia. This was a randomized controlled trial with no assessor blinding[a]. Using the block randomization procedure, the patients were randomly allocated to either the mirror group (n = 9) or the control group (n = 9), after obtaining the baseline measurements. A consecutive sampling method was used until the required sample size was obtained. The flowchart of the study design is summarized in Figure 2.

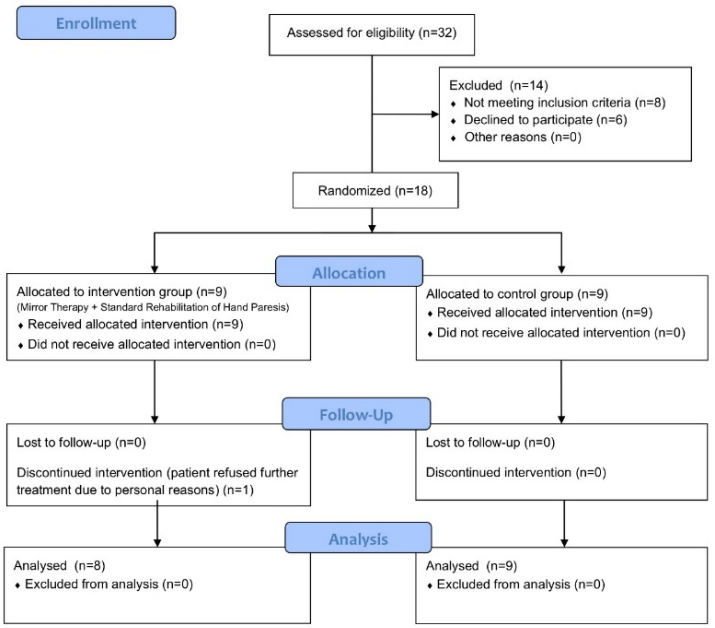

Figure 2. Flow diagram for randomized subject assignment in this study.

Participants

The participants in this study were stroke patients who visited the rehabilitation outpatient clinic at Dr. Soetomo General Academic Hospital in Surabaya, Indonesia. Patients were eligible if they had: (1) their first episode of hemiparesis due to stroke within 3 weeks-6 months, (2) visus 1/60, (3) Brunnstrom score for hand between stages 1 to 4 (inclusive), (4) good understanding and ability to follow simple verbal instructions, (5) no severe cognitive disorders (Mini-Mental State Examination score 24), (6) no limitation of wrist and finger range of motions before stroke, and (7) willingness to participate in the study after signing a written informed consent. Patients were excluded from this study if they had any of the following conditions: (1) uncontrolled hypertension, (2) cardiorespiration disturbance, (3) apraxia, or (4) severe hemispatial neglect. Subjects were dropped out of this study if they missed continuously 2 consecutive therapy sessions in a week.

[a]Clinical trial REBEC register in process number: 13140.

Sample size

The sample size was estimated using the pilot data's pooled estimate of within-group standard deviations (3.2). The power calculations revealed that 18 individuals were required to provide an 80 percent ($\beta = 0.20$) chance of identifying a 20 percent ($\alpha = 0.05$) difference between the groups.

Intervention

Control Group: For 5 weeks, both the mirror and control groups were assigned to a 20-minute standard stroke rehabilitation program, 2 days a week, 10 sessions. The frequency of treatment was prescribed at 2 days a week in accordance with standard guidelines of the post-stroke rehabilitation program in our Rehabilitation Outpatient Clinic, and with the consideration of general compliance or adherence of patients in our center. The standard program for hand paresis was designed according to patients' need. The patient performed occupational therapy consists of activity of daily living (ADL), sensorymotor stimulation, and range of motion exercise.

Mirror Group: giving the standard program as in the control group and added with 20 minutes of mirror therapy. The position of the subjects were sitting in front of a table, and a mirror was vertically placed on the table (Figure 1). The nonparetic hand was placed in front of the mirror, while the paretic hand was behind the mirror. The training consisted of several steps: (1) movements of nonparetic hand (mirror therapy protocols developed by the authors: wrist flexion, extension, pronation, supination, fingers and thumb extension, count the fingers, grasp, hook, roof, pinch) while patients maintained focus and looked into the mirror; (2) the image of their nonparetic hand then could be seen in the mirror as a reflection of the normal hand movement; (3) the paretic hand was hidden behind the mirror, so that subjects could not see it; (4) subjects were instructed to try to move the paretic hand exactly the same while moving the nonparetic hand.

The sessions were performed under the supervision of occupational therapist and physiatrist involved in the rehabilitation team.

Outcome measurements

Motor recovery for the hand and upper extremity (Brunnstrom stages) and functional independence in self-care were measured using the The Functional Independence Measure (FIM) instrument's self-care items (Ottenbacher et al., 1996). Outcome measurements were taken at the start of therapy (pretreatment) and after 5 weeks (10 sessions). There were 6 stages of motor recovery in the hemiplegic arm and hand defined by Brunnstrom. The higher Brunnstrom scores showed improvement of movement quality reflecting motor recovery (Latham, 2008; Yavuzer et al., 2008).

The FIM is a popular tool for evaluating independent performance in self-care, sphincter control, transfers, locomotion, communication, and social cognition. It is a functional status component in the Uniform Data System for Medical Rehabilitation. The FIM scores can range from 1 to 4 (reliability and validity have been demonstrated in the United States) or from 1 to 7. (Küçükdeveci et al., 2001; Ottenbacher et al., 1996; Wade, 1992; Caro et al., 2016). Because this study focused on upper limb motor

function measurement, the 4-range scores of the FIM self-care subscale were chosen. The total score ranges from 5 (lowest) to 20 (highest).

Statistical analysis

SPSS 11.5 with a significance level of $P < 0.05$ was used to analyze the data. For continuous variables, the t test was used for independent samples, and the chi-square test or Mann-Whitney test was used for categorical data. The change in scores for each group was calculated using the Mann-Whitney test for ordinal data (Brunnstrom score) and an independent samples t test for continuous variables (FIM self-care subscale). The ANACOVA test was used to control the effect of confounding variables.

Results

The study included 18 outpatients (Table 1) that met the inclusion criteria from September 2010 until April 2011. Stastitical analysis was performed on 17 patients after 10 sessions (5 weeks). One patient (from the mirror group) was dropped out of the study for personal reasons. Table 1 shows the baseline clinical characteristics of the two groups.

The groups did not differ in terms of age, Mini-Mental State Exam (MMSE) score, time since stroke, sex, paretic side, or FIM self-care scores ($P > 0.05$) (Table 1). Baseline comparisons of the type of lesion and Brunnstrom score showed significant between-group differences. The ANACOVA test showed that the type of lesion and Brunnstrom score had no effect on FIM self-score change ($P > 0.05$) (Table 2).

Table 1. Clinical Characteristics of the Mirror and Control Groups.

Characteristics	Both groups	Mirror group	Control group	*P**
No of patients	18	9	9	-
Age (year)	50.56 ± 7.571	52.67 ± 8.573	48.44 ± 6.187	0.248 †
MMSE score	25.17 ± 1.098	25.44 ± 1.014	24.89 ± 1.167	0.264 ‡
Time after stroke (weeks)	5 ± 2.058	4.22 ± 0.972	5.78 ± 2.587	0.184 ‡
Sex (female/male)	9/9	4/5	5/4	0.637 €
Paretic side (right/left)	8/10	4/5	4/5	1.000 €
Dominant (right/left)	18/0	9/0	9/0	-
Lesion type (infarction/bleeding)	11/7	8/1	3/6	0.046 €
Brunnstrom scores	Median: 1 (minimal: 1, maximal: 3)	Median: 2 (Minimal: 1, Maximal: 3) *Mean rank*: 7.44	Median: 2 (Minimal: 1, Maximal: 3) *Mean rank*: 11.56	0.048 ‡
FIM self-care	10 ± 2.870	10.33 ± 2.291	9.67 ± 3.464	0.637 †

Note: Values are n or mean ± standard deviation (SD), except for Brunnstrom scores. * *P* value of difference at baseline. † t test independent samples. € Chi-square test. ‡ Mann-Whitney test.

Table 2. The ANACOVA Test for Type of Lesion and Brunnstrom Score.

Confounding variables	Dependent variables	F	*P*
Lesion type	Change of FIM self-care scores	1.463	0.246
Brunnstrom scores	Change of FIM self-care scores	0.887	0.362

The mirror group showed significant upper limb motor recovery (changes in Brunnstrom stages) and level of independence (changes in FIM self-care) improvement after 10 sessions compared to the control group ($P < 0.05$) (Table 3).

Table 3. Differences in Change Scores for Upper Limb Motor Recovery and Level of Independence Between Groups.

Parameter	Baseline to after 10 sessions		
	Mirror group	Control group	*P**
No of patients	8	9	-
Change of Brunnstrom scores	2.13 ± 0.835	1.22 ± 0.833	0.039 ‡
Change of FIM self-care scores	7.75 ± 2.121	4.89 ± 1.764	0.008 †

Note: Values are n or mean ± standard deviation (S.D.). * *P* value of difference at baseline. † t test independent samples. ‡ Mann-Whitney test.

Discussion

The mirror therapy and standard protocol used in this study were designed to meet the ACSM/AHA (American College of Sports Medicine/American Heart Association) standard guidance for neuromuscular exercises for stroke and brain injury and in accordance with conditions in developing countries such as socio-economic and educational status, national insurance coverage system, and subjects' compliance (Billinger et al., 2014; Winstein et al., 2016). The findings of this study revealed that mirror therapy enhanced upper limb motor recovery and level of independence in self-care after 10 sessions (5 weeks) of treatment when compared to normal treatment ($P < 0.05$). The positive results are in accordance with other studies despite differences in study design. The Cochrane collaboration review of mirror therapy indicated that mirror therapy has been shown to be useful in improving motor function following a stroke (Thieme et al., 2018). Yavuzer et al. observed an increase in motor recovery and hand function after 20 sessions of mirror therapy (5 days/week) treatment till 6 months of follow-up. Despite a short sample size and the absence of a reference group, mirror treatment improved motor recovery in chronic stroke patients (Yavuzer et al., 2008). Stevens and Stoykov's before and after study in two chronic stroke patients revealed improvements in Fugl-Meyer score, range of motion, speed, and hand dexterity after 3 times per week of mirror therapy for 4 weeks (Stevens & Stoykov, 2003). Sathian et al. found that giving chronic stroke patients rigorous two-weeks of mirror treatment increased hand movement and grasp strength (Sathian et al., 2000). The recent study by Jung-Hee Kim and Byounghee Lee 2017 in south korea showed that the mirror therapy during 30-minutes, 5 times per week for 4 weeks showed significant improvement in grip strength, manual dexterity, and FIM levels compare to sham therapy (Hee Kim & Lee, 2017).

The underlying mechanism of how mirror therapy can be used in motor recovery is mainly based on facilitating sensory (visual) feedback of the seemingly healthy extremity to the brain, provided by looking at the unaffected side through the mirror (mirror illusion), thus the learned-nonuse phenomenon is not triggered (Altschuler et al., 1999; Jee, 2020; O'Brien et al., 2021). Neuroplasticity is also said to be activated with this

mechanism. Standard rehabilitation protocol often fails to include bimanual functional activity as an important relearning program throughout the recovery phase (Barton & Wolf, 1993; Dimyan & Cohen, 2011; Kim, 2021). The second proposed mechanism is based on clinical, neurophysiology, and imaging studies that show motor imagery involves neural networks the same as motor execution, which is overlapped mainly in the parietal lobe, premotor cortex, cerebellum, and basal ganglia (Rossiter et al., 2014; Sütbeyaz et al., 2007; Yavuzer et al., 2008). The third one is based on increased signal and activation of contralateral (stronger) and ipsilateral sensorymotor cortex in healthy subjects performing strong grasp at one side of the body, measured by functional Magnetic Resonance Imaging (fMRI) (Hamzei et al., 2020; Stoykov & Corcos, 2009). How humans are able to learn new skills just by looking (visual image) is because of the activation of mirror neurons. These neurons are activated during imagery, observation, and execution (Bhasin et al., 2021; Lundborg & Rosén, 2007; Nogueira et al., 2021; Sütbeyaz et al., 2007; Yavuzer et al., 2008).

Many factors, including biological and environmental ones, influence functional recovery after a stroke. One of the environmental factors is therapy given to post-stroke patients, while biological factors are those that come from the patient himself, such as age, time after stroke, type of stroke, and so on (Kusuma et al., 2021). Initial disability measured by Functional Independence Measure (FIM) or Barthel Index are said to be the strong predictor of outcome disability and motor recovery other than age, time after stroke, type of stroke, location, and cognitive function (Hendricks et al., 2002; Hsueh et al., 2002; Koyama et al., 2005). In this study, the initial disability measured by Brunnstrom scores for the hand is worse in the mirror group than in the control group. ANACOVA test was performed to control this confounding variable, and the result showed that initial Brunnstrom scores had no significant effect on level of independence (self-care). Time after stroke in this study was still in the golden period of the relearning process of recovery. Neuroplasticity and spontaneous recovery after stroke, are said to occur in between 6 months and 1 year after stroke (Coleman et al., 2017; Dimyan & Cohen, 2011; Su & Xu, 2020) This factor could have an effect on this study's positive results.

Studies of whether the type of stroke, infarction and hemorrhagic, have different functional prognosis outcomes are still debatable. In this study, baseline comparisons of the type of lesion showed a significant difference. The ANACOVA test showed that the type of lesion had no significant effect on level of independence (self-care). This finding is consistent with the findings of Jorgensen et al., who discovered that the type of lesion had no effect on recovery time or neurologic deficit (Etherton et al., 2018; Grefkes & Fink, 2020; Jørgensen et al., 1999; Sullivan et al., 2009). There was no difference in functional independence between infarction and hemorrhagic stroke 1 year after onset (Paolucci et al., 2003; Perna & Temple, 2015).

This is one of the few studies in Indonesia that examines the effect of additional mirror therapy on stroke patients. This study evaluated the treatment effect of mirror therapy in motor recovery and hand function after stroke earlier (after 10 sessions or 5 weeks, 2 times per week) than other studies. Many other studies in mirror therapy after stroke reported positive results with the frequency of a daily (5 days/week) rehabilitation program and with longer follow-up measurements. This was not feasible in our Rehabilitation Outpatient Clinic. The general compliance of patients with our program

was 2 times/week, and the reasons were socioeconomic status (patients can't afford to come often to the hospital), lack of caregivers, and demographic condition (patients live far from the rehabilitation center). Further study is needed to analyze whether additional mirror therapy can be discontinued after 10 sessions of additional mirror therapy.

This study's limitations are: (1) not a population-based study; (2) reduced power of study due to drop-out of 1 sample after 5 sessions; (3) intervention cannot be blinded due to exercise-based treatment; (4) non-blinded assessor (5) using outpatient subjects, therefore can not control subject bias.

Conclusion

This study confirmed that the addition of 10 sessions (2 days a week for 5 weeks) of mirror therapy to the standard rehabilitation program in subacute stroke patients improved upper limb motor recovery and level of independence in self-care. Thus, mirror therapy can be used in addition to standard rehabilitation protocols for subacute stroke. The frequency of therapy is also less than other studies so that it can be applied in developing countries such as Indonesia, which have special problems.

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Author's Contributions

Lydia Arfianti, Fatchur Rochman and Imam Subadi formulated the research plan and methodology. Data collection, data analysis, and interpretation was performed by Lydia Arfianti under supervision of Fatchur Rochman and Imam Subadi. Hanik Badriyah Hidayati contributed to confirmation of findings and analysis. Lydia Arfianti wrote the first draft of the article. Critical revisions were performed by Lydia Arfianti and Hanik Badriyah Hidayati. All authors approved the final version of the text.

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