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The Effect of Mirror Therapy to Improve Upper Extremity Function in Stroke Patients: A Meta-analysis

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Abstract

This meta-analysis systematically reviewed studies on mirror therapy focused on arm and hand function in stroke patients, aiming to comprehensively assess the efficacy of mirror therapy interventions and furnish empirical support for its potential application and future development in the context of stroke rehabilitation. A rigorous search for articles published in international journals up to the year 2022 was conducted. Various assessment tools were employed to calculate effect sizes, evaluating the impact of mirror therapy on arm and hand function in stroke patients. Utilizing a random-effects model, mean effect sizes were determined, yielding a total effect size of 0.545. The effect sizes for the Brunnstrom Recovery Stage (BRS), Box and Block Test (BBT), Modified Barthel Index (MBI), Fugl-Meyer Assessment (FMA), and grip strength test were 0.957, 0.596, 0.490, 0.488, and 0.417, respectively. In summary, we suggest that mirror therapy engenders positive changes in functional recovery among stroke patients, establishing a foundation for its tailored clinical application based on individual subject characteristics.

Keywords: *Mirror therapy, Upper extremity function, Stroke, Meta-analysis*

1. INTRODUCTION

Stroke, a neurological disorder resulting from abnormalities in cerebral blood flow, afflicts 55% to 75% of post-stroke patients, leading to motor impairment and challenges in utilizing the paretic side of the hand in daily activities [1, 2]. Several evidence-based interventions, such as constraint-induced movement therapy, shaping exercises, robotic-assisted rehabilitation, and functional electrical stimulation, are currently available to enhance arm and hand motor recovery [3-5]. Within the framework of motor learning theory, the mirror neuron system plays a crucial role as a foundational element of motor control theory, facilitating cognitive-motor tasks encompassing observation, comprehension, recall, imagination, and imitation of movement [6]. Mirror neurons, found in brain regions, activate equally when observing a specific movement and when executing a similar movement [7]. Mirror therapy, a treatment leveraging the mirror neuron system, has been

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applied to hemiparetic patients through functional brain imaging. In this technique, the paralyzed extremity is positioned behind a mirror and moved while observing the reflected non-paralyzed extremity, inducing a visual illusion and stimulating the primary motor area on the paralyzed side [8-10]. Despite a steady examination of the effects of mirror therapy, there remains a dearth of systematic and comprehensive studies evaluating the overall impact of mirror therapy. Consequently, this study employs a meta-analysis to systematically synthesize mirror therapy research on arm and hand function in post-stroke patients. The objective is to assess the efficacy of these interventions and provide empirical support for the future application and development of mirror therapy in the post-stroke population.

2. METHODS

2.1 Literature Review

This investigation conducted an extensive search for articles published in international journals up to the year 2022. Databases such as PubMed, Cochrane Library, Research Information Sharing Service, Database Periodical Information Academic, and Science Direct were systematically queried for relevant articles using search terms like 'stroke,' 'mirror therapy,' 'motor function,' 'motor recovery,' 'motor performance,' 'motor skill,' 'motor control,' 'upper extremity,' and 'arm and hand.' The selection criteria for articles in this meta-analysis included: studies with mirror therapy as the independent variable and arm and hand motor function or activities of daily living as the dependent variable; experimental design with a comparison group and a validated mean difference between groups; and studies incorporating the FMA as a measurement variable. A total of 740 studies were identified, with fourteen papers meeting the criteria of 'patient: stroke,' 'intervention: mirror therapy,' 'comparison: traditional movement therapy,' 'outcomes: BBT, BRS, FMA, grip strength, and MBI,' and 'timing: 2-8 weeks.' Of these, eight studies utilizing task-oriented training were further selected. The meta-analysis interpreted study results in terms of effect sizes, with criteria set at 0.20 or less indicating a small effect size, 0.20-0.80 indicating a medium effect size, and 0.80 or greater indicating a large effect size [11].

2.2 Measurement Variables

BBT is a standardized assessment tool used to evaluate hand and arm dexterity for various everyday tasks. It consists of a 2.54 cm long cube of wood and a rectangular box with a central divider. The test-retest reliability of the BBT is r=0.98 for the right hand and r=0.94 for the left hand [12]. BRS is a qualitative assessment of the recovery process of movement control in post-stroke hemiplegic patients, and it categorizes the motor recovery process of the upper extremity, hand, and lower extremity into six stages [13]. A higher score indicates a higher degree of recovery. The reliability of the BRS is r=0.90 [14]. FMA is a tool for assessing physical recovery after a stroke. The inter-rater reliability is 0.96, which is the average of three measurements with the most commonly used tool for hand assessment [15]. Grip strength is measured with the subject in an upright sitting position, shoulders drawn inward, elbow joint flexed to 90 degrees, lower arm in neutral position, and wrist flexed an average of 25 degrees. The inter-rater reliability is 0.96, which is the average of three measurements with the most commonly used tool for hand assessment [16]. Shah et al (1989) modified and supplemented it to create MBI, which is now widely used because its validity and reliability were proved [17, 18]. It consists of 10 specific activities of daily living, divided into 7 self-care index items and 3 mobility index items, and each behavior is scored on a 5-point scale out of 100. It is known to have a test-retest reliability of r=0.89 and an inter-rater reliability of r=0.95 [19].

3. RESULTS

Figure 1 shows the result and a plot that the overall effect size value amounted to 0.545, encompassing a 95% confidence interval of 0.359 to 0.731. This holds statistical significance as the confidence interval excludes zero, and the effect size closely approaches 0.5, signifying the moderate effectiveness of mirror therapy.

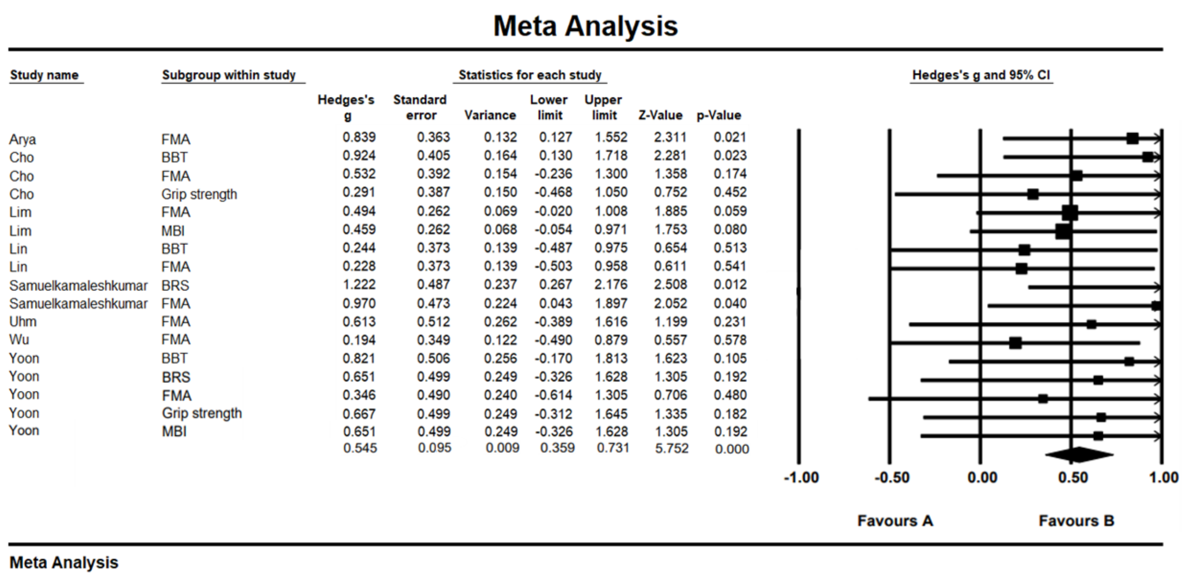

Figure 1. Forest plot of a meta-analysis of the mirror therapy

Table 1 shows the effect size by measurement variables that the BRS demonstrated a substantial effect size (ES=0.957, 95% CI: 0.303 to 1.612), while the BBT (ES=0.596, 95% CI: 0.140 to 1.053), MBI (ES=0. 490, 95% CI: 0.046 to 0.935), FMA (ES=0.488, 95% CI: 0.235 to 0.742), and grip strength test (ES=0.417, 95% CI: -0.159 to 0.994) exhibited moderate effect sizes. Notably, the BRS was the sole measure with a large effect size exceeding 0.8, while the BBT, MBI, and FMA demonstrated moderate effect sizes. The grip strength test did not yield a statistically significant difference. A visual representation of the effect sizes and their 95% confidence intervals for the eight individual studies was presented in a forest plot for a comprehensive overview.

Table 1. Effect size by measurement variables

Outcome	K	ES (g)	SE	95% CI	*p*
BBT	3	0.596	0.233	0.140 ~ 1.053	p<0.010
BRS	2	0.957	0.334	0.303 ~ 1.612	p<0.004
FMA	8	0.488	0.129	0.235 ~ 0.742	p<0.000
Grip Strength	2	0.417	0.294	-0.159 ~ 0.994	p<0.156
MBI	2	0.490	0.227	0.046 ~ 0.935	p<0.030

In this investigation, an analysis of publication bias was conducted for all studies to assess the robustness of the findings. The funnel plot illustrates Hedges' g (effect size) on the x-axis and the standard error on the y-axis. The presence of bias in the data would manifest as asymmetry, indicating potential inaccuracies. However, Figure 2 shows a relatively symmetrical distribution of effect sizes across individual studies, suggesting no publication bias.

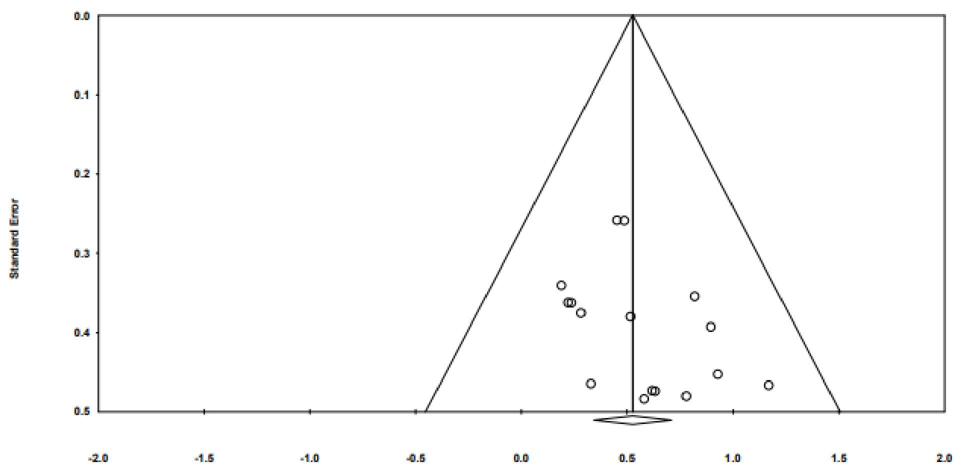

Figure 2. Funnel plot of standard error by Hedges' g

4. DISCUSSION

The overall effect size of mirror therapy on arm and hand function in post-stroke patients was deemed moderate. Notably, the sub-components of the assessment revealed a substantial effect size for BRS, BBT, MBI, FMA, and grip strength, all indicating a moderate effect size.

The noteworthy increase in BRS levels following mirror therapy demonstrated a large effect size, underscoring the significant impact of mirror therapy on upper limb function recovery. BRS, a valid tool for evaluating spasticity and synergy in hemiplegic patients, has been associated with the reduction of spasticity and control of limb synergy in previous research. In a study by [20], BRS was reported to be significantly correlated with the Modified Ashworth Scale (r=-0.81) and Ratio of the Developmental Slope of the H-reflex (HSLP) to measure muscle stiffness (r=-0.54). By modulating the excitability of primary motor interneurons through motor and perceptual activities, mirror therapy facilitates the normalization of cerebral hemispheric balance, a crucial factor in post-stroke motor recovery [10]. Post-stroke brain injury inhibits conduction through the cerebral volume, resulting in reduced activity in the paretic primary motor area and over-excitement in the non-paretic primary motor area [20, 21]. Mirror therapy, by reflecting actual ipsilateral arm and hand movements in the mirror, activates the contralateral primary motor area, promoting cerebral sheath reorganization conducive to functional recovery [10, 22, 23]. This simultaneous change in primary interneuron excitability promotes cerebral reorganization suitable for functional recovery [21]. Notably, mirror therapy with simultaneous movement of both extremities proves more effective, as it hinders interaction between cerebral hemispheres and excessive inhibitory conduction [24, 25].

However, a limitation of our study is the small number of journals analyzed, which needs to be addressed in future studies to amass more individualized researches on the effects of mirror therapy. Our evidence suggesting the heightened effectiveness of mirror therapy using digital therapeutic devices compared to traditional methods underscores the need for additional investigations in this area [26].

5. CONCLUSION

We conducted this study to confirm the usefulness of mirror therapy on the arm and hand function of post-stroke patients and provide data to plan interventions. We found that the collective impact of mirror therapy on arm and hand function among individuals recovering from stroke was categorized as moderate. The detailed examination of assessment sub-components demonstrated a notable effect size for BRS, BBT, MBI, FMA, and grip strength, all consistently pointing towards a moderate effect size. From previous studies, we can assume that mirror therapy, through the reflection of real ipsilateral arm and hand movements in a mirror, triggers activation in the contralateral primary motor area, fostering cerebral reorganization. We suggest that mirror therapy for post-stroke patients showed positive changes in functional recovery, which can be used as a basis for the clinical application of mirror therapy according to the characteristics of the subjects. Future studies will also need to validate the objective effectiveness of mirror therapy using digital equipment.

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