Research Paper

Immediate Effect of Mirror Therapy Using Pegboard Training on Hand Function and Muscle Activities in Individuals With Asymmetrical Hand Function

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Citation Yodchaisarn W, Suriyaamarit D, Udom C. Immediate Effect of Mirror Therapy Using Pegboard Training on Hand Function and Muscle Activities in Individuals With Asymmetrical Hand Function. Iranian Rehabilitation Journal. 2023; 21(2):263-272. http://dx.doi.org/10.32598/irj.21.2.1759.1

http://dx.doi.org/10.32598/irj.21.2.1759.1

Article info:
Received: 14 Apr 2022
Accepted: 06 May 2023
Available Online: 01 Jun 2023

Keywords:
Motor imagery, Electromyography, The 9-hole peg test (9HPT), Non-dominant hand, Asymmetrical hand function

ABSTRACT

Objectives: A proper function of hands is critical for doing daily activities and work, especially when using electronic devices. This study determined the effect of mirror therapy on individuals with asymmetrical hand function.

Methods: Forty-two men with asymmetrical hand function were recruited. All participants were randomly divided into sham control (n=21) and mirror therapy (n=21) groups. Both groups were tested before and after training using the 9-hole peg test (9HPT). The sham control group received pegboard training, and the mirror therapy group received mirror therapy using the pegboard. During training, hand muscle activities were recorded using surface electromyography. The obtained data were analyzed using the t-test and Mann-Whitney U test.

Results: Non-dominant hand function on the 9HPT showed significant improvement in the mirror therapy group compared with the sham control group (P=0.021). The asymmetric hand function was also improved in the mirror therapy group. Muscle activities of the non-dominant hand were not significantly different between groups.

Discussion: Mirror therapy using the pegboard had an immediate effect on improving non-dominant hand function. This finding has implications for possible preventive strategies against common hand problems and improving the efficient use of both hands.

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Highlights

• Individuals with asymmetrical hand function are at a greater risk of injury.

• Training with mirror therapy on a 9-hole pegboard is quick and effective, and effects are immediately seen after training.

• Mirror therapy can increase job efficacy in various settings and prevent injury in individuals with a major handicap in using both hands.

Plain Language Summary

In general, our hands are used differently. The dominant hand is more accurate and adept at being used than the non-dominant one. As a result, there is a risk of injuring the non-dominant hand when performing tasks requiring simultaneous accuracy from both hands. This outcome may yield less effective work. The accuracy of the non-dominant hand was enhanced immediately following pegboard training using a mirror, making both hands' functions more accurate. This result was accomplished by practicing hand function for a short period while looking in the mirror. In this way, the opposite side of the brain is stimulated, increasing the ability of the opposing hand to be more precise.

Introduction

The hands are the most active part of the human body and are frequently used in daily activities, work, and exercise. Especially in the age of technology, electronic devices, such as smartphones and computers/laptops, they have become increasingly important in our daily lives.

Hand function in daily activities involves various hand maneuvers, including the 3-jaw chuck grip, which is usually used to grasp and release an object. This maneuver is powered by the wrist flexor and extensor, especially the flexor digitorum superficialis and extensor carpi radialis brevis muscle [1]. Efficient hand function is a combination of strength, sensation, range of motion, and dexterity [2]. The non-dominant hand is used less frequently than the dominant hand, and the non-dominant hand is less powerful and efficient than the dominant one [3]. As a result, a condition known as asymmetrical hand function can occur, in which hands' functions are markedly different.

Asymmetrical hand function may substantially impact jobs that require both hands simultaneously, such as musicians, surgeons, dentists, athletes, waiters, and typists. Additionally, it increases the likelihood of injury to the non-dominant hand [4], such as forearm fractures in children, which usually occur on the non-dominant hand [5], or limits the efficacy of work requiring both hands, such as orthopedic surgery [6]. Thus, non-dominant hand training is important to improve asymmetrical hand function and reduce the incidence of hand injuries.

Several treatments are available to improve asymmetrical hand function, including constraint-induced movement therapy (CIMT) [7], hand-arm bimanual intensive therapy [8], video therapy, and mirror therapy. While both CIMT and mirror therapy employs the same unimanual technique, their approaches are different, with CIMT focusing primarily on the affected limb and mirror therapy on the unaffected limb. Training the unaffected or dominant limb may be superior and easier than training the non-dominant or affected limb. As a result, it may be beneficial in treatment. Mirror therapy is widely used to treat patients with neurological problems by facilitating the mirror or visuomotor neurons. Hence, brain function is improved bilaterally, and hand function can be improved in patients with neurological [9, 10] and musculoskeletal hand problems [11]. Compared with conventional therapy, mirror therapy substantially improves individuals with flexor and extensor tendon injuries, joint damage, and finger fracture active range of motion [11]. Although many studies have used mirror therapy to improve hand function, most research has been conducted on people with underlying pathologies. The effectiveness of this therapy in treating asymmetrical hand function is unknown.

Several hand exercises improve hand function, including the circle drawing task [12], ball rotation [13], wrist flexion and extension, and pegboard training [14, 15]. Pegboard training is a hand function training using the

hand in the 3-jaw chuck position, such as holding a pen during writing, buttoning, and tying [16]. Thus, pegboard training may improve hand function in daily life activities. Previously, there have been studies on the effects of long-term training (simple movement, simple task, complex task, pegboard apparatus) that can improve hand function in symptomatic and asymptomatic hand problems [15, 17]. In addition, the effect of mirror therapy and chopsticks on the coordination and dexterity of the non-dominant hand was recently investigated in healthy adults. The results found that coordination and dexterity were improved after training in both the experimental and control groups. However, the change in muscle activation after training has not been studied [18].

To our knowledge, no research has examined the immediate effect of mirror therapy using the pegboard training task on non-dominant hand function and muscle activation in asymmetrical hand function. The immediate benefit of mirror therapy is needed to inspire asymptomatic individuals with asymmetrical hand function to prevent hand injury and enhance work efficiency. We hypothesized that mirror therapy and the 9-hole peg test could immediately enhance hand function and muscle activities after training. Hence, this study investigated the effectiveness of mirror therapy with the 9-hole peg test on hand function and muscle activities in individuals with asymmetrical hand function.

Materials and Methods

A randomized control trial was conducted at Walailak University's Motion Research laboratory from July to December 2020.

Study participants

A total of 42 healthy young adult males [19, 20] were recruited in this study with the following inclusion criteria: 1) An individual with right-hand dominance (100% right response in the Edinburgh handedness questionnaire) [21]; 2) Age range between 18 and 25 years; 3) No vision problems or corrected vision problems; and 4) No history of injury, symptoms, or limited range of motion of both upper extremities. Those who were tested for hand function with the 9-hole peg test (9HPT) and their difference between the right- and left-hand functions was less than 6% were excluded from the study [21]. All volunteers were informed of the research protocol and signed a consent form before participating in the study. All participants were divided into two groups, the mirror therapy group (n=21) and the sham control group (n=21), using the simple random sampling method (drawing numbers), and the allocation was concealed (Figure 1).

Study measurements

The double-blind method was applied in this study. Four assessors did the measurement and training. The

Figure 1. Participant flowchart recruitment

first assessor screened the volunteers based on the inclusion and exclusion criteria, collected baseline characteristics of the participants (weight, height, BMI, finger thickness of the first, second, and third fingers of both hands), assessed hand function using the 9HPT, and collected left-hand muscle activities using surface electromyography (sEMG, Delsys Inc., Massachusetts, USA). The second assessor randomly allocated participants into each group. The third assessor trained the participants in the sham control group, and the fourth trained the participants in the mirror therapy group. Each participant was scheduled at different times and trained in a private room. The test-retest reliability (intra-rater reliability) of the 9HPT was good ($ICC_{3,1}$=0.834). During training, sEMG with a rectangular electrode and a bandpass filter within 20-500 Hz (Delsys Inc., Massachusetts, USA) was used to acquire the muscle activities of the flexor digitorum superficialis muscle (FDS) and the extensor carpi radialis brevis muscle (ECRB). Due to anthropometric differences (subcutaneous tissue thickness, muscle length, contraction velocity, muscle mass, fiber type, age, subtle changes in posture, and skin impedance), the EMG amplitude process in the form of mean root square was normalized to the percentage of maximum voluntary contraction (%MVC).

Study intervention

Each participant was seated in an adjustable chair and rested the non-dominant hand in a mirror box. The pegboard training program was adapted from the standard protocol for the 9HPT [21]. The sham control group received pegboard training only, and participants used the dominant hand to pick up and place the pegs into the tray for 9 rounds. The mirror therapy group received mirror therapy using the pegboard. Participants used the dominant hand to pick up and place the pegs into the tray for 9 rounds, combined with observing their hand movement in the mirror and imagining that movement as the movement of their non-dominant hand following the trainer's instruction in each round (Figure 2).

Outcome measures

The present study measured hand function using the 9HPT before and after training. Every participant performed the test in triplicate (3 times) within 5 minutes. Muscle activities (%MVC) of the FDS and ECRB during training were also recorded using the sEMG [22].

Sample size calculation

The sample size to compare the sham control and mirror therapy group was calculated based on the Equation 1 [23]:

$$1.\ n = \frac{2\sigma^2(Z_{1-\alpha/2} + Z_{1-\beta})^2}{(\mu 1 - \mu 2)^2}$$

With $Z_{1-\alpha/2}$=1.96, $Z_{1-\beta}$=1.645, μ1-μ2=1.48, and σ^2=1.42, the required sample size was calculated to be 17. The required sample size was increased to 21 persons per group in considering dropout. With an effect size of 0.78, the sample size requirement was adequate for this investigation.

Data analysis

All study data were recorded and entered in the SPSS software, version 26 (IL, Chicago, USA). Descriptive characteristics were calculated using Mean±SD. The percentage of asymmetrical hand function was calculated from the difference between the right and left hand functions. All variables were used to test the normal distribution.

Data from the 9HPT had a normal distribution and were analyzed using parametric statistics. The dependent samples t-test was performed to compare hand function using the 9HPT between pre- and post-training in each group. The independent samples t-test was employed to compare hand function between groups. Muscle activities during the preparation period (the first 200 ms) [24], the middle of the training period, and the final period (the last 300 ms) were selected to represent each group [12]. A comparison of muscle activity data (non-normal distribution) between the groups was performed using the Mann-Whitney U test. All analyzes were conducted with a significance level of 0.05.

Results

A total of 87 male volunteers with right-hand dominance, aged between 18 and 25 years and without complaints of hand symptoms, were screened for eligibility. Forty-five volunteers (51.70%) were excluded due to the following reasons: non-dominance in the right hand (3.44%), symmetrical hand function (39.08%), history of upper extremity (UE) injury (2.30%), and unwillingness to participate in this study (6.90%) (Figure 1).

Forty-two men were included in this study. Their mean age was 20.6±1.36 years and had a difference of

Table 1. Participants' characteristics (n=21 per group)

Variables		Mean±SD/%		P
		Sham Control	Mirror Therapy	
Age (y)		20.57±1.29	20.62±1.47	0.911
BMI (kg/m²)		22.93±3.92	24.33±6.83	0.417
bMHQ		89.78±9.50	89.29±12.01	0.883
Right finger thickness (cm)	Thumb	4.80±0.28	4.81±0.41	0.896
	Index finger	4.10±0.28	4.19±0.38	0.385
	Middle finger	4.34±0.28	4.36±0.27	0.782
Left finger thickness (cm)	Thumb	4.81±0.38	4.81±0.45	0.985
	Index finger	4.02±0.23	4.14±0.23	0.120
	Middle finger	4.26±0.25	4.29±0.23	0.703
Asymmetrical hand function by 9HPT (%)		11.98±4.77	10.50±4.45	0.305

9HPT: The 9-hole peg test.

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11.23%±4.60% between the right and left hand functions. At baseline, the two groups had no statistically significant variations in their characteristics (age, BMI, hand function score using bMHQ, finger thickness, and the percentage of asymmetrical hand function) (Table 1).

The sham control group's training length was recorded and varied from 2.48 to 5.65 minutes, with an average of 5.60 minutes. The training length in the mirror therapy group varied from 4.28 to 10.54 minutes, with an average of 7.08 minutes. Non-dominant hand function before and after training was significantly different in the mirror therapy group (P<0.001) but not significantly differ-

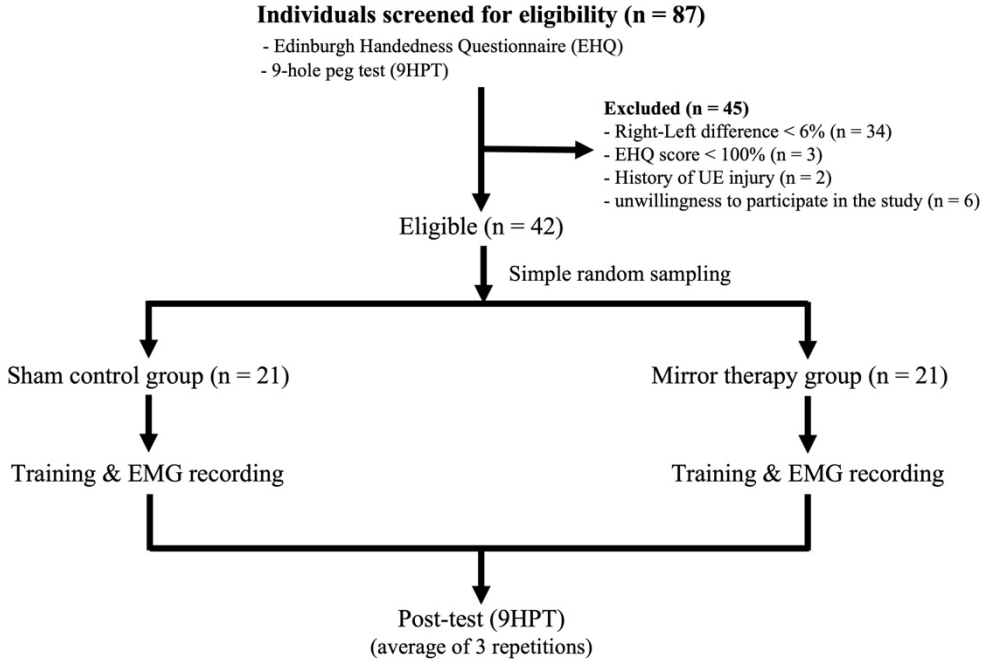

Figure 2. Mirror therapy training

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Table 2. Comparing non-dominant hand function by the 9-hole peg test (9HPT) between pre- and post-training in the sham control group and mirror therapy group (n=21 in each group)

Groups	Mean±SD		P
	Baseline	After Training	
Sham control	21.07±1.75	20.71±2.16	0.346
Mirror therapy	19.77±1.71	18.29±1.94	<0.001*

*Significance at P<0.05 with the dependent samples t-test.

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ent (P=0.346) in the sham control group (Table 2). After training, 12 participants in the sham control group (57%) and 18 in the mirror therapy group (86%) showed improved hand function.

Left-hand function after training compared to right-hand function before training (asymmetrical hand function) was reduced from 11.98% to 10.16% in the sham control group and from 10.50% to 2.95% in the mirror therapy group. The mean percentage in the sham control group was 10.53%±6.52%, whereas in the mirror therapy group, it was 5.85%±4.41%. The mean difference in non-dominant hand function was significantly different between the sham control and mirror therapy group (P=0.021) (Figure 3). Concerning the percentage of asymmetrical hand function after treatment, hand function was improved in both groups.

The non-dominant hand's FDS and ECRB muscle activities during the training's preparation, middle, and final periods were not significantly different between the sham control and mirror therapy groups. Muscle activities during training improved muscle activation in both groups, especially in the mirror therapy group (Figure 4).

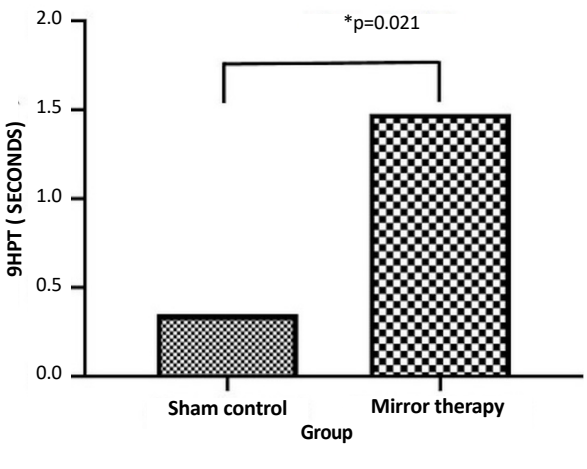

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Figure 3. Comparing non-dominant hand function (mean difference) between the sham control group (n=21) and mirror therapy group (n=21)

*Significance at P<0.05 with independent samples t-test.

Discussion

The present study investigated the effectiveness of mirror therapy on non-dominant hand function in individuals with asymmetrical hand function. During the recruitment of participants, 52% (42 out of 81) of the asymptomatic volunteers had asymmetrical hand functions, indicating that more than half of the volunteers with asymptomatic hand functions may be prone to have hand problems and require hand function training.

The results of the present study indicate that mirror therapy using the pegboard significantly improves hand function in the mirror therapy group compared to the sham control group. These findings are consistent with previous research, which found that pegboard training of the dominant hand can improve non-dominant hand function [16, 17]. Interestingly, our study is a short-period training, while the others were conducted in long-term periods. Therefore, the possible mechanism for improving hand function may be due to the effect of mirror therapy, as evidenced in a previous study using mirror therapy along with chopsticks [18]. Mirror therapy uses visual feedback to enable bilateral motor training. It stimulates functional improvement of the brain through the visuomotor neurons (mirror neurons), which has resulted in cross-activation and neuroplastic changes [25, 26]. In a previous study, a neuroplastic change occurred after 4 weeks of training [27]; thus, the results of the present study may be due to more cross-activation, increased motor-evoked potential amplitudes [25], and muscle activation [28]. Surprisingly, the percentage of asymmetrical hand function decreased immediately, especially in the mirror therapy group. The percentage difference between the right and left hand was less than 6% (15 of 21 participants), indicating that the hands functioned symmetrically following the treatment.

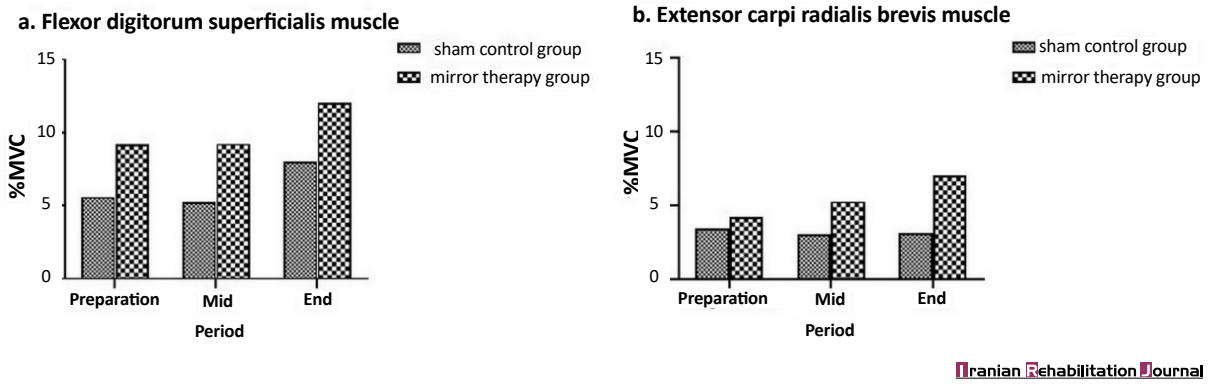

Figure 4. Non-dominant hand muscle activities (a) FDS and b) ECRB muscles) in the sham control group and mirror therapy group

FDS: Flexor digitorum superficialis muscle; ECRB: The extensor carpi radialis brevis muscle.

During the preparation, middle, and end of the training, there were no differences between the sham control and mirror therapy groups in the non-dominant hand's FDS and ECRB muscle activities. These results contradict a previous study that investigated a crossover design, used the circle drawing task, and determined the first dorsal interosseous muscle activity. It was found that mirror therapy significantly increased non-dominant hand muscle activities [12]. These outcomes can be related to different tasks, different muscles used, the short training period (less than 10 minutes), and the activation of motor overflow, which is superiorly induced in challenging tasks and for elderly participants [29]. The improvement in hand muscle function was not significant because this study's design task was merely for asymptomatic participants. Additionally, this might be due to the position of the forearm and wrist when holding and releasing the peg, which might differ according to the individual. As a result, ECRB muscle activity did not increase significantly [30].

Concerning hand muscle activities during training, although the increase between the two groups was not significantly different, the mirror therapy group tended to have greater muscle activation than the sham control group (Figure 4). In contrast, both groups activated the FDS more than the ECRB. Muscle activities increased during the preparation and training periods. In the preparation period, the initial response after receiving commands provided the mirror therapy participants with greater motor imagery and preparation than the sham control group. Regarding the muscle activities during the training period, although the increase in muscle activities was not significantly different, the mirror therapy group tended to have a greater increase than the sham control group.

Study limitations and suggestions

The present study showed significant improvement in hand function within and between groups. However, our study had some limitations. First, this study focused only on asymptomatic individuals, and the results should be generalized with caution to other population groups. Second, the present study did not determine hand muscle strength, a component of hand function that may be correlated with hand dexterity and hand muscle activities. Further studies should therefore investigate hand muscle strength before training. Third, the present study recorded muscle activities of the non-dominant hand only. As motor overflow can increase under fatigue [12], further studies should also collect data on muscle activities of the dominant hand to represent the motor overflow during the mirror therapy training. Lastly, the present study only determined the number of training rounds, which was 9 rounds, without specifying the training time, which may be a confounding factor.

Conclusions

Mirror therapy using pegboard training immediately enhanced the non-dominant hand with asymmetrical hand function in young adult males. The possible effect may be related to the activation of the mirror neuron and cross-activation in the brain. The present study can improve the efficiency of work that requires both hands for a short duration without directly practicing the non-dominant hand.

Ethical Considerations

Compliance with ethical guidelines

The study protocol was approved by the Human Research Ethics Committee of Walailak University (Code: WUEC-19-040-02).

Funding

The authors received no financial support for this article's research authorship and publication.

Authors' contributions

Conceptualization, writing the original draft, review, editing, and final approval: All authors; Methodology and investigation: Chadayu Udom and Wantanee Yodchaisarn.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

We thank all participants for their effective cooperation in this study.

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