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Research Article

Effects and Adherence of Mirror Therapy in People with Chronic Upper Limb Hemiparesis: A Preliminary Study

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Mirror therapy is a promising therapy with some benefit for motor recovery in people with chronic hemiparesis. However, there has been little investigation on the effect on upper limb sensory impairments, activity limitations, and participation restrictions. A within-subject, repeated-measures study with 12 people with chronic hemiparesis was conducted. Participants underwent a thirty minute sensorimotor mirror therapy home-based exercise program, conducted three times per week for six weeks. Compliance with the program and the effect on sensory outcomes were determined. Light touch threshold and proprioceptive error, upper limb activity limitations, and participation restrictions were measured at baseline (Week 0), immediately after (Week 6), and six weeks (Week 12) following the intervention. Compliance with the program was fair, 66% of supervised and 62% of unsupervised sessions were completed. The paretic hand performed worse compared to nonparetic hand at baseline with no difference in sensory measures demonstrated over time. Activity limitations and participation restrictions improved by Week 12 ($P < 0.05$). This sensorimotor mirror therapy home-based exercise program showed small improvements in light touch threshold and proprioception that appear to be functionally important for this group of people with chronic hemiparesis. Mirror therapy may be a useful tool for clinicians particularly for patient independent use.

1. Introduction

Less than 20% of stroke survivors recover functional use of the paretic upper limb, limiting independence and negatively impacting quality of life [1, 2]. Following stroke, the recovery of skilled movement requires accurate somatosensory function, in particular, light touch and proprioception [3]. It appears that a relationship exists between the amount of sensory impairment and the degree of motor recovery [4]. With somatosensory loss present in more than 60% of people with stroke [5], it is important that rehabilitation interventions target sensory as well as motor impairments [6]; as somatosensory function contributes to performance of activities of daily living following stroke [7]. The majority of recovery occurs within the first six months of stroke; although there is some suggestion that for people with chronic stroke, continuing rehabilitation can have functional benefits [8, 9]. In the current health management climate, with rehabilitation services targeting the acute and subacute periods after stroke, there are typically less allied health resources available to people with chronic stroke [10]. Therefore, independent practice involving sensory and motor training, such as using mirror therapy, may be a useful adjunct to therapy to allow further cortical activation and subsequently improving activity and participation capacity.

The mirror box, which is a small box with a mirror on one side, is a novel affordable device which may benefit the recovery of sensorimotor impairments following stroke. The paretic hand is hidden inside the box and the nonparetic hand moves outside the box [11]. By watching the reflection of the nonparetic hand in the mirror, the desired movements of the paretic hand can be observed.

Recent systematic reviews [12–14] report that mirror therapy may benefit motor outcomes across a range of different conditions, including stroke. However, included studies were mostly of low methodological quality, investigated the mirror therapy across a range of conditions using a range of outcome measures, making meta-analysis impossible, and consensus statements difficult.

The role of mirror therapy for sensory impairments has received some investigation. Certainly benefits of mirror therapy for reducing pain in people with phantom limb pain [11] and others with chronic pain syndromes [15–17] have been demonstrated. A recent study [18] also demonstrated improvement in tactile discrimination in people with chronic regional pain syndrome following a specific tactile training program using mirror therapy providing support that mirror therapy may influence sensory impairments common following stroke, though this requires further investigation. Exactly how mirror therapy may influence sensory impairments is unclear. It has been suggested that the visual input provided by the reflection of the mirror is combined with altered or absent sensation of the paretic hand via the corpus callosum or via the activation of mirror neurons [11, 19]. In healthy adults, mirror therapy has also demonstrated increased motor and sensory cortex activity, which is associated with neuroplasticity [20, 21].

While the efficacy of the mirror box has yet to be fully established for patients with stroke, it also remains to be seen if stroke patients will independently practice with the mirror box following a period of therapist directed instruction. Therefore, the aims of this preliminary study were to determine the feasibility of a mirror box sensorimotor exercise program, with particular emphasis on compliance to the program, and to evaluate the effect of a six-week mirror box exercise program on somatosensory function immediately and six weeks following the exercise program in people with chronic upper limb hemiparesis.

2. Methods

2.1. Design. A within-subject repeated-measures study was carried out. Participants underwent mirror therapy for 30 minutes, 3 times per week for 6 weeks. Measures were taken three times; before the intervention (Week 0), immediately (Week 6), and six weeks (Week 12) following the conclusion of the intervention (Figure 1). Hospital and University Human Research Ethics committees approved the study and informed consent was obtained from all participants.

2.2. Participants. Participants were eligible to be included in the study if they had chronic upper limb hemiparesis, scored at least 24 on the Mini-Mental State Examination [22], and had conversational English. Potential participants were excluded if they had a degenerative neuromuscular condition or injury of the hemiparetic upper limb; scored zero or the maximum score on Items Six (Upper Limb), Seven (Hand), or Eight (Advanced Hand) of the Motor Assessment Scale [23]; were less than 18 years of age. Participants were recruited from local stroke support groups and hospitals using several strategies including presentations to local stroke support groups, discussion with hospital physiotherapists, and the use of flyers. Demographic information collected from participants included age, gender, cause of hemiparesis, side, and duration of hemiparesis.

2.3. Intervention. Participants were prescribed one supervised and two home-based sensorimotor mirror therapy exercise sessions three times per week for six weeks. Each session was 30 minutes duration. Mirror therapy in the study was provided via a mirror box; a small, light-weight device available commercially (Reflex Pain Management). The sensorimotor exercise program involved a range of exercises, including motor retraining tasks such as range of movement and gripping activities; functional tasks and sensory retraining activities such as feeling different textured objects. Participants were encouraged to focus on the reflection in the mirror, with movement of the paretic hand inside the box if possible. Several strategies were included designed to monitor participant progress, progress the exercises as required, and to optimize participant compliance with the mirror therapy exercise program. One session per week was conducted in a group supervised by the study investigators and the other two sessions were completed independently at home. The duration and frequency of the exercise sessions were selected to not be too time consuming or arduous for participants to complete. Participants received an individualised exercise program, based on personal goals, abilities and deficits. Written handouts of the sensorimotor mirror therapy exercise program were provided to all participants and a diary was kept to record compliance with the exercise program, and reviewed at each supervised session.

2.4. Outcome Measures. Primary outcome measures included program compliance and sensory function as determined by light touch threshold and proprioception. Compliance was determined using a diary to record the number and time spent in supervised and unsupervised sessions each week. Any adverse event (e.g., pain, headaches, blurred vision) experienced by participants was recorded in the exercise diary. In addition, participants were specifically questioned regarding any adverse event at the weekly supervised session. Effect of the combined supervised and home-based mirror therapy program was determined by measuring sensorimotor impairments, activity limitations and participation restrictions relevant to the hand and upper limb and overall quality of life.

Sensory measures of light touch threshold and proprioception, specifically joint position sense, were measured at Week 0, 6, and 12 for the paretic and nonparetic hands. Light touch threshold was measured at five sites on each hand, wrist, dorsal second metacarpal, thenar and hypothenar eminences, and the tip of the index finger, using Semmes Weinstein monofilaments [24], with the smallest filament felt recorded as the light touch threshold for each site. Each filament was tested three times and a positive response to the filament was defined as occurring within three seconds of the application of the filament. Monofilaments have

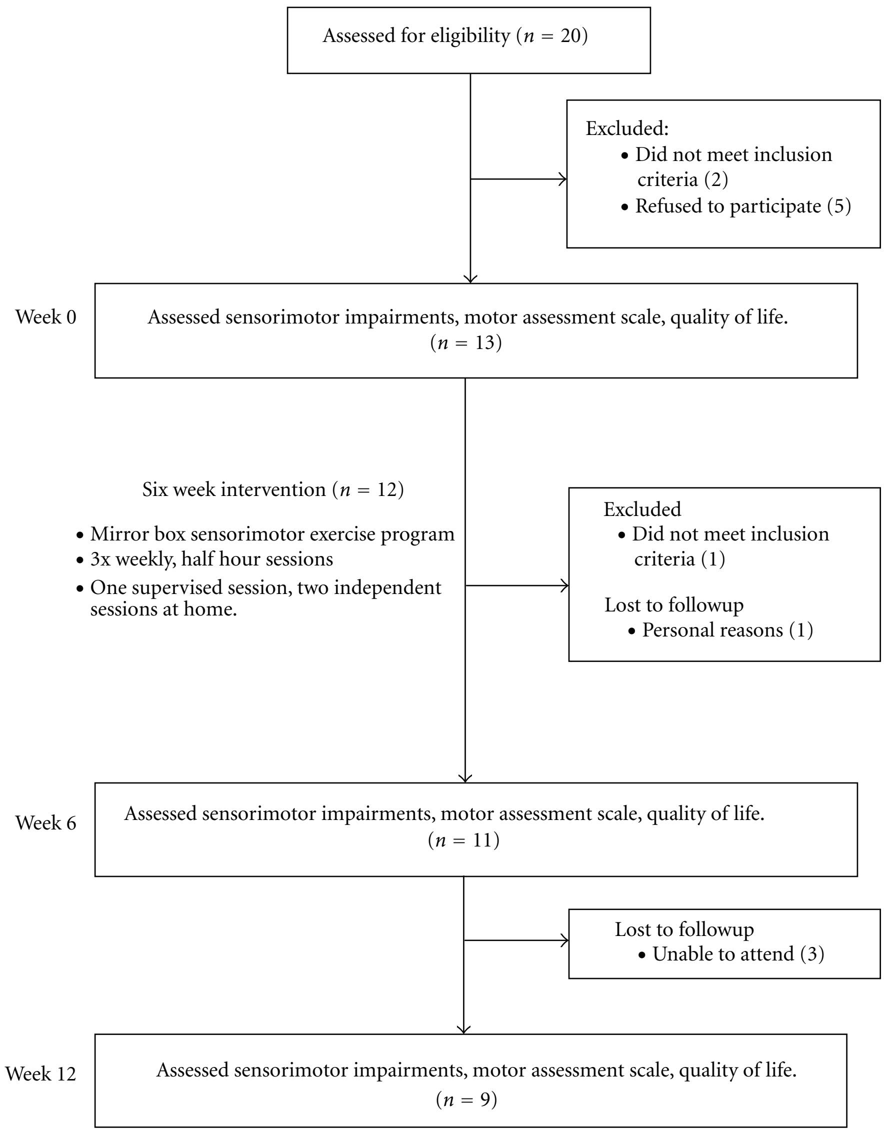
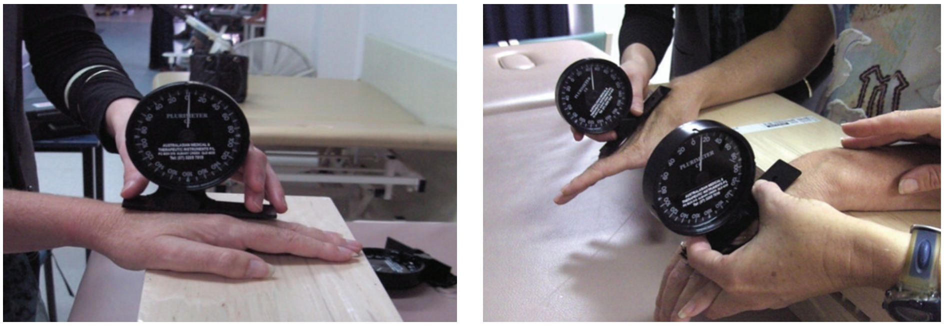


Figure 1: Flow diagram of intervention.

been used to map sensory loss in people with stroke [6]; and demonstrated to have both intratester and test-retest reliability as there is very little variability in force application [24].

Proprioception of the paretic hand was measured using two plurimeters (Ausmedic CE), one on each hand, at the wrist, first and second metacarpophalangeal joints within flexion and extension using a procedure similar to one previously described [25]. The participant stood at a height-adjustable plinthe, with the shoulder in a neutral position, elbow at 90 degrees of flexion and the hands resting over a 12-cm box. The joint to be tested was positioned in a neutral position over the box to allow full range of movement, and the plurimeter set to zero (Figure 2(a)). With the participant blindfolded, the paretic side was positioned, and the participant was asked to copy the position with the nonparetic hand (Figure 2(b)). The position of both hands was recorded and the difference between hands was calculated. Three trials were recorded at each joint, and the average error between hands was calculated as the mean proprioceptive error. Test-retest reliability of this measure was determined prior to study commencement with no significant differences in the amount of joint position error when assessed two days apart in a group of six physiotherapy students ($P > 0.05$).

Following the completion of the first mirror therapy exercise program, analysis revealed no significant change ($P > 0.05$) in the nonparetic hand for light touch threshold and proprioception between Week 0 with Week 6 and Week 12. Therefore, due to time constraints, the nonparetic hand was only measured at Week 0 in the subsequent group, and data analysis completed with the nonparetic hand at Week 0 only for all participants.



(a) (b)

Figure 2: Measurement of proprioception at the neutral starting position (a) and at the assessed wrist position (b).

Secondary outcome measures included active range of movement of wrist extension, radial deviation, supination, and first and second metacarpophalangeal extension measured using plurimetry (Ausmedic CE) [26]; maximal grip strength (kg) of the paretic and nonparetic hand using Jamar dynamometer (SI Instruments, Australia) according to the American Hand Society guidelines [27]. Upper limb activity limitations were measured using the Motor Assessment Scale upper limb (UL-MAS) composite score; the sum of Items 6, 7, and 8. This composite score has been demonstrated to have acceptable internal consistency (Cronbach's alpha = 0.83) making it a valid and reliable independent measure of upper limb function [28]. Participation was measured using the Patient-Specific Functional Scale [29]; participants rated three tasks they were having difficulty with from 0–10 (with 10 being normal function) at Week 0 and these tasks were reassessed at Weeks 6 and 12. Participants also rated their perception of their health state using the vertical visual analogue scale (VAS) of the EuroQol 5D [30] scored from 0 to 100; 0 representing "worst imaginable health state" and 100, "best imaginable health state." The EuroQol 5D has been shown to be valid and reliable in people with stroke [31, 32].

2.5. Data Analysis. Descriptive statistics, including means and standard deviations were calculated for all outcome measures for all time points. Data not normally distributed were analysed using nonparametric statistics. Compliance was determined as a percentage of number of exercise sessions completed, compared to the total number of required exercise sessions. The amount of time spent practicing during supervised and unsupervised sessions over the period of the intervention was analyzed as a percentage of the required time. Effect of the mirror box sensorimotor exercise program was determined for all primary and secondary outcome measures using actual differences and percentage change from baseline at each time point. Paired t-tests or Mann-Whitney U test for parametric and nonparametric variables, respectively, were used to determine differences for the paretic hand between Week 0 and Week 6, and between Week 0 and Week 12. Differences between the nonparetic hand at Week 0 and the paretic hand at Weeks 0, 6, and 12 was determined for all measures using paired t-tests and Mann-Whitney U tests for parametric and nonparametric variables, respectively. Analyses were performed using SPSS, version 14.0.1 for Windows, and statistical significance was set at 0.05.

3. Results

Of the 20 potential participants who responded to the recruitment strategies, a total of 12 participants were appropriate for inclusion to the study. Reasons for exclusion included no movement recovery in paretic hand ($n = 1$), and participants electing not to commence the study due to other commitments ($n = 7$). Eleven were stroke survivors and one had suffered a traumatic brain injury. The mean age was 59 (SD 15) years, duration of hemiparesis was 82 (SD 70) months, and eight (67%) participants had left hemiparesis. One participant was unable to complete the Week 6 assessment, but returned for the Week 12 assessment. Three participants were unable to complete the Week 12 assessment. There were no differences between participants who completed all assessments and those who did not. No adverse effects were reported by participants throughout the duration of the intervention.

3.1. Compliance with the Intervention. Overall compliance with the mirror box sensorimotor exercise program was 85%, with a total of 183 sessions out of a required 216 completed by participants. Three (25%) participants completed more than the required amount of unsupervised practice. Rescoring these participants with the maximum number of required unsupervised sessions, that is, two; compliance was 63%. Participants completed on average 4.1 (SD 1.7) supervised sessions and 89 out of a required 144 unsupervised sessions (62%), for an average of 33 (SD 18) minutes per week for the unsupervised sessions. At least one unsupervised session was completed by 75% of participants each week. The reasons given for missing sessions included other commitments or forgetting to practice.

3.2. Effect of Mirror Box Therapy. Light touch threshold of the wrist, dorsal second metacarpal, thenar and hypothenar eminences, index finger, and a mean of all tested sites, for the nonparetic hand at Week 0 and the paretic hand at

Table 1: Descriptive statistics of light touch threshold at Weeks 0, 6 and 12.

Location	Non-paretic hand	Paretic hand			Paretic Hand Difference^		Non-paretic minus Paretic Hand Differences#		
	Week 0	Week 0	Week 6	Week 12	Week 6 minus Week 0	Week 12 minus Week 0	Week 0	Week 6	Week 12
Wrist	2.66 (0.68)	3.59 (1.21)	3.87 (1.01)	3.59 (0.85)	0.28 (1.32)	0.00 (1.04)	−0.93 (−1.61 to −0.25)	−1.21 (−1.92 to −0.50)	−0.93 (−1.49 to −0.36)
Dorsal 2nd Metacarpal	2.77 (0.67)	4.19 (1.49)	3.93 (1.15)	3.74 (0.96)	−0.26 (1.51)	−0.46 (1.47)	−1.42 (−2.46 to −0.38)	−1.16 (−0.20 to −0.33)	-0.97§
Thenar Eminence	3.48 (0.64)	4.45 (1.24)	4.36 (1.21)	3.55 (0.62)	−0.08 (1.47)	−0.90 (1.48)	−0.97 (−1.83 to −0.10)	−0.88 (−1.62 to −0.15)	−0.07 (−0.399 to 0.26)
Hypothenar Eminence	3.43 (0.59)	4.71 (1.32)	4.11 (1.09)	4.10 (1.01)	−0.59 (1.26)	−0.61 (1.71)	−1.23 (−2.04 to −0.51)	−0.69 (−1.27 to −0.10)	−0.67§
Index finger	3.47 (0.62)	4.06 (1.12)	4.13 (1.06)	4.12 (0.94)	0.05 (0.83)	0.06 (1.36)	−0.59 (−1.28 to 0.09)	−0.66 (−1.30 to −0.01)	−0.65§
Mean	3.16 (0.54)	4.20 (1.09)	4.08 (0.93)	3.82 (0.71)	−0.12 (1.02)	−0.38 (1.17)	−1.04 (−1.72 to −0.36)	−0.92 (−1.48 to −0.36)	−0.66 (−1.07 to −0.24)

^Negative values represent an improvement in sensation.
#Negative values indicate the non-paretic hand has better sensation, increasing positive values indicate improvements in the paretic hand.
§95% CI's were not calculated for non-parametric tests.

Table 2: Descriptive statistics of proprioceptive error (°) of the paretic hand at Weeks 0, 6 and 12.

Joint	Week 0	Week 6	Week 12	Paretic hand Difference^	
				Week 6 minus Week 0	Week 12 minus Week 0
Wrist Extension	17.58 (11.86)	16.95 (10.43)	16.85 (7.90)	−0.62 (12.29)	−0.72 (15.00)
2nd Metacarpophalangeal Extension	23.93 (20.52)	12.51 (6.82)	17.48 (11.36)	−11.41 (20.66)	−6.45 (19.24)
1st Metacarpophalangeal Extension	14.07 (9.45)	11.67 (4.73)	13.52 (5.02)	−2.40 (9.01)	−0.55 (9.87)
Mean	18.52 (10.81)	18.32 (9.38)	15.95 (5.86)	−0.21 (4.10)	−2.57 (10.71)

^ Negative values represent a decrease in proprioceptive error.

Week 0, Week 6, and Week 12 are presented in Table 1. By Week 6 mean (SD) light touch threshold of the paretic hand decreased by 2.86%, ranging from 3.87 (1.01) to 4.36 (1.71) ($P > 0.05$); at Week 12, had decreased to 9.05% ($P > 0.05$). Light touch threshold of the nonparetic hand was significantly more sensitive than the paretic hand at Week 0 for all measures ($P < 0.05$) except the tip of the index finger ($P = 0.08$). These differences between the two hands remained for all sites at Week 6 ($P < 0.05$). By Week 12 thenar eminence light touch threshold had improved and there was no difference between the two hands ($P = 0.66$). Differences between the hands for all other sites remained ($P < 0.05$). Proprioception (joint position sense) of the paretic hand at Weeks 0, 6, and 12 are presented in Table 2. At Week 0, the mean proprioceptive error ranged from 14.07° (SD 9.45) to 24.93° (SD 20.52) across the three joints tested. The mean proprioceptive error for the three joints decreased by 1% by Week 6 and 14% by Week 12 ($P > 0.05$).

Active range of movement and grip strength of the paretic hand at Weeks 0, 6, and 12, and the nonparetic hand at Week 0, are presented in Table 3. Paretic hand active range of movement increased 4% and 20% by Week 6 and Week 12, respectively, ($P > 0.05$). At Week 0, there was a significant difference in active range of movement between the paretic and nonparetic hands. By Week 6, there was no difference between hands for radial deviation ($P = 0.08$). By Week 12, there was no difference between hands for thumb extension ($P = 0.09$). Between hand differences remained for all other joints at Week 6 ($P < 0.05$) and Week 12 ($P < 0.05$). At Week 0, mean grip strength of the paretic hand was 7.33 kg (SD 6.77), almost a quarter of the strength of the nonparetic hand, 31.58 kg (SD 18.96). Paretic hand grip strength increased 17% by Week 6 ($P = 0.20$) and 38% by Week 12 ($P = 0.06$). Significant differences were found between the nonparetic hand at Week 0 and the paretic hand at Weeks 0, 6, and 12 ($P < 0.05$). UL-MAS scores did not change between Week 0 and Week 6 ($P > 0.05$). However, by Week 12 the score had significantly improved ($P = 0.03$). Mean Patient-Specific Functional Scale score at Week 0 was 2.12 (SD 1.97), which increased to a maximum of 3.69 (SD 3.52) at Week 6 ($P = 0.02$) and 3.33 (2.36) at Week 12 ($P = 0.01$). The mean VAS score of the Euroqol-5D at Week 0 was 61.8 (12.5), which increased significantly over the duration of the intervention to 74.7 (14.5) in Week 6 ($t = 2.41$, $P = 0.035$) and 74.4 (10.5) at Week 12 ($t = 2.95$, $P = 0.01$).

4. Discussion

The sensorimotor mirror therapy exercise program used in the study was found to be a feasible treatment tool for people with chronic hemiparesis and the effect on sensory impairments including light touch sensation and proprioception appeared to be promising in this group of people with chronic hemiparesis. Small benefits were found for upper limb activity limitations and participation restrictions suggesting that this sensorimotor mirror therapy exercise program led to increased use of the paretic hand.

A recent systematic review concluded that mirror therapy exercise program may have a positive effect on motor function in people with chronic stroke [12]; and it has been suggested that mirror therapy may affect sensory impairments in people with conditions other than chronic hemiparesis [33]. Only one study was found that investigated sensory changes in people with chronic hemiparesis [34], but in that study mirror therapy was a component of a larger rehabilitation program limiting the conclusions of the role of the mirror therapy. The current study found light touch sensation improved to approach a level similar to that of the nonparetic hand, though this improvement was generally not significant. However, at the thenar eminence, the nonparetic hand improved to the extent that there were no longer significant differences between the two hands. Proprioceptive error at the paretic wrist and hand also decreased over the duration of the intervention to approach zero. This suggests that mirror therapy may have had an important role in producing the sensory changes demonstrated previously [34], and furthermore, that mirror therapy may be of benefit in improving sensation in people with chronic hemiparesis.

The improvements in sensation seen in the present study appear to be functionally important for people with chronic hemiparesis. Light touch sensation is important for safety and influences other aspects of cutaneous sensation [6]. Improvements in light touch and proprioceptive sensation have been shown to be related to improvements in motor quality [35], as sensation provides feedback for movement according to theories of motor control. Correspondingly, the changes in sensation observed in the current study were also associated with changes in motor impairments and function. The current study supported previous findings of a trend toward improvements in active range of movement at the wrist and hand [36, 37] and grip strength [34, 37, 38]. These motor impairment improvements, even though not significant in the current study, possibly contributed

Table 3: Descriptive statistics of active range of movement (°) and grip strength (kg) for the non-paretic hand at Week 0, and the paretic hand at Weeks 0, 6 and 12.

Measured joint	Non-paretic hand	Paretic hand			Paretic hand difference^		Non-paretic minus paretic hand differences#		
	Week 0	Week 0	Week 6	Week 12	Week 6 minus Week 0	Week 12 minus Week 0	Week 0	Week 6	Week 12
Wrist Extension, deg	64.42 (19.04)	33.00 (30.74)	35.82 (27.38)	44.11 (18.19)	2.82 (25.70)	11.11 (25.77)	31.42 (11.85 to 50.99)	28.60 (4.23 to 52.97)	20.31 (2.21 to 38.40)
2nd Metacarpo-phalangeal Extension, deg	36.25 (10.57)	18.33 (17.26)	18.18 (15.85)	20.00 (14.07)	−0.15 (8.57)	1.67 (9.53)	17.92 (7.69 to 28.14)	18.07 (9.32 to 26.82)	16.25 (7.35 to 25.15)
Radial Deviation, deg	33.27 (11.19)	18.83 (18.81)	22.00 (18.15)	17.11 (8.74)	3.17 (13.71)	−1.72 (14.92)	14.44 (2.03 to 26.85)	11.27 (−1.64 to 24.18)	16.16 (8.25 to 24.07)
Supination, deg	86.17 (11.36)	46.83 (35.74)	39.27 (31.45)	57.78 (31.67)	−7.56 (15.21)	10.95 (25.27)	39.33 (19.48 to 59.19)	46.89 (29.94 to 63.85)	28.39 (12.42 to 44.35)
1st Metacarpo-phalangeal Extension, deg	40.33 (14.99)	17.83 (18.48)	20.00 (21.78)	25.22 (17.66)	2.17 (12.37)	7.39 (12.56)	22.50 (4.40 to 40.60)	20.33 (0.84 to 39.83)	15.11 (−3.02 to 33.24)
Grip Strength, kg	31.58 (18.96)	7.33 (6.77)	8.55 (7.90)	10.11 (5.98)	1.22 (3.11)	2.78 (4.53)	24.25 (11.494 to 37.01)	23.03 (9.95 to 36.12)	21.47 (7.74 to 35.21)

^Positive values represent an improvement.
#Positive values indicate the non-paretic hand has better range of movement or grip strength compared to the paretic hand. Decreasing values indicate the paretic hand is improving in range of movement or grip strength.
deg: degree.

to increased activity and function of the paretic limb as demonstrated by significant improvements in items of the Motor Assessment Scale composite score, Patient-Specific Functional Scale, and EuroQOL-5D.

Compliance with the sensorimotor mirror therapy exercise program in the current study was fair; with 75% or participants completing at least one unsupervised session at home each week. Factors which may have contributed to this include the use of both supervised and unsupervised sessions and the use of a program that was goal-directed and individualised for each participant. However, we note with caution that the compliance rate was monitored using self-report data, which has a tendency to be overestimated [39]. Regardless, these findings suggest that a mirror therapy exercise program may be a feasible option for independent therapy, when guided and supervised regularly by a therapist.

5. Limitations

There were several limitations in the design of the current study which need to be considered in future research. This study had a small sample size of 12 participants. As the study was insufficiently powered to fully investigate the effect of the mirror therapy on sensory outcomes; the feasibility of using the mirror box independently by stroke survivors was investigated. The study would have been enhanced had additional baseline measures been conducted to ensure that any changes observed were likely to be due to the mirror therapy program. In addition, a decision was made to only measure the nonparetic hand at Week 0 in the second group and to report all comparisons relative to this Week 0 measure. Although our preliminary analyses demonstrated that the sensory measures were not different over the three assessments, it is possible that these findings were erroneous potentially affecting our outcomes. Future studies should endeavor to recruit larger, more homogenous sample populations (including consideration of people with either acute or chronic hemiparesis) and evaluate sensorimotor mirror therapy exercise program against a control group using a randomised control trial design measuring both hands at all assessment points. Additionally, consideration should be given to the measures of sensory function to be used. We chose clinically available measures but other more sensitive and responsive measures may be more suitable. Future research should also investigate the effect of changing parameters of the sensorimotor exercise program, including duration and frequency of exercise parameters to investigate the effect of different exercise regimes.

6. Conclusion

The current study demonstrated that mirror therapy can be used in an active sensorimotor exercise program with the potential for benefits in sensation; as well as motor impairments, activity limitations, and participation restrictions in people with chronic hemiparesis. Although results were not significant, given the small sample size and the limitations of the study, the observed improvements are a promising result for future research and to support the use of mirror therapy as a rehabilitation technique, particularly for independent use.

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