Original Article

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Effect of Motor Imagery Training with Sensory Feedback on Sensory-Motor Function of the Upper Extremity in Patients with Chronic Stroke

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ABSTRACT

BACKGROUND AND OBJECTIVE: Conventional rehabilitation in stroke patients is more likely to use repetitive movements to improve motor function, which may be difficult for people with motor limitations. Mental imagery training can be done without moving the affected limbs, and this method is safe, cheap and accessible. The aim of this study is to investigate the effect of motor imagery training with sensory feedback on sensory-motor function of the upper extremity in patients with chronic stroke.

METHODS: In this non-randomized clinical trial, 30 stroke patients with level of upper extremity function according to Brunnsrom's recovery ≥ 2, and cognitive function level according to MMSE ≥ 21 were selected through non-probability sampling from rehabilitation centers and randomly divided into intervention and control groups. Patients in the control group received conventional rehabilitation programs, and patients in the intervention group received motor imagery training with sensory feedback in 12 sessions (45 – 60 minutes), in addition to conventional rehabilitation programs. Before and after the interventions, sensory and motor functions were assessed using Box-Block test, Purde-Pegbord test, range of motion, FMA-UE total and FMA-UE coordination/speed, 2-point-discrimination, Nottingham-Sensory Assessment, Modified-Ashworth Scale and Stroke Impact Scale.

FINDINGS: Mean percentage of changes in motor function and speed/coordination of upper extremity, shoulder and elbow range of motion and gross dexterity was higher in the interventional group (50%, 50%, 80%, 50% and 80%, respectively) compared with the conventional rehabilitation group (20%, 18%, 50%, 30% and 30%, respectively) ($p \leq 0.05$). However, both interventions had similar effect on sensory function, fine dexterity, muscle tone and activities of daily living.

CONCLUSION: The results of the study showed that motor imagery training with sensory feedback along with conventional rehabilitation could enhance the motor function, gross dexterity and range of motion of the upper extremity in chronic stroke patients.

KEY WORDS: *Upper extremity, Functional, Motor imagery, Sensory-motor, Sensory feedback, Stroke*.

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Introduction

Stroke occurs as a result of poor blood flow to the brain in certain parts of the brain. Stroke is the second leading cause of death in the world (1) and the fourth cause of death in Iran (2). 85% of people who experience stroke have a residual impairment in their upper extremities, and 55-75% of these defects directly affect their quality of life (3). Therefore, in rehabilitation programs for these patients, improving the movement of the upper extremities should be emphasized for independence in the daily functions of life. Conventional rehabilitation in people with stroke is more about repetitive movements to improve motor function. One of the disadvantages of this method is that recovery depends on the degree of function in the involved organ, which may be difficult for people with motor limitation. However, Motor Imagery (MI) is the conscious repetition of a movement without its real implementation, which can take place without moving the involved limb and is a safe, inexpensive and accessible method that people can easily learn (4). There are two types of MI: 1) Kinesthetic imagery: a sense of movement from someone's own internal perspective; and 2) Visual imagery: performing functions from an external perspective (from the perspective of the third person who looks from outside).

Motor imagery can increase the activity of the mirror neuron network. Moreover, there are similarities between MI and the actual implementation of movement in terms of mental synchronization, overlapping of the brain regions, and the electromyography activity of the target muscle, and these similarities are more in kinesthetic imagery (5-9). Previous studies that evaluated the effects of MI training did not focus on examining the idea of the kinesthetic type of MI separately from visual imagery. In most studies, mental exercises have generally been used and no particular type of MI has been considered (10–12). So far, few studies have investigated the effect of MI training in stroke patients. In the studies of Kim et al. and Luzia et al. in 2015, the effect of kinesthetic MI exercises on improving the function of upper extremity of stroke patients were investigated and the results showed that rehabilitation with MI exercises combined with physical exercises increased recovery in stroke patients (13,3). Moreover, Guttman et al. showed improvement in reaching speed in stroke patients after MI exercises (14). In addition to MI, sensory feedback based on ide-motor theory can be effective in cognitive performance of the mind (5-9). Therefore, the use of sensory feedback can increase the impact of MI exercises, but none of the previous studies have investigated this issue. Therefore, the aim of this study is to investigate the effect of kinesthetic MI exercises with sensory feedback on the sensory-motor functions of the upper extremity of chronic stroke patients.

Methods

After being approved by the Ethics Committee of Iran University of Medical Sciences (IUMS) with the code of ethics: IR.IUMS.REC.1394.9411355007 and clinical trials registration number: IRCT: 20140416017301N5, this experimental study was conducted among 30 patients with chronic stroke who referred to hospitals and rehabilitation centers of Tehran. People diagnosed with stroke (by the neurologist), which occurred within the last six months, having upper extremity function level 2 and above based on the Brunnstrom scale (15), having a minimum cognitive function level of 21 and above based on the Mini-Mental Scale Examination (MMSE) (13), lack of musculoskeletal problems that led to contracture and joint deformity, lack of unilateral neglect, lack of dementia and depression (according to the neurologist's diagnosis) (4), lack of receptive-expressive aphasia, and the ability to read and write were included in the study. In case of recurrent stroke and if the patient was not willing to continue treatment, the patient was excluded from the study during the treatment protocol.

After the consent form was signed by the participants, initial evaluations were performed and the patients were randomly divided into intervention and control groups. Duration of treatment for both intervention and control groups was 12 sessions, 3 times a week and 45 to 60 minutes each time in rehabilitation centers. The exercises for control group were conventional rehabilitation exercises that include exercises affecting muscle tone, exercises related to the movements of the daily functions of the upper extremity, exercises to reduce pain and edema of the upper extremity (16). In addition to conventional rehabilitation exercises, the exercises for intervention group included kinesthetic MI exercises of the upper extremity with sensory feedback. These exercises were performed for the important functions of the upper extremity against the tonic spasticity conditions whose absence caused problems in the activities of daily living, including: shoulder abduction, external shoulder rotation, elbow extension, forearm supination, wrist extension and flexion of the metacarpophalangeal joints of the fingers. Sensory feedback was also provided by the examiner according to the passive movement of the joints in the defined conditions according to MI exercises.

Instruments

Box–Block Test (BBT): This test evaluates the function of the upper extremity, and the test score is equal to the number of blocks displaced in 60 seconds by the hand of the patient (17).

Purde – Pegboard Test (PPT): This test evaluates the fine motor skill. The tools of this test include a wooden plate with two cavities on the right and left (each containing 25 nails) and two central cavities (the left cavity containing 40 washers and the right cavity contains 20 collar). In the present study, the assembly sub-test of this test was used, which includes placement of the nail, first washer, collar and second washer, and the score is equal to the number of assemblies performed by the patient's hand in 30 seconds (17).

Goniometer: The goniometer was used for measurement of range of motion in shoulder abduction, elbow extension, forearm supination and metacarpal extension of the index finger (18).

Modified – Ashworth Scale (MAS): The MAS was used to measure the muscle tone of the elbow flexion, forearm pronation and flexion of the fingers 2, 3, 4, 5, in which the tone is categorized from 0 to 4; 0 represents normal tone and 4 represents the resistance to the passive movement from early range of motion (19).

2-Point-Discrimination (2PD): The static–2PD test was used to assess the sense of discrimination between the tip of the thumb, and the third and fifth fingers, and the total score of the three fingers was calculated as the final score (20).

Nottingham – Sensory Assessment (NSA): In this study, the kinesthetic part of this test was used in shoulder, elbow, wrists and hands to evaluate the proprioceptive sense, and the total score of these areas was calculated as the final score (21).

Stroke – Impact Scale (SIS): This is a comprehensive stroke-impact scale questionnaire for evaluate activity of daily living in stroke patients. It has eight items with total score of 100 (22). In this study, item 5 was used for ADL / IADL and item 7 was used to evaluate the function of the hand.

Fugl-Meyer Assessment- Upper Extremity (FMA-UE): This test evaluates upper extremity motor impairment and includes 33 items. The maximum score of this test is 66 and represents the proper motion (23). In this study, the items of total FMA-UE and FMA-UE coordination / speed were used.

Shapiro – Wilk test was used to examine normal distribution in different variables. In order to investigate the effect of interventions on different variables, first the percentage changes in scores before and after treatment was calculated. The independent t-test was used to compare the difference in scores between the intervention and control groups. In the analysis of the results, Eta Square shows the effectiveness of the treatment.

Results

In this study, 15 patients with a mean age of 68.26 years (standard deviation: 8.32) in the control group (10 males and 5 females, 9 patients with right – side involvement and 6 patients with left – side involvement) and 15 patients with a mean age of 64.80 years (standard deviation: 10.22) in the intervention group (11 males and 4 females, 10 patients with right – side involvement and 5 patients with left – side involvement). In all of the measured variables, the post-treatment scores improved in both intervention and control groups compared to the time before the treatment, and the improvement in most of the variables in the intervention group was more than

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the control group (Tables 1 and 2). The results of this study showed that the mean percentage of changes in the range of shoulder abduction and elbow extension, gross motor skill (BBT), overall function, and speed / coordination of upper extremity in the intervention group were significantly higher than the control group ($P \leq 0.05$), which shows that MI exercises with sensory feedback improved these variables. In addition, the results of this study showed that the mean percent of discrimination (2PD) and proprioceptive sense (NSA), muscle tone (MAS), range of motion of for forearm supination, wrist extension and flexion of the metacarpophalangeal joints of the fingers, activities of daily living (SIS) and fine motor skill (PPT) was not significantly different between the intervention and control groups, i.e., MI exercises with sensory feedback could not significantly change the improvement of these variables in intervention group compared with the control group.

Table 1. The mean and percentage of changes in sensory variables, tone and range of motion in both intervention and control groups before and after treatment

Variable	Group	Before treatment (Mean±SD)	After treatment (Mean±SD)	Mean changes (%)	Eta Suareq	P-value	t-test
Discrimination based on 2PD test (score)	Intervention	3.60±1.76	4.20±1.82	19±29	0.01	0.54	0.62
	Control	4±1.92	4.46±1.55	13±30			
Proprioceptive sense based on NSA (score)	Intervention	4.93±1.90	5.80±1.56	26±27	0.092	0.10	1.68
	Control	5.06±1.57	5.60±1.63	12±16			
Muscle tone-elbow extension based on MAS test (score)	Intervention	1.70±0.25	1.36±0.35	- 20±15	0.04	0.29	1.09
	Control	1.63±0.29	1.40±0.33	- 13±15			
Muscle tone-forearm pronation based on the MAS test (score)	Intervention	1.76±0.37	1.50±0.37	- 13±16	0.00	0.97	- 0.04
	Control	1.66±0.40	1.43±0.45	- 12±19			
Muscle tone-Extension of fingers 2, 3, 4, 5 based on MAS test (score)	Intervention	2.03±0.63	1.80±0.67	- 11±15	0.00	1	0
	Control	1.93±0.59	1.73±0.65	- 11±16			
Range of Motion- Abduction of the shoulder Based on Goniometric Test (score)	Intervention	93.93±40.20	99.80±39.75	8±7	0.14 (large)	* 0.04	2.15
	Control	102.40±42.59	106.73±42.71	5±4			
Range of Motion- Elbow Extension Based on Goniometric Test (score)	Intervention	111.73±22.51	117.46±22.29	5±3	0.13 (moderate)	* 0.04	2.08
	Control	116.06±24	120.20±23.49	3±1			
Range of Motion- Forearm Supination Based on Goniometric Test (score)	Intervention	33.26±20.32	39±20.26	25±23	0.10	0.09	1.76
	Control	36.80±21.23	41.13±21.80	15±9			
Range of Motion- metacarpal extension of the index finger based on Goniometric Test (score)	Intervention	24.93±16.04	39.13±16.05	17±17	0.01	0.48	0.71
	Control	38.33±17.05	41.93±17.62	11±13			

Abbreviations: 2PD = 2 Point Discrimination; NSA = Nottingham Sensory Assessment; MAS = Modified Ashworth Scale; ROM = Range Of Motion; MP = Metacarpal Phalange (*$p \leq 0.05$)

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Table 2. The mean and percentage of changes in skills, functional and daily activities of life in the intervention and control groups before and after treatment

Variable	Group	Before treatment (Mean±SD)	After treatment (Mean±SD)	Mean changes (%)	Eta Square	P-value	t-test
Gross motor skill based on BBT (number/60s) (score)	Intervention	19.66±9.46	21.10±26.03	8±7	0.15 (large)	* 0.03	2.28
	Control	21.53±9.20	22.9±20.16	3±8			
Fine motor skill based on PPT test (number / 30s) (score)	Intervention	0.73±0.70	1.13±0.74	33±50	0.03	0.46	0.75
	Control	0.86±0.63	1.13±0.63	18±40			
Upper extremity motor function based on Total FMA-UE test (score)	Intervention	34.46±10.84	36.33±10.93	5±4	0.15 (large)	* 0.03	2.24
	Control	37.40±11.23	38.46±11.50	2±2			
Coordination / Speed of the motor function of upper extremity based on the FMA-UE Coordination / Speed test (score)	Intervention	2.73±0.96	3.86±0.91	50±32	0.24 (large)	* 0.005	3.03
	Control	3.13±0.91	3.66±1.04	18±23			
Daily Living Activities-Except ADL / IADL Based on SIS_1 Test (score)	Intervention	44.80±3.91	45.66±4.41	1±2	0.00	0.69	0.40
	Control	45.13±5.26	45.86±5.34	1±1			
Daily Living Activities-Except hand performance based on the SIS_2 Test (score)	Intervention	13.86±3.22	4.53±3.44	5±5	0.02	0.39	0.87
	Control	14.73±3.55	15.20±3.38	3±4			

Abbreviations: BBT = Box-Block Test; PPT = Purde-Pegboard Test; FMA-UE = Fugle-Meyer Assessment-Upper Extremity; ADL = Activity of Daily Living; SIS = Stroke Impact Scale; SIS1 = SIS (item 5); SIS2 = SIS (item 7) (*p≤0.05)

Discussion

The results of this study showed that performing MI exercises with sensory feedback along with conventional rehabilitation exercises improved the range of motion of shoulder abduction and elbow extension, overall performance, gross motor skill, and speed / coordination of upper extremity in patients with chronic stroke. The results of this study showed that the overall performance of the upper extremity, the range of motion of shoulder abduction and elbow extension, as well as the gross motor skill in the upper extremity were significantly improved after MI exercises with sensory feedback, while this improvement was not seen in the fine motor skill. One of the reasons for this is the fact that MI exercises depend on the level of complexity of upper extremity skills; thus, gross motor skills are learned shortly during MI exercises, but fine motor skills require longer MI exercises (24).

Another reason for this difference in the improvement of fine and gross skills may be due to the fact that the movements of the more proximal parts of the upper extremity (such as the shoulder) involve the primary somatosensory cortex and the premotor cortex bilaterally, whereas distal movements of the extremities (fingers) only involve these areas unilaterally (25). Therefore, the movements of the proximal parts (such as the shoulder and elbow) may involve the two hemispheres, and higher involvement in the sensory-motor areas may be the cause of improvement of the shoulder and elbow movements compared to the distal parts. Consistent with the results of the present study, a significant improvement in the overall function of the upper extremity was observed after MI exercises in the study of Kim et al. (3). Craje et al. also showed that MI exercises had a significant effect on the gross motor skill of the upper extremity, but had no effect on fine motor skill (24).

In this study, speed / coordination of upper extremity also improved significantly after MI exercises, which can be justified by the ide motor theory. According to this theory, when predictive sensory feedback of a function is provided for the person before performing the function, that function is cognitively invoked in the mind and it helps the person choose and start the desired function quickly. In activities that require more speed

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and coordination, sensory feedback delays the queuing phenomenon by activating the mental display of the response to be executed (9). In addition, in a study on the effect of MI exercises in stroke patients, a reduction in the duration of the Jebsen-Taylor Hand Function Test was observed after these exercises (4).

In this study, MI exercises with sensory feedback had no significant effect on sensory function (discrimination and proprioceptive sense). The results of a study by Confalonieri et al. showed that during kinesthetic MI exercises, most of the inferior parietal lobule area, bilateral premotor cortex and supplementary motor area are activated and little activity is observed in the primary somatosensory cortex (26). Since MI exercises in this study focused mainly on motor exercises, it is possible that less activity and stimulation are in the primary somatosensory cortex. In this study, there was no significant improvement in sensory function and this is suggested be considered in future studies. In this study, there was no significant change in muscle tone in these patients after receiving MI exercises with sensory feedback, which is contrary to the results of the study by Milton et al., and perhaps this is because of the difference in the use of the assessment tools. In the above-mentioned study, electromyography para-clinical test was used to measure muscle tone, but MAS test was used in the present study (7). There was no significant difference in the scores of activities of daily living between the intervention and control groups, that is, MI exercises with sensory feedback had no significant effect on the total score of the activities of daily living in stroke patients. However, lack of effect on the total score of the test does not necessarily mean that the activities of daily living are not affected by MI exercises, but the length of treatment can have a significant effect.

In fact, it may be possible that repeating the MI exercises in the involved organ may influence the activities of daily living, as suggested in a study by Page et al. on stroke patients (27). It is suggested that further studies be carried out on a larger statistical society with a longer period of training for the stroke patients. The limitations of this study include failure to consider the involved area and the type of stroke (ischemia or hemorrhagic), which may affect the outcome of the study, and it is suggested to be considered in future studies. The results of this study showed that doing MI exercises with sensory feedback along with conventional rehabilitation exercises improved the range of motion in shoulder and elbow movement, gross motor skills and overall motor function, as well as the coordination and speed of movement of upper extremities in patients with chronic stroke.

Conflict of Interest: No conflicts of interest.

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