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Effectiveness of Self-Action Observation Therapy as a Novel Method on Paretic Upper Limb and Cortical Excitability Post-Stroke: A Single-Subject Study

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Abstract

Background: Action Observation Therapy (AOT) is a top-down approach that has been recently introduced in the rehabilitation of neurological disorders mainly after stroke. The main goal of this study was to investigate the effects and feasibility of a new technique in AOT procedure (called self-AOT) following periods of no treatment and routine AOT intervention on upper limb motor function, occupational performance and neurophysiological changes in a stroke patient.

Methods: A single-subject A-B-A-C design was used and a 58-year-old woman with a 3-year history of left hemiplegia poststroke participated in this study. In the baseline (A1, A2) phases, the patient received no treatment. In the first intervention (B phase), she received a 4-week AOT, and in the second intervention (C phase), a 4 week of Self-AOT was practiced. In all phases, upper limb motor recovery as a target outcome was evaluated on 4 occasions using the Fugl-Meyer assessment. Upper limb function, dexterity and spasticity were assessed using Action Research Arm Test, Box-Block Test and Modified Modified Ashworth Scale respectively. Occupational Performance/Satisfaction was assessed with Canadian Occupational Performance Measure and to assess neuroplasticity, Motor Evoked Potential was recorded by Transcranial Magnetic Stimulation. Visual analysis, slope, and percentage of non-overlapping data were used for assessing the changes between phases.

Results: Percentage of non-overlapping data and slopes indicated that motor recovery had clinically relevant improvements after both interventions compared to baselines. Other outcomes also showed improvements except for spasticity of wrist/elbow flexors and Motor Evoked Potential of opponens indicis.

Conclusion: Self-AOT may be as effective as other procedures of AOT for improving upper limb motor function, occupational performance/satisfaction, and cortical excitability post-stroke.

Keywords: Action Observation Therapy, Mirror Neurons, Neuroplasticity, Stroke, Upper Limb

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Introduction

Stroke can lead to sudden disruption and adverse change in performance and engagement of everyday ac-

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↑What is "already known" in this topic:
As an effective and beneficial method, AOT is recently used for stroke rehabilitation. AOT is usually available and inexpensive. Therefore such characteristics have led to more investigations and research on this new method.

→What this article adds:
The feasibility and efficacy of a new procedure for AOT implementation, here called "Self-AOT", was tested successfully. Instead of using another person as a model for filmmaking in this new method, a patient can act as a model for her/himself. According to the results, Self-AOT as like current AOTs, could improve upper limb function and corticospinal excitation in stroke patient.

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tivities (1). About 70-80% of stroke survivors have impairments in their upper limb (UL) (2). Many of them do not regain functional use of the paretic UL, which can affect self-care and also community life participation (3). The patients usually remain dependent on some activity of daily living, which often requires the use of one or both ULs (4). There are new rehabilitation methods to enhance recovery of upper extremity post-stroke such as robotics, brain stimulation, mirror therapy and action observation, although research is still needed to investigate their variant aspects of efficacy (5).

Action Observation Therapy (AOT) is a novel rehabilitation strategy used in patients with neurological disorders such as cerebral palsy, Parkinson's disease, and stroke (6). In this method, some movements and actions of healthy models are shown on a video or a live demonstration; then the patient must try to imitate and execute those actions (7). Neuroscientific studies have claimed that AOT's theoretical basis is on the evidence that observation of goal-directed action (8) activates the Mirror Neuron System (MNS), which is the same neural active mechanism while executing that action (6). Functional connections have been reported between mirror neuron areas and the motor cortex (9). The activation of MNS during the AOT process stimulates cortical motor representations that may lead to the UL motor recovery after stroke (10). According to the literature, there are significant improvements in UL motor function as a result of AOT (7, 8, 11), although the evidence for using this method as an intervention to promote UL motor function was estimated as moderate (7).

To improve AOT effects, this method has been investigated in combination with other treatments such as mental imagery (12), functional electrical stimulation (13), or botulinum toxin injections (14). Although there is not an individual standard protocol for AOT, some research has examined variations in its characteristics, such as showing videos of actions recorded from multiple angles (11, 15) or at different speeds (15). There are also studies that have used simple movements or less meaningful tasks for observation and execution such as thumb adduction/abduction, squeezing a ball or transferring blocks/pegs (16, 17). Although some research has included more complex and goal-directed tasks during AOT, such as working with the computer mouse, turning cards/coins , and drinking a cup of tea (8, 15), there is not sufficient research on the use of selected tasks/occupations by the patients which are more meaningful to them. It is believed that the mirror neuron system is more active when observing a complex and purposeful activity compared to a simple action, so one way for more MNS excitation might be using activities that are in line with everyday activities and based on one's experiences (18). As mentioned earlier, AOT is based on MNS, and if MNS function could be augmented within this technique, it would enrich this new neuro-rehabilitation treatment and contribute to a better motor recovery and performance in paretic UL of stroke patients. Another possible way to improve MNS excitation could be derived from a neuro-rehabilitation method called "Mirror Therapy (MT)" in which the movements of the unaffected limb are reflected in a mirror that is placed in front of the patient and in the mid-sagittal plane. In this process, the brain is deluded and the patient feels that the affected limb is moving. AOT and MT may have some common points and theories but their procedure is different (19). Scarce studies have examined some of the features of the MT technique while implemented in AOT format in stroke patients (19, 20). Nagai and Tanaka reported that in healthy subjects, observing one's own hand provokes more brain activation than observing other's hand (21). Also, it has been pointed out in Bandura's theories of observational learning, that the more a model that resembles the observer performs an activity successfully, the more likely the observer is to perform the activity with success and self-efficacy (22). Therefore, feasibility of using the patients as their own models in AOT process would be a worthy issue to be surveyed.

In this study, the first hypothesis was that AOT, when included in meaningful tasks and occupations selected by the patient, could enhance motor recovery, spasticity, the performance of UL, cortical excitability and also occupational performance/satisfaction. The second and main hypothesis of this study was that if AOT could be modified by using the mirrored videos of the patient practicing goal-directed and meaningful actions with her/his non-paretic UL (While an illusion of moving and activity of the affected side is created), it could improve the outcomes mentioned earlier more than usual AOT. To the best of our knowledge, this is the first study to investigate the feasibility and efficacy of Self-AOT on UL function, spasticity, corticospinal excitability and occupational performance besides the UL motor recovery.

Methods

Experimental design

To show the effectiveness of a novel method of intervention or to compare it with established interventions, Single-Case Experimental Design (SCED) would be a reasonable choice. We used Single-Case Reporting guidelines in Behavioral interventions (SCRIBE) to observe the rigor and quality of the study (23).

To consider the two hypotheses introduced earlier, we selected a SCED with baselines and two phases of interventions. This study examined the benefits of Self-AOT compared to Action observation using an alternate treatment design with A_1BA_2C sequence. The A phases consisted of baseline periods of 2 weeks with no treatments; A_1 before phase B and A_2 between 2 training paradigms (B and C). In the B phase, the subject underwent 12 sessions (3 times per week for 4wk) of AOT (watching and imitating healthy model's task execution videos). In the C phase subject underwent 12 sessions (3 times per week for 4wk) of a new AOT procedure here called Self-AOT (watching and imitating her own task execution videos).

Participant

A 58-year-old woman (E.Z) with right parietal lobe ischemic stroke resulting in left-sided hemiplegia was re-

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cruited from the occupational therapy outpatient service of the rehabilitation faculty. She had a stroke 2 years and 11 months before the study. At the time of recruitment, the subject had severe motor impairments as characterized by a score of 31 out of 66 in the Fugl-Meyer Assessment Upper-Extremity section. She was independent in walking to the research center with the help of a quad-cane, and also, she had the tolerance and ability to sit safely on a chair for the evaluation/intervention sessions. The subject also had an acceptable cognitive state (score of 28 in Mini-Mental State Examination) and no visual problem so she could properly participate in action observation and execution procedure. She was a right-handed native-Persian speaker who had 13 years of formal education and a 4 years bachelor's degree and was retired after 25 years of work as an accountant.

Outcome Measures

All clinical outcomes were evaluated before initiating the baseline A_1, before 4 weeks of AOT (intervention B), before and after 2 weeks of baseline A_2, and immediately after 4 weeks of Self-AOT (intervention C). A follow-up was conducted with 1 measurement occasion, 2 months after the interventions were completed. As the target outcome, during each baseline (A_1 and A_2), UL motor recovery was measured on 4 occasions, 2 times a week. During intervention phases, these evaluations were performed once a week (4 occasions for B and 4 occasions for C phase).

Fugl-Meyer Assessment of Upper Extremity (FMA-UE). FMA-UE is used to measure motor recovery after stroke. The upper extremity domain of this test includes 33 items for UL motor function that are rated based on a 3-point ordinal scale (0=cannot perform, 1=can partially perform, 2=can perform fully). The summation of scores will be a maximum of 66. Construct validity, inter-rater, and intra-rater reliability of this scale have been reported as very good (24).

Canadian Occupational Performance Measure (COPM). COPM is a semi-structured interview to identify patient's problems in the occupational areas (self-care, productivity, and leisure/play) using a 0-10-point Likert scale for scoring. In this study, COPM was used to identify occupational problems and also to measure subjects' perception of their performance and satisfaction with the selected tasks before and after each intervention. The validity, reliability and responsiveness of the COPM are reported as acceptable in many diseases such as stroke (25). An increase of two or more points indicates a minimum of clinically significant change in this outcome measure (26).

Actual Task Performance Assessment. In addition to subjective evaluation and from the patient's point of view, to increase the validity of the data and the results of the interventions, a scale derived from Chedoke arm and hand activity inventory was used as an objective assessment (27). In which eating sub-tasks that were used as training components in the sessions were scored according to the assessor's opinion.

Action Research Arm Test (ARAT). ARAT is an assessment of UL performance developed by Lyle with 19 items divided into four subtests (28). Each item in the subtests including grasp, grip, pinch, and gross movements, is scored with 0, 1, 2, or 3, with higher scores indicating better arm motor performance. If the total scores are summed up in this test, a maximum score of 57 would be gained. The ARAT has been found useful in prior studies evaluating stroke patients across a wide spectrum of impairments. The test has been reported as valid and high Inter-rater and intra-rater reliability have been calculated for ARAT (28).

Box and Block Test (BBT). The BBT is a UL performance measurement and was used to determine gross manual dexterity. The test involves picking up blocks out of a box and transferring them over a wall into the other side of the box. The total scoring is by counting the number of blocks carried over the partition from one side to the other for 60 seconds. The BBT has a very high test-retest and inter-rater reliability (24).

Modified Modified Ashworth Scale (MMAS). The MMAS is used for quantifying spasticity. It has omitted the additional grade of 1+ and redefined grade 2 with the aim of improving the reliability and validity of the MMAS (29). The scoring points are between 0-4: 0 No increase in muscle tone and 4 affected part(s) rigid in flexion or extension. In this study to quantify elbow and wrist flexors, the patient was assessed in the supine position and with standard handlings (30). This scale has been used successfully in clinical trials to evaluate UL spasticity in stroke patients (31). We used the Persian version of MMAS that has as very good reliability in the upper limb (29).

Motor Evoked Potential (MEP). One of the variables related to brain physiology and motor pathways that can be recorded by the Transcranial Magnetic Stimulation (TMS) device is MEP (32). Depending on the brain stimulation area, there would be a recordable MEP produced at the end of the corticospinal pathway, where the target muscles contract. The tendon muscles or finger extensors are usually used for this recording (33). In this study, Central Motor Conduction Time (CMCT) and amplitude were the analyzed findings related to the MEP. To record the MEP using Magstim 200 stimulator the patient had to sit in a quiet room in a special chair (32). Cerebral cortex area M1 and appendix of the seventh cervical vertebra (C7) were selected as stimulation points for Extensor Indicis and Opponens Pollicis as target muscles. About 3 to 5 waves with good reproducibility and high intensity were selected to record the MEP. The CMCT was calculated by subtracting cervical latency from the M1 latency (34).

All clinical assessments were administered orderly by a trained occupational therapist with 10 years of experience. To increase the reliability of assessments, 10 stroke patients were assessed before the main study to check the Inter-Observer Agreement (IOA) between the blind observer and another expert assessor (35). The agreement for the outcomes was more than 80%. A physical medicine and rehabilitation specialist with sufficient experience in the use of TMS assessed the MEP in a separate session from other evaluations. Both assessors were blind to the order of study phases.

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Intervention Protocol

Initially, by using COPM, the participant negotiated to eat as an important occupation (score 8 out of 10 for COPM importance section). Thereby some eating-related tasks such as using a fork, pouring water from a bottle to glass and drinking from a glass with an affected limb (Left side) were selected. In an expert panel consisting of one neuroscientist and 4 occupational therapists working in neurologic rehabilitation settings, based on the evidence and expert opinions, the selected tasks were analyzed and divided into short part sequences of the whole task execution (Table 1).

Afterward a Fujifilm camera X-H1 filmed those actions and tasks while acted by a young, healthy model to prepare the films for intervention 1 (phase B). After providing a final version of the edited video footage, to identify the time required for assessments and to ensure patient safety and technical considerations, a one-week pilot AOT study was conducted with another stroke patient. Then, the main study was initiated with the participant E.Z.

For the second intervention (Phase C), we recorded a video from the E.Z executing the same selected tasks as analyzed previously and within the same technical process. The only difference with the previous videos (shown in phase B) was that the model for the films was the patient herself executing the same tasks (I-IV in Table 1) with her intact UL (Right side). Due to motor learning theories and approaches (36, 37) we provided 3 sessions to observe and practice each task, so a total of 12 sessions were considered for the four tasks. To maintain the effects of the previous practiced task, at the end of each task practice period (after 3 sessions) and at the beginning of the next sessions (for 6 minutes), the previous tasks had been viewed as a complete task and then performed as a whole. For example, the activity I was selected for the first 3 sessions and activity II for the next 3 sessions. Therefore, in the fourth session of study, before observing and performing the components of activity II, whole task observation/execution of activity I should have been performed for 6 minutes (3 minutes observation + 3 minutes execution).

Each of the I-IV activities included functional components that were briefly explained to the patient at the beginning of each of the three intervention sessions. To increase procedural fidelity (23, 35), a written and detailed protocol was provided for the therapist. According to Table 1, the steps followed in each session were as described below:

1) The video of how to perform each component (Part-Task) was played from 3 angles for a total of about 2 minutes (each angle ≈ 3 times).

2) After watching the video (Action Observation) of each activity component, the participant should have performed the same movements and tasks for 3 minutes. If necessary, in addition to monitoring the intervention session, the therapist provided appropriate physical assistance for the patient to complete the activity.

3) Before the end of each session and after observing and performing all the components, the whole task was shown for about 3 minutes in 3 angles (i.e., each angle for 1 minute).

4) After watching the whole task video, the participant should have practiced the same movements and tasks for 3 minutes.

Note that the process of AOT sessions for intervention phases B and C were as same as above with the difference that in phase B, the patient had to watch and imitate videos of a healthy actor (Fig. 1), in contrast, in phase C, the patient had to watch and imitate mirrored videos of herself as if she was practicing the tasks with her affected hand (Fig. 2). The training protocol was led by the first author, who is an experienced occupational therapist in stroke rehabilitation.

Statistical Analysis

In this single case experimental study, visual analysis was used to depict the FMA-UE changes during various phases through graphic data (23). Also, the Percentage of Non-overlapping Data (PND) method was used in which by calculating the results of data points and comparing them with the results of the baseline, it was possible to analyze the increase or decrease in the results. The slope and trend of the data points were estimated and the over-

Table 1. Eating related tasks (I-IV), their subtasks, and the procedure time

Subtask	Task I Pour water from a bottle into a glass	Task II Pour water from pitcher to glass	Task III Drink from a glass of water	Task IV Eat a piece of carrot with fork	AO Film Time	Performance Time
A	Reach to bottle	Reach to pitcher	Reach to glass	Reach to fork	2m	3m
B	Grasp the bottle	Grasp the pitcher	Grasp the glass	Grasp the fork	2m	3m
C	Bring the bottle near to the glass	Bring pitcher near to the glass	Bring glass near to the mouth	Bring fork near to the carrot	2m	3m
D	Pour water into a glass	pour water into a glass	Drink from glass	Bring the carrot to the mouth	2m	3m
E	Reach out to desktop	Reach out to desktop	Reach out to desktop	Reach out to the dish	2m	3m
F	Release the bottle	Release the pitcher	Release the glass	Release the fork	2m	3m
G	Rest arm	Rest arm	Rest arm	Rest arm	2m	3m
H	Whole Task	Whole Task	Whole Task	Whole Task	2m	3m

Note: AO: Action Observation

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Fig. 1. EZ is watching and imitating a video of a Healthy Model (AOT)

Fig. 2. EZ is watching and imitating a video of herself as if she is practicing with her left (plegic) hand in the video

laps and immediacy were also checked (38). To provide an initial baseline (phase A_1), a series of data points were collected before the first intervention (phase B), which was then followed by data points gathered during phase B. After withdrawing the first intervention, data point collection was continued during baseline A2 and also during the second intervention (phase C). All other measurements were just analyzed before and after each phase, by simply comparing the scores.

Results

FMA-UE

The results of UL motor recovery assessed by FMA-UE are shown in Figure 3. The stability of the results is evident in the first baseline (A_1).

The slope in the 1st intervention (phase B) demonstrated change when compared to the baseline phase, and also, according to its PND, it was highly effective for the participant (PND was 100%). Afterward when intervention 1 was withdrawn, in the second baseline (A_2 phase), a de-

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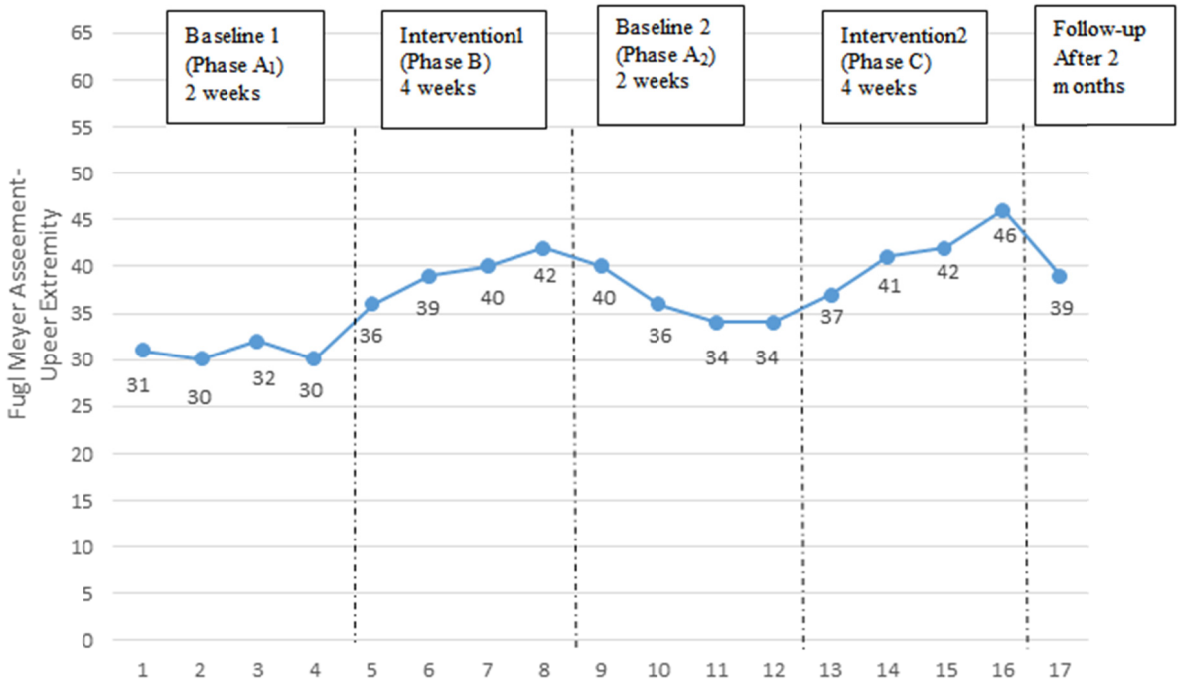

Fig. 3. Multiple data points (17 occasions) for the target outcome measure upper extremity motor recovery (FMA-UE). Trend of changes in phases A_1, B, A_2, C.

crease in the results was seen toward the level of the first baseline. Once again, during intervention 2 (phase C), the client demonstrated a slope in UL motor recovery with a tendency toward improvement with a best FMA-UE score attained during all phases of the study (46/66). The PND of intervention 2 (phase C) was also 100% compared to the first baseline. We cannot calculate an exact PND for intervention 2 compared with the second baseline because of no certain data stability in the second baseline prior to phase C. The estimated slopes of A_1, B, A_2 and C phases were 0.25, 1.75, (-)2 and 2.5, respectively. As a final motor recovery result, after two months of follow-up, a mild decrease in the score is reported (FMA-UE=39).

The results of other outcome measures before and after each intervention are presented in Table 2.

Table 2. Results of outcome measures before and after intervention 1 and 2 and also after 2 months follow-up

Outcome measures			Prior to Intervention 1	After intervention 1	Prior to Intervention 2	After Intervention 2	Follow-up
FMA-UE	Arm		18	28	23	27	22
	Wrist		2	4	2	6	4
	Hand		5	5	4	8	8
	Coordination		5	5	5	5	5
	Total		30	42	34	46	39
COPM (Performance)			2	7	8	10	10
COPM (Satisfaction)			3	8	8	10	10
Actual Task Performance score	Task 1 (pouring water)		1	2	2	4	4
	Task 2 (drinking from glass)		1	2	2	3	3
	Task 3 (fork)		1	3	3	4	4
	Task 4 (cutting meat)		1	2	2	4	4
ARAT	Grasp		1	10	12	17	14
	Grip		2	2	2	2	2
	Pinch		0	0	0	0	0
	Gross Movement		3	4	3	5	3
	Total		6	16	17	24	19
BBT			7.33	10	7.66	10.30	10
MMAS (Elbow flexors)			2	2	2	2	1
MMAS (Wrist flexors)			3	2	2	2	2
MEP (Opponenens Policis)		CMCT	11.40	11.60	10.80	11.10	
		Amplitude	0.80	1.20	0.60	0.80	N/A
MEP (Extensor Indicis)		CMCT	11.90	10.20	9.20	8.90	
		Amplitude	0.20	0.40	0.40	0.60	N/A

Note: COPM: Canadian Occupational Performance Measure, FMA: Fugl-Meyer Assessment, ARAT: Action Research Arm Test, MMAS: Modified Modified Ashworth Scale, MEP: Motor Evoked Potential, CMCT: Central Motor Conduction Time N/A: Non-Applicable

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COPM

Changes before and after both treatments were equal to or greater than 2 COPM scores, which clinically indicate the effectiveness of the treatments used (26). The extent of increase after the first intervention was more than the changes calculated for the second intervention. However, this might be as a result of maintained effects of intervention 1 even after withdrawing the first intervention.

Actual Task Performance

All the 4 tasks assessed show an increase of 1-2 scores before and after both interventions without an obvious superiority between two interventions Table 2.

ARAT

ARAT had an increasing score in both B and C stages, without any decline in time between the two interventions.

BBT

In contrast to ARAT, a decrease in results of BBT after intervention 1 is seen.

MMAS

There was no change in elbow flexors spasticity before and after both treatments. And the only change in elbow extensors was a 1 score decrease pre-post B phase among all phases.

MEP

MEP of opponens' muscle did not show a significant improvement although CMCT and amplitude related to the MEP of extensor indices muscle were slightly improved.

Discussion

Effects on FMA-UE

The effect of AOT interventions on UL motor improvement has been reported in previous studies (8, 15) , which mostly used predetermined activities in their procedure. With the aim of making the intervention more purposeful and cooperative for the patient, in the present study, the patient-selected activities were used in planning and arranging AOT sessions. As like as most routine AOT studies (11, 39, 40), individualized and patient-selected action observation also improved the patient's UL motor recovery (FMA-UE) in the first phase of the intervention with a 12-point change, which is clinically important according to the minimal clinical important detectable change of FMA-UE test. This rate of change considering the stability of the initial baseline possibly indicates the effectiveness of 1st intervention.

After 4 weeks of AOT, during the 2nd Baseline (A_2), the decrease in FMA-UE scores shows that the effect of the first treatment (AOT) was discontinued. FMA-UE scores were not stable after 1st intervention withdrawal (AOT), although these scores had not declined to the level before intervention. After the 2nd baseline, Self-AO had similar improving effects on motor recovery.

Considering the PND (=75%) and the 12-point changes of FMA-UE in phase C compared to phase A_2, it can be stated that this new method (Self-AO) has acceptable effectiveness. Comparing the first and second interventions (B and C), since the slope of changes in the process of the first and second interventions was 1.75 and 2.5, respectively, it can probably be reported that Self-AOT caused a change in FMA-UE slightly more than AOT, which to ensure this further claim research is needed in the form of stronger evidence such as randomized control trials.

The decrease in the UL recovery score during the 2 months follow-up was lesser than the 2 weeks of baseline A_2. Therefore, it might be said that Self-AO had a more lasting effect than the routine AOT. Among FMA-UE subscales, most sections had improvements during both interventions except the coordination subscale. The cause might be that the observed and practiced eating tasks were not speed-dependent and could not enhance the time assessed in this subscale.

Effects on COPM

According to change in COPM scores, patient's occupational performance and satisfaction show an increasing trend in both intervention phases. This is in line with the theory and evidence that the more functional and meaningful the intervention, the better the occupational performance/satisfaction results (36). The maintenance and durability of the COPM scores after withdrawing the interventions were remarkable. However, this maintained effect after treatment 1 (during phase A_2) limits a definite comparison between Self-AOT and AOT.

Effects on Actual Task Performance

The results of tasks evaluation rated by the assessor were completely in line with COPM scores and indicated the potential usefulness of both interventions. It should be noted that there is a difference between the level of patient performance scores from her own point of view (via COPM) and that of the assessor, but both have reported positive trends. This mismatch between perceived performance and actual performance scores has been reported in a previous study (41).

Effects on BBT

To some extent, the trend of changes in BBT outcomes was similar to the FMA-UE trend and had positive changes after both intervention periods. A similar effect on BBT is reported in recent related research (15, 39, 40). Like FMA, the BBT outcome measure decreased after withdrawing the first intervention, although this drop was lesser after the second intervention and at the time of follow-up evaluation.

Effects on ARAT

Considering the changes in ARAT (Table 2), it can be stated that both AOT and Self-AOT probably have beneficial effects on ARAT, mainly on the grasp and gross movement sub-categories. This might be due to the form

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of tasks (I-IV) used in the interventions that are not focusing on pinch and grip skills. In contrast to BBT and FMA, no decrease in ARAT total scores was reported during baseline 2. This might be explained by the relation between extensor indicis MEP improvements and ascending scores of ARAT's grasp sub-test during the research phases. The grasp section of ARAT is mainly about grasping and releasing different sizes of blocks; the larger the blocks the more finger extension is needed. So, the results of the grasp section might be approved by descending trend of extensor indicis MEP as a representative for extensor muscles improvement.

Effects on MMAS

In the case of spasticity in the elbow and wrist flexor muscles, no specific change is reported in our results. In a survey comparing an AOT group with a control group of patients with sub-acute stroke, Kim and colleagues (15) couldn't report a significant difference in spasticity reduction between the two groups. Similar to the tasks used in our research, the tasks exercised in Kim's study were some routine tasks. One way to reduce spasticity is repetitive and dynamic stretching (42), and although during routine daily activities, many muscles may be elongated they generally don't reach the maximal length and probably do not improve in muscle tone. So without any adjunct techniques for managing spasticity, observation and execution of eating activities and other daily activities routine tasks may not affect spasticity. In contrast to the present study, in a clinical trial, Zhu et al. reported a significant spasticity reduction after AOT. Besides the observation of tasks in the AOT group, they provided a combination of simple but multi-joint movements such as fingers adduction/abduction and forearm supination/pronation that might have been the reason for spasticity improvement in both groups (8).

Effects on motor evoked potentials

There are a few studies that investigated the MEP after AOT as an outcome measure of cortical representation (16, 39). The results of the present study in MEP latency of Extensor Indices showed a gradual and lasting decrease during the interventions, although the change in MEP of opponents' muscles was not interpretable. Clenik et al. (16) stated a significant effect on corticospinal excitability when thumb movements are in congruence with the thumb movement's video seen in the action observation process. In another study, Fu et al. (40) showed that when combined with traditional rehabilitation, AOT could increase MEP amplitude and also decrease the MEP latency. In our work, although the muscles used for recording the corticospinal excitability were not as same as the muscles assessed in the mentioned studies, in one of two muscles evaluated Extensor Indicis, similar results were seen. Opponenens Policis muscle didn't show a certain MEP change trend.

Limitations and suggestions

In the present study, although there were limitations such as having just one participant, lack of control group, and non-random order of interventions, the results can approximately confirm the effectiveness of Self-AOT in the range of AOT effectiveness. In variables such as FMA-UE, the Self-AOT slope and changes were even greater and more significant than the AOT intervention. With regard to the spasticity, only wrist and elbow flexors were evaluated, so it is suggested to consider the fingers spasticity in future research. Since washout periods in outcome measures such as COPM are not operational, and the effect of learning is likely to affect task repetitions and practice at home and consequently the results, it is not possible to state with certainty that the second intervention is superior to the first one. If randomized clinical trial research with an appropriate sample size is performed on these two types of interventions, their effectiveness can be compared more accurately.

It can be proposed that in situations where it is not possible to make films from healthy models and spend time preparing multiple films, the Self-AOT method is probably a proper choice because, with the assistance of family or therapist, many patient-selected activities can be filmed from the non-affected side and in preferred setting within a short time. The exercise and movement videos of his/her healthy side can be mirrored and edited via a simple technique that is available in most mobile phones and computers. Although this technique has some similar aspects to mirror therapy, and they both tend to make visual illusions and to trick the brain but they have their own uniqueness. In MT because of the size and the situation of the mirror box, the patient may be limited to watch and perform some desktop tasks through 1 angle and cannot see her/his whole body situation. In contrast, Self-AOT can provide more complicated and routine tasks such as hair combing, tooth brushing and such tasks in which other body parts may be needed to be seen from different angles. Besides, MT is based on live demonstrations of the patients' intact hands via a mirror box, but Self-AO is recorded and can be watched anytime and anywhere just by using a TV, Lap tab or smartphone.

Besides continuing research on Self-AO with more strong study designs, it is suggested to apply and test this technique in new technologies and approaches such as virtual reality or game therapy.

Conclusion

This study shows that if a patient with stroke is filmed while performing meaningful activities with her/his healthy side and then mirrored versions of those videos are shown and practiced in the form of Self-AOT, it may improve occupational performance/satisfaction and cortical excitability as well as UL function. Self-AOT as a new approach to the action observation process seems to be as effective as previous AOT methods, although it may raise more cooperation and enthusiasm for the patient watching and imitating her/his own videos.

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Compliance with ethical guidelines

This study was ethically approved by the Ethics Committee of Iran University of Medical Sciences (IUMS), Tehran, Iran (Ethical Code: IR.IUMS.REC.1397.840). The subject signed a written informed consent before participating in this study.

Conflict of Interests

The authors declare that they have no competing interests.

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