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Original Article

The effects of action observation training and mirror therapy on gait and balance in stroke patients

Ho Jeong Lee, MS, PT[1)], Young Mi Kim, PhD, PT[1)*], Dong Kyu Lee, MS, PT[1)]

[1)] *Department of Rehabilitation Science, Graduate School, Daegu University: 201 Daegudae-ro, Jillyang, Gyeongsan-si, Kyeongbuk 712-714, Republic of Korea*

Abstract. [Purpose] The aim of this study was to evaluate the effects of action observation training and mirror therapy to improve on balance and gait function of stroke patients. [Subjects and Methods] The participants were randomly allocated to one of three groups: The action observation training with activity group practiced additional action observation training with activity for three 30-minute session for six weeks (n=12). The mirror therapy with activity group practiced additional mirror therapy with activity for three 30-minute sessions for six weeks (n=11). The only action observation training group practiced additional action observation training for three 30-minute sessions for weeks (n=12). All groups received conventional therapy for five 60-minute sessions over a six-week period. [Results] There were significant improvements in balance and gait function. The action observation training with activity group significantly improved subjects' static balance. The action observation training with activity group and the mirror therapy with activity group significantly improved subjects' gait ability. [Conclusion] The activation of mirror neurons combined with a conventional stroke physiotherapy program enhances lower-extremity motor recovery and motor functioning in stroke patients.

Key words: Action observation training, Mirror therapy, Balance

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INTRODUCTION

Action observation training is based on mirror neurons that fire when one performs movements or observes the movements of others; it is a cognitive intervention method applied to improve motor skills and learning in athletes, ordinary people, and patients with motor disorders[1, 2)].

Sensory motor disorders in post-stroke patients during observation of motor action have caused changes to the adjacent cortical penumbra area[3)]. Hemiparesis has been treated with mirror therapy which encourages cortical changes[4)].

As another intervention method using the activation of mirror neurons, Ehrsson et al.[5)] presented visual optical illusion as a cognitive intervention method to promote the recovery of stroke patients' motor functions. Thirumala et al.[6)] verified the effects of mirror therapy using mirror neurons by showing that when upper limb and hand movements were observed through a mirror, the excitement of the primary motor area and bilateral inferior parietal lobe increased.

Based on findings that a combination of the observation and performance of actions made the mobilization of the brain structure's functional internal connection more efficient[1, 2)]. Brain activation increased when observed motions were actually performed rather than merely observed[7)]. It is important to practice and learn observed actions[8)]. This study intended to examine the effects of cognitive interventions like mirror therapy training and motion observation training on stroke patients' balance and gait.

*Corresponding author. Young Mi Kim (E-mail: h1015m@naver.com)

SUBJECTS AND METHODS

Stroke patients were recruited based on referrals from clinicians in an inpatient rehabilitation hospital. 35 stroke patients were selected as the sample, which was randomly and evenly divided into three groups: (1) the action observation therapy with activity (AOTA) group (n=12), (2) the mirror therapy with activity (MTA) group (n=11), and (3) the action observation therapy (AOT) group (n=12). The inclusion criteria included (1) more than six months post-injury, (2) the ability to walk 10 m independently without aid, (3) a Mini Mental State Examination (MMSE) score of 23 or higher, and (4) no visual perception deficits.

Individuals were excluded if they had an orthopedic disorder that could interfere with the experiment, neglect of space on the affected side, or any other neurologic disease or auditory or visual deficit that could prevent data collection.

For the AOTA group, the average age was 62.8 ± 7.4 years, the average height was 165.3 ± 6.9 cm, and the average weight was 68.3 ± 9.7 kg. For the MTA group, the average age was 57.27 ± 5.7 years, the average height was 165.6 ± 6.6 cm, and the average weight was 61.8 ± 10.6 kg. For the AOT group, the average age was 59.8 ± 6.7 years, the average height was 162.2 ± 8 cm, and the average weight was 59.9 ± 10.6 kg. Using Levene's variance homogeneity test and a normality test on the general physical characteristics, no statistically significant difference was found between the three groups ($p>0.05$). The Daegu University Research Ethics Board approved the study protocol, and all the subjects gave their informed consent.

The training program was conducted three times per week, for six weeks, from March to July 2014. The AOTA group conducted action observation using a video for 15 minutes a day and physical training of the same motions as the observed ones, for 15 minutes a day. The MTA group received mirror therapy for 15 minutes a day and physical training of the same motions without a mirror for 15 minutes a day. The AOT group conducted action observation only, without physical training, for 30 minutes a day. The three groups received general physical therapy twice per week for 30 minutes per day.

For action observation training, a mirror therapy program by Sütbeyaz et al.[9] was modified and complemented. Dorsiflexor training was composed of three stages according to the level of difficulty, and action observation training consisted of three stages; each stage was conducted six times for two weeks. All training was conducted active assistive exercise with physical therapist. The first stage was composed of knee joint extensor and dorsiflexor training. The second stage consisted of knee joint flexor and dorsiflexor training. The third stage was comprised of hip and knee joint flexor and dorsiflexor training.

For mirror therapy training, a mirror with width and length were 50 cm and 70 cm, respectively, and a step board whose height, width, and length were 20 cm, 60 cm, and 50 cm, respectively, were employed. The subjects flexed their knees at 90 degrees on a chair with their back and arms in a comfortable position, and to receive visual feedback only with the non-paretic leg on the mirror, the mirror was placed on the paretic side and the step board was arranged in front of the non-paretic lower limb. Step board was used to reflect the non-paretic side properly. Their training program consisted of three steps including the same motions as those of the action observation training.

The AOT group sat comfortably in an arm chair and watched a video of motions performed by other people through the monitor installed 1 m away from them. To minimize deviations among individuals, the front and lateral side videos were produced separately for the left and right hemiplegic subjects. While viewing the video, the subjects were asked not to follow the content of the video or move, and the therapist encouraged the subjects to concentrate on the content of the video.

To assess balance index, the Biodex Balance System (BBS, SD, Biodex Inc., USA), a type of balance measuring equipment, was used. In this study, postural stability and fall risk were used to measure the static and dynamic balance indexes, respectively. The Modified Functional Ambulation Profile (mEFAP) is used to evaluate task-specific gait ability and to measure the walking time taken to perform the five tasks in different environments. Interrater reliability for the total E-FAP was≥0.997.[10] The different tasks consist of walking 5 m on a hard and even ground surface, walking 5 m on carpet, getting up from a chair, walking 3 m, and then sitting in the chair, crossing a structuralized obstacle course, and climbing up five stairs. The descriptive statistics, tests for normality (Shapiro-Wilk Test), and homogeneity of variance were calculated as the outcome variables using SPSS 21.0 software for Windows. A paired t-test was used to determine pre- and post-experiment differences, and one-way analysis of variance was performed to investigate intergroup differences. The least significant difference (LSD) was used for post-hoc analysis. The significance level was set at 0.05.

RESULTS

The Overall Balance Index (OBI) significantly decreased in the AOTA group ($p<0.05$), did not significantly decrease in MTA group, did not significantly differ but increased in the AOT group, and no significant difference was found between the groups ($p>0.05$). The Anteroposterior Balance Index (ABI) significantly decreased in the AOTA group ($p<0.05$), did not significantly differ but increased in the MTA and AOT groups, and no significant difference was found between the groups ($p>0.05$). The Mediolateral Balance Index (MBI) did not significantly differ but decreased in the AOTA, MTA, and AOT groups, and no significant difference was found between the groups ($p>0.05$). The fall risk did not significantly differ but decreased in the AOTA group and MTA group, did not significantly differ but increased in the AOT group, and no significant difference was found between the groups ($p>0.05$).

Table 1. The comparison of means for variables between pre- and post-values for the three groups (Unit: score)

	Variables	AOTA		MTA		AOT	
		Pre-value	Post-value	Pre-value	Post-value	Pre-value	Post-value
Balance	OBI	2.3 ± 2.0	1.2 ± 0.8*	1.2 ± 0.5	1.1 ± 0.7	1.4 ± 0.9	1.5 ± 0.9
	ABI	1.3 ± 1.0	0.6 ± 0.5*	0.8 ± 0.5	0.9 ± 0.7	0.8 ± 0.5	0.9 ± 0.5
	MBI	1.4 ± 1.7	0.8 ± 0.6	0.5 ± 0.3	0.5 ± 0.3	1.0 ± 0.7	0.9 ± 0.7
	FR	2.8 ± 1.4	2.3 ± 0.5	2.6 ± 0.6	2.1 ± 1.0	2.5 ± 1.1	2.9 ± 1.0
Gait	mEFAP	102.2 ± 45.5	54.2 ± 41.4*	74.0 ± 35.0	60.0 ± 22.8*	118.1 ± 60.0	101.4 ± 50.5

*Significantly different between pre and post (p<0.05)
OBI: Overall Balance Index; ABI: Anteroposterior Balance Index; MBI: Mediolateral Balance Index; FR: fall risk; mEFAP: Modified Emory Functional Ambulation Profile

The mEFAP significantly decreased in the AOTA and MTA groups (p<0.05), did not significantly differ but decreased in the AOT group, and no significant difference was found between the groups (p>0.05) (Table 1).

DISCUSSION

AOTA significantly improved subjects' static balance based on the OBI and ABI.

Hiyamizu et al. divided their subjects into a group that observed others' motions and mimicked them, a group that observed their own motions and mimicked them, and a group that performed motions only without any observation and applied balance training on a level surface to the three groups. They found a significant improvement in the balance of those who observed their own motions and training them[11]. Such result is considered to be because dorsiflexion movement stimulated proprioceptors within the muscles and tendons, improving proprioceptive senses, thereby ameliorating damaged functions, and increasing anteroposterior stability, thereby having a positive effect on static balance ability. This is consistent with prior reports that the movement of the ankles among the lower limbs plays an important role in balance recovery[12] and strategies to maintain anteroposterior stability included ankle, hip, and stepping strategies[13].

The FR did not significantly differ in all groups. In a study by Cha et al. whose subjects were 20 stroke patients, the subjects performed task-oriented exercises five times per week, twice a day, for four weeks and there were significant improvements in static and dynamic balance indexes[14]. There was an increase in dynamic balance ability in the AOTA and MTA groups, without statistical significance, however. In that an exercise program for balance improvement should be dynamic and related to actual functions[15], the video in the present study did not greatly affect subjects' dynamic balance ability because it was composed of static movements in a sitting posture, not dynamic movements moving the center of gravity with the application of weight.

Nonetheless, AOTA and MOT significantly improved subjects' gait abilities, as demonstrated by their mEFAP outcomes, supporting the findings of several previous studies. In a study by Park et al., 21 stroke patients were divided into a control group (11 subjects) that observed a landscape and an experimental group (10 subjects) that observed gait motions 30 minutes per day, three times per week, for four weeks. Then, they showed significant differences in a 10-m walking test, a figure of 8 walking test, the dynamic gait index, and stance phase, swing phase, and stride, which are gait asymmetry scores[16]. In a study by Sutbeyaz et al. whose subjects were sub-acute stroke patients, mirror therapy training was applied where their ankles were dorsiflexed 30 minutes per day, for five days per week, for four weeks. The experimental group saw their Brunnstrom stage and functional independence measure (FIM) score significantly improve. They reported that a combined method of mirror therapy training and general physical therapy may strengthen a stroke patient's lower limb motor function and recovery of motions.[7] In a study of 34 sub-acute stroke patients to whose lower limbs mirror therapy training and virtual therapy were applied, Ji and Kim presented that mirror therapy was an applicable intervention to improve the lower limb functions of stroke patients by verifying that the mirror therapy group saw their single support, step length, and stride significantly improve.[17]

Based on previous research results and a report[18] that motor memory was formed in a group when action observation and actual training of such images were conducted, but motor memory was not formed in a group that was trained with the same motions but observed other images, the present findings also indicated that observing and performing motions repetitively would have enabled motor learning by activating mirror neuron cells. In addition, the physical training of performing the same motions after their observation strengthened the recovery of the damaged areas by adding elements of action performance to motion observation and may have more greatly affected the recovery of the patients' abnormal brain activity and functional recovery. A limitation of this study was that it utilized a small number of participants, and it was not confirmed that the positive effects persisted.

In conclusion, AOTA improves static balance and gait function, and MOT improves gait function. Mirror neuron activation combined with a conventional stroke physiotherapy program enhances lower-extremity motor recovery and motor functioning in stroke patients. The effect is enhanced when the action is executed following observation. Furthermore, research should be done using mirror neuron activation to develop methods to improve the gait function and balance of stroke patients.

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