Effects of Action Observation Training on Grip and Pinch Strengthening in Chronic Stroke Patients

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Purpose This study aims to examine the effects of the muscle strengthening exercises combined with action observational physical therapy (AOPT) as a treatment for muscle weakness, a major damage in stroke patients. ***Methods*** A total of 18 chronic stroke patients consisted of nine patients with right hemiplegia and nine patients with left hemiplegia, who had passed at least 12 months from the onset, were selected as the subjects of this study among the patients admitted to the B rehabilitation hospital located in Gyeonggi-do. The subjects of this study were randomly divided into the test action observational grip and pinch strengthening (AOGPS) group and Imaginary grip and pinch strengthening (IGPS) group. Each group performed grip and pinch strengthening through different interventions. In order to evaluate the improvement in hand muscle strength, the hand grip and pinch strengthening was measured with the JAMAR Hydraulic Hand Dynamometer, Jamar Hydraulic Pinch Gauge in this study. ***Results*** As for the comparison of the changes in the grip and pinch strength before and after intervention between the two groups, the change in hand grip was the AOGPS group and the IGPS group, indicating a statistical significance(**$p<0.01$). The change in the lateral pinch also demonstrated a statistical significance (***$p<0.001$) between the AOGPS group and the IGPS group. ***Conclusion*** This study aimed to examine whether the AOGPS training was effective in improving muscle strength, and the AOGPS training was found to be effective in improving the hand grip and pinch strength.

Key Words Action observation physical therapy, Grip, Pinch, Strengthening, Stroke

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Ⅰ. Introduction

Neurological disorders caused by damage to upper motor neurons include muscle paralysis and muscle weakness, and a typical disease is stroke. Stroke-induced muscle weakness is closely associated with loss of agility, coordination disorders, and balance and gait disorders.

From the traditional clinical point of view of stroke rehabilitation training, control of the abnormal muscle tone and stiffness was the most important factor in rehabilitation, and resistance training was assumed to increase stiffness. However, recent studies reported that strengthening of muscles was not associated with increase in stiffness, and that active muscle strengthening exercises rather reduced stiffness and improved daily life performance.[1,2]

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Normal muscle strength can be explained by factors such as the number of motor units mobilized, discharge and firing rates of the motor units, and frequency, and stroke has been reported to cause muscle weakness and muscle paralysis due to an absence of these factors.[3] As for muscle weakness, evidence is being suggested that stroke is accompanied by muscle atrophy, and damage of descending tract is reported to result in muscle weakness and loss of coordination ability due to a reduced number of active motor units, a reduced firing rate of the motor units, and a reduced number of motor units available for recruitment.[4,5] In terms of functionality, muscle weakness causes impairment in dexterity, the ability to perform certain tasks accurately and quickly, and such impairment in dexterity mainly causes dysfunction in manipulation of tools due to insufficient coordination of muscle activity and impaired timing of muscle contraction.[6] In general, for muscle weakness, although there could be differences depending on the neuromuscular system of each individual and the adaptation to the environment, the location and degree of damage are the most important factors, and the enhancement of muscle performance through active strengthening of muscles is crucial for more successful neurorehabilitation.[3)]

Recently, the Action Observation Physical Training (AOPT) is the treatment method proposed as a new alternative to motor learning in neurorehabilitation. AOPT is not only applied for the motor learning of normal people,[7)] but also applied for stroke patients,[8)] patients with Parkinson's disease,[9)] children with cerebral palsy,[10)] and patients with orthopedic diseases to understand and learn motions, boasting a wide range of use in clinical practice.[11)] Active research is conducted on AOPT focusing on the mirror mechanism.[12)]

AOPT is based on the mechanism of mirror neurons. Mirror neurons were discovered in the early 1990s at the University of Parma in Italy as these special brain cells were found in macaque monkeys, and they have been found in humans as well.[13)]

Mirror neuron system (MNS) is characterized by the firing of the neurons in same area of the observers when they observe another individual performing a complex task, first discovered in area F5 of macaque monkeys.[13)] The neurons in area F5 have been reported to be more actively fired when performing a motor task; when observing the performance of a motor task; when observing a matched motion; when observing an experienced or meaningful motion; or when observing a motion of interest. MNS is an area currently known to be associated with the movement of the human mouth, hands, and feet, and it is also involved in understanding of motion, learning and imitation of complex motion, and internal rehearsal of motion such as motor imagery.[14,15)]

Furthermore, in recent studies, MNS has been reported to respond to the facial expressions, voices, and body expressions of others, and these mirror neurons are easily fired by experience and are known to be closely associated with perception or cognition.[12,16)]

AOPT is being proposed as an innovative alternative in neurorehabilitation as it is most important to promote the circuit of sensory-motor execution in neurorehabilitation, and mirror neurons generally respond to perceive and act, thereby activating the neurons in various motor areas of the cerebrum while observing the motion of others. Since mirror neurons can control damaged motor neurons based on visual sensory stimulation and act as an important interface for communication between the external environment and the patient, AOPT in more complex situations during motor learning can promote the execution of motion.

Therefore, this study aims to examine the effects of the muscle strengthening exercises combined with AOPT as a treatment for muscle weakness, a major damage in stroke patients.

II. Material and Methods

1. Subjects

A total of 18 chronic stroke patients consisted of nine patients with right hemiplegia and nine patients with left hemiplegia, who had passed at least 12 months from the onset, were selected as the subjects of this study among the patients admitted to the B rehabilitation hospital located in Gyeonggi-do. The criteria for selecting subjects were as follows.

1) Those with no cognitive impairment scoring 24 points or higher in the Korean version of Mini-Mental Status Examination
2) Those who can understand and imitate motions during AOPT
3) Those with no abnormality in sight and hearing
4) Those who can measure grip strength and pinch strength with JAMAR® hand dynamometer

This study was conducted after explaining the purpose and methods of study to the subjects and receiving their consent to participation.

2. Experimental Methods

The subjects of this study were randomly divided into the experimental group and the control group. Each group performed grip and pinch strengthening through different interventions.

1) Action Observational Grip and Pinch Strengthening (AOGPS)

For the AOGPS group, the test group of this study, the video of the therapist performing the grip and pinch training with the JAMAR® hand dynamometer while sitting down filmed at a 45-degree angle in the front and side was presented to the subjects so that they can watch the grip and pinch strengthening training motions simultaneously. The AOGPS group watched the grip and pinch training video played at the normal speed and at a speed twice as slow for five minutes, and carried out the grip and pinch strengthening training for 10 minutes, which was repeated twice for a total of 30 minutes per session, three sessions per week for three months. (Figure 1)

2) Imaginary Grip and Pinch Strengthening (IGPS)

The IGPS group, the control group of this study, imagined the grip and pinch motion for five minutes, and carried out the grip and pinch strengthening training for 10 minutes, which was repeated twice for a total of 30 minutes per session, three sessions per week for three months.

3. Measuring Methods and Tools

1) Posture for Measurement

The grip test was performed while the subjects were sitting down comfortably with their back straight in a chair with a backrest according to the method of Kellor et al. (1971).[17]

The subjects were asked to bend their elbow joint by 90° with the shoulder and elbow joints attached to the torso while holding the JAMAR Dynamometer with their wrist in a neutral position. The tester supported the JAMAR Dynamometer with a hand from the bottom to prevent the movement of the instrument while the therapist demonstrated the motion for the test, and encouraged the subjects to exert their utmost power following the verbal instructions of the therapist. The subjects were allowed to take a rest for two minutes after each measurement, and the average of the three measurements was used to increase the reliability. The JAMAR Dynamometer tests were carried out twice in total, before and after the study.

2) Measurement of Hand Grip and Pinch Strength

In order to evaluate the improvement in hand muscle strength, the hand grip and pinch strengthening was

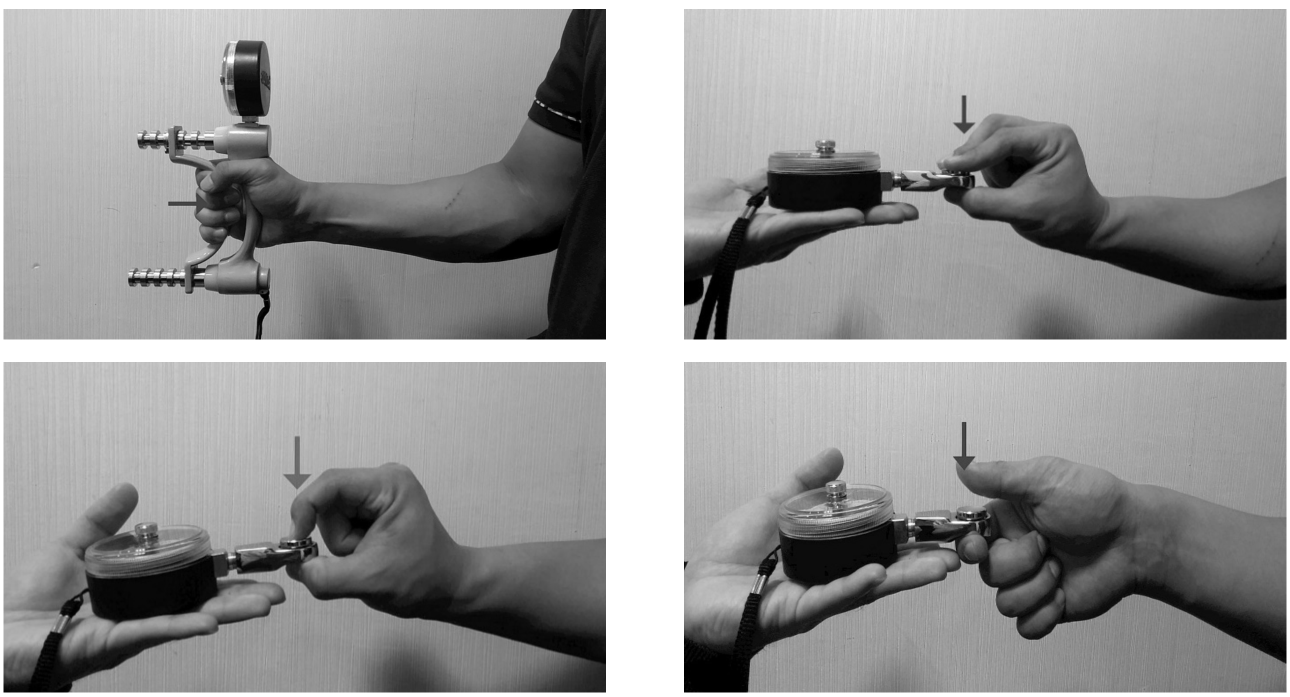

Figure 1. Action observational grip and pinch strengthening video screen

measured with the JAMAR Hydraulic Hand Dynamometer (Sammons Preston, Co., IL 60673-3040, USA), Jamar Hydraulic Pinch Gauge(Sammons Preston, Co., 749805, USA) in this study. The JAMAR Hydraulic Hand Dynamometer is a clinical test tool for therapists, which allows quick and convenient measurement of the hand strength in stroke patients. The JAMAR Hydraulic Hand Dynamometer has an accuracy within ±7%, with reliability of r=0.88 between test and retest (r=0.88) and reliability of r=0.99 between testers. The validity test result between the grip muscle strength and the manual muscle testing using the JAMAR Hydraulic Hand Dynamometer demonstrated a significant correlation.[18,19)]

4. Data Analysis

The SPSS version 20.0 for Windows was used for the statistical analysis in this study.

The general characteristics of the subjects were calculated as the mean and standard deviation by descriptive statistics. As a result of the Shapiro-Wilk test, it did not meet the normal distribution, and a non-parametric test was performed. The Wilcoxon signed-rank test was performed to determine the difference between before and after training in each group, and the Mann-Whitney U test was performed to compare the mean value differences before and after training for the two groups. The statistical significance level was set to α=.05.

Ⅲ. Results

1. General Characteristics of Subjects

In this study, 18 subjects were selected and randomly divided into nine in the AOGPS group and nine in the IGPS groups. The general characteristics of the subject were as follows. (Table 1)

2. Comparison of Changes in Grip and Pinch Strength in Each of the AOGPS and IGPS Groups

The comparison of the changes in grip and pinch strength in each of the two groups in this study was as follows. (Table 2)

Looking at the changes in the grip and pinch strength before and after intervention in each group, in the AOGPS group, the hand grip increased from 17.70kg before study to 18.76kg after study (*$p<0.05$); the lateral pinch increased from 5.72kg to 6.52kg (**$p<0.01$); the 3-jaw pinch increased from 3.63kg to 4.44kg (**$p<0.01$); and the tip pinch increased from 2.41kg to 2.98kg (*$p<0.05$), demonstrating an overall increase in the average values. In the IGPS group, the

Table 1. General Characteristics of the Subjects

Variables		AOGPS (n=9)	IGPS (n=9)
Gender	Male	5	4
	Female	4	5
Age (year)		62.22±14.46	63.11±12.45
Weight (kg)		65.6±7.44	67.81±8.79
Lesion type	Hemorrhage	6	5
	Infarction	3	4
Paretic side	Right	5	4
	left	4	5
Time from stroke to rehab (months)		19.22±5.31	18.88±3.94

M±SD: M: mean, SD: standard deviation, AOGPS: action observational grip and pinch strengthening, IGPS: Imaginary grip and pinch strengthening, *$p<.05$

Table 2. Comparison of grip and pinch strength before and after intervention in the groups

			After intervention M±SD	z	p
AOGPS (N=9)	Grip (kg)	17.70±3.46	18.76±3.51	-2.527	0.012*
	Lateral Pinch (kg)	5.72±1.27	6.52±1.34	-2.670	0.008**
	3-jaw Pinch (kg)	3.63±1.10	4.44±0.77	-2.670	0.008**
	Tip Pinch (kg)	2.41±1.21	2.98±1.18	-2.524	0.012*
IGPS (N=9)	Grip (kg)	17.69±4.07	17.85±4.05	-2.251	.024*
	Lateral Pinch (kg)	4.41±0.88	4.52±0.87	-2.449	.014*
	3-jaw Pinch (kg)	3.72±1.42	4.37±1.67	-2.539	.011*
	Tip Pinch (kg)	1.44±0.72	1.91±0.56	-2.549	.011*

Before intervention M±SDM±SD: M: mean, SD: standard deviation, AOGPS: action observational grip and pinch strength ening, IGPS: Imaginary grip and pinch strengthening, *p<.05, **p<.01

Table 3. Comparison of the difference in the mean between the two groups

	AOGPS (n=9) M±SD	IGPS (n=9) M±SD	*z*	*p*
Hand Grip (kg)	1.06±0.69	0.17±0.14	-2.282	.005**
Lateral Pinch (kg)	0.80±0.53	0.11±0.08	-3.423	.001***
3-jaw pinch (kg)	0.82±0.55	0.65±0.36	-.670	0.503
Tip pinch (kg)	0.57±0.47	0.46±0.41	-2.842	.369

M±SD: M: mean, SD: standard deviation, AOGPS: action observational grip and pinch strengthening, IGPS: Imaginary grip and pinch strengthening, *p<.05, **p<.01, ***p<.001

hand grip increased from 17.69kg before study to 17.85kg after study (*p<0.05); the lateral pinch increased from 4.41kg to 4.52kg (*p<0.05); the 3-jaw pinch increased from 3.72kg to 4.37kg (*p<0.05); and the tip pinch increased from 1.44kg to 1.91kg (*p<0.05), demonstrating an overall increase in the average values.

3. Comparison of Changes in Grip and Pinch Strength between the AOGPS and IGPS Groups

The comparison of the changes in the grip and pinch strength between the two groups in this study was as follows. (Table 3)

As for the comparison of the changes in the grip and pinch strength before and after intervention between the two groups, the change in hand grip was 1.06kg in the AOGPS group and 0.17kg in the IGPS group, indicating a statistical significance(**p<0.01) (Table 3). The change in the lateral pinch also demonstrated a statistical significance (***p<0.001) with 0.80kg in the AOGPS group and 0.11kg in the IGPS group. (Table 3) However, the change in the 3-jaw pinch was 0.82kg in the AOGPS group and 0.65kg in the IGPS group (*p>0.05), and the change in tip pinch was 0.57kg in the AOGPS group and 0.46kg in the IGPS group (*p>0.05), indicating no statistical significance. (Table 3)

Ⅳ. Discussion

The main impairments caused by stroke include degradation of muscle contraction, muscle weakness and stiffness. The degradation of muscle contraction and muscle weakness lead to postural instability, asymmetrical gait disorders, and loss of functionality in daily living. In particular, hand strength is essential for sports activities and activities of daily living, and the main hand motions include grip and pinch. The hand grip and pinch strengths are important factors in muscle function, general weakness, nutritional status, physical activities and muscle disability.[20] It is also reported that the hand grip and pinch strengths can be an important indicator of the whole body strength, and that they have a direct correlation with the workload and the body mass index.[21]

The study by Harris et al. (2001) reported that quadriceps femoris muscle weakness appeared immediately after stroke, and this was a neurophysiological result of impairment of upper motor neurons rather than disuse atrophy.[22] Hasio and Newham (2001) reported that the isometric maximal voluntary torque values of the quadriceps muscle and biceps femoris muscle were significantly weakened over the three months after the onset of stroke, compared to the normal control group. Such results suggested the need for an active muscle strengthening intervention from the early stage.[23]

This study examined the effects of AOPT on the grip and pinch strength in 18 chronic stroke patients with an aim of verifying whether AOPT could be a new alternative means of intervention to the muscle strengthening exercises in neurorehabilitation. In this study, the subjects repeatedly watched the video of the normal motion in the mid-plane and sagittal plane at the normal speed and at a speed twice as slow as the normal speed, and practiced to perform the grip and pinch motion correctly. As a result of this study, both the test group and the control group showed significant improvement in the gripping ability (table 3). However, in the pinch comparison between the two groups showed significant improvement in the lateral pinching ability (table 3). Such results suggest that AOPT is effective in improving the gripping ability and lateral pinching ability as the AOPT effectively promotes the premotor cortex, an area that responds when a purposeful or complex motion is requested, or when a task-oriented action is required, which can be explained by the role of the mirror neurons, as reported by a previous study.[13]

Fadiga et al. (1995) reported that the primary motor cortex (M1), a major area in the cerebral cortex associated with movement, was activated when the video of hand motion is viewed as if performing the actual motion.[24] This suggests that one's own motor program can be activated simply by observing the motion of others. Buccino et al. (2009) reported that brain activity was more amplified when observing a flawless mug than a broken mug.[25] In addition, Cross et al. (2006) reported that more diverse areas of the cerebral cortex were activated when watching the motion of professional dancers after rehearsal than the motion without rehearsal.[16]

According to Maeda et al. (2002), as for the movement of the index finger, the size of the motor evoked potential of the cerebral cortex was greater when observing the extension-flexion movement associated with vertical movements than the abduction-adduction movement associated with horizontal movements; when observing the movements with natural (away) hand orientations than unnatural hand orientations. Such results suggest that the activity of motor neurons in the cerebral cortex is more effectively promoted when observing the motions that are consistent with the motivation and previous experience of the observer during AOPT.[26] Considering the results of this study, AOPT requires the subjects to move on to a complex task of performing an accurate motion from observing the motion, and the subjects receive more accurate sensory feedback information from visual information. Such sensory information may have induced accuracy of the motion to effectively improve the strength. Especially, the result that the AOGPS group showed significant improvement in the pinching ability compared to the IGPS group may have been caused by the increase in the motivation of the subjects to perform a more elaborate and difficult motion, resulting in more careful observation of the motion. Mirror neurons are characterized by a higher firing rate while observing more difficult and complex movements like the pinch motion in this study, and AOPT stimulates the mirror neurons to facilitate the adaptation of stroke patients with impaired functionality in daily life movements and problems with execution of motions adapt to the external environment to the external environment.

In conclusion, AOPT proposed as a new means of neurorehabilitation which enables patients to learn various and complex movements required in the environment more economically and flexibly by observing normal movements. It has the advantage of making it easier to learn job-related movements and daily life movements.

This study aimed to examine whether the AOGPS training was effective in improving muscle strength, and the AOGPS training was found to be effective in improving the hand grip and pinch strength. However, it is difficult to generalize the results of this study as it was conducted in a small number of subjects, and the functional effects were not identified as the ability to perform various daily life movements associated with hand function was not evaluated. In future studies, it would be required to investigate the effect of muscle training combined with AOPT on the hand manipulation ability and daily life movements, and it would also be required to investigate the effect of ankle muscle strengthening exercise combined with AOPT on the muscle tone, gait performance and functional ability.[27,28]

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