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Effects of a Bilateral upper Limb Training Program Using a Visual Feedback Method on Individuals with Chronic Stroke: A Pilot Clinical Trial

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Abstract: *This study aimed to pilot test a newly developed bilateral upper limb rehabilitation training program for improving the upper limb function of individuals with chronic stroke using a visual feedback method. The double-group pretest-posttest design pilot study included 10 individuals with chronic stroke (age >50 years). The intervention (four weekly meetings) consisted of five upper limb training protocols (wrist extension; forearm supination and pronation; elbow extension and shoulder flexion; weight-bearing shift; and shoulder, elbow, and wrist complex movements). Upper limb movement function recovery was assessed with the Fugl-Meyer Assessment of the Upper Extremity, the Wolf Motor Function Test, the Trunk Control Test, the modified Ashworth Scale, and the visual analog scale at baseline, immediately after, and four weeks after the intervention. The Fatigue Severity Scale was also employed. The Fugl-Meyer Assessment of the Upper Extremity and Wolf Motor Function Test showed significant improvement in upper limb motor function. The Trunk Control Test results increased slightly, and the modified Ashworth Scale decreased slightly, without statistical significance. The visual analog scale scores showed a significant decrease and the Fatigue Severity Scale scores were moderate or low. The bilateral upper limb training program using the visual feedback method could result in slight upper limb function improvements in individuals with chronic stroke.*

Keywords: Stroke, Upper Extremity, Physical and Rehabilitation Medicine, Feedback, Sensory

1. Introduction

Stroke is a major cause of death worldwide and the most significant contributor to disability [1]. Only one-third of survivors can functionally reuse their upper limbs [2]. Functional use of the upper limb affects the independent living, mood, and community involvement [3]. The upper limb is used in most activities of daily living; thus, upper limb motor function improvement after stroke is vital [4].

To restore the upper limb function of individuals with stroke, conservative treatments such as muscle strengthening exercise, proprioceptive neuromuscular facilitation method, biofeedback, task-oriented training [5, 6], constraint-induced movement therapy [7], bilateral upper limb training [8-15], and upper limb training using robots [16, 17] are proposed. Bilateral upper limb exercise in stroke survivors has been associated with increased speed and tenderness [9, 11] and long-term restoration of function [8, 12, 13, 15]. However, a single rehabilitation training program showed insufficient motor function improvement in patients with chronic stroke and has shown conflicting results. Abbot [18] suggested that when two or more rehabilitation training methods are used, the effect may be greater than that of a single method.

Feedback on accurate exercise performance improves motivation, and feedback on poor exercise performance promotes skill enhancement [19]. Feedback can be either task-intrinsic feedback, obtained through the patient's visual, tactile, proprioceptive, auditory inputs, or task-extrinsic feedback, such as encouragement, charts, and tones. Individuals with stroke tended to rely on extrinsic feedback because of the effects of brain damage on the internal feedback mechanism [19]. With the wide variety of brain injury sites and types, selecting the optimal feedback for each patient appears complicated [20].

Several previous studies applied feedback to bilateral upper limb exercise. The exercises were performed with a metronome [21], or the bilateral upper limb exercises were performed by moving the handle of the plate based on an auditory cue [12, 15]. Feedback was also used to allow the paralyzed hand to passively assist in aligning with the rhythm of the active movement of the non-paralyzed hand [22, 23]. The upper limb function improved when visual feedback was provided, i.e., by showing the upper limb movement of the patient on the computer screen using a device equipped with a sensor for detecting motion and force [24-26].

Pollock et al. [27] conducted a Cochrane Review of interventions to improve upper limb function after stroke. A total of 1,840 studies, including 40 reviews, were analyzed, and 18 individual treatments and dosing treatment settings were proposed. Although each treatment showed upper limb function improvement after stroke, no evidence that could support their use as routine treatment exists, and information was insufficient to compare interactions between treatments, which in turn suggests the need for a large, powerful, effective combination treatment.

Most of the patients experience spontaneous functional recovery for the first 3 to 6 months after stroke onset [28]. Rehabilitation that is continued after the acute phase results in persistent restoration of exercise control, coordination ability, and balance ability [29]. Moreover, rehabilitation programs that are cost-effective, systematic, and effective appear necessary to enable a number of patients with chronic stroke to participate in the long term after hospital discharge [30]. Particularly, providing a program that can induce excitement and motivation is needed to enhance the sense of accomplishment while ensuring the accuracy and repeatability of the exercise without the direct assistance of a physical therapist.

Therefore, this study aimed to pilot test the newly developed bilateral upper limb rehabilitation training program using the visual feedback method for improving upper limb function in individuals with chronic stroke.

2. Materials and Methods

2.1 Study participants

A total of 22 subjects, who satisfied the following conditions: those who have stroke of ≥6 months with hemiplegia due to stroke, those who have severe-moderate level exercise deficits based on Fugl-Meyer Assessment score [31] (<50 points), those who do not have severe spasticity on the paralytic upper limb with modified Ashworth Scale score of ≥2, those who have no severe cognitive deficits with a Mini-Mental State Examination score of ≥22 points, and those who could understand and sign the agreement, were enrolled in this study. Those who do not have visual field defects or unilateral neglect, those who could not recognize changes in the computer screen because of decreased visual acuity, and with neurological or orthopedic defects in the upper limb were excluded from the study (n=12). All patients provided written informed consent, and the study was approved by the research ethics committee (NRCIRB 2013-03-017).

Ten patients were included in the study (9 males, 1 female). The average stroke onset of the patients was 15.1 months. The mean age was 54.1 years and the mean height and weight were 166.9 cm and 54.6 kg, respectively. Five patients had cerebral hemorrhage and five patients had cerebral infarction. Seven had left-sided and three had right-sided paralysis. In the baseline evaluation, the average muscle stiffness of the subjects was 1.4, and the mean score in the simplified mental state evaluation was 30 points.

2.2 Design

This is a pilot clinical trial. The subjects were classified as severe group (Fugl-Meyer Assessment score ≤26 (n=5)) or moderate group (Fugl-Meyer Assessment score >26 (n=5)) [32] (Table 1).

Variables were measured at baseline (pretest), immediately after the intervention (posttest), and 4 weeks thereafter (follow-up).

Table 1. Characteristics of the study participants

	Severe group (n=5)	Moderate group (n=5)	Total (n=10)
Sex (n)			
Men	4	5	9
Women	1		1
Side of stroke (n)			
Right	2	1	3
Left	3	4	7
Type of stroke (n)			
Infarction	2	3	5
Hemorrhage	3	2	5
Time after stroke (month)	14.8	15.2	15
Age (years)	46.8	61.4	54.1
Heights (cm)	167.2	166.6	166.8
Weights (kg)	65.8	65.4	65.6
MAS (scores) [1]	1.8	1	1.4
MMSE (scores) [2]	30	30	30
FMA (scores) [3]	17.8	44.6	31.2

MAS, modified Ashworth Scale; [2] MMSE, Mini-Mental State Examination; [3] FMA, Fugl-Meyer Assessment

2.3 Development of the visual feedback bilateral upper limb training equipment

The development of training equipment consists of five protocols.

2.3.1 Protocol 1 - Distal Part 1 (wrist extension)

- Development of wrist extension training equipment

· The principle of attaching the forearm to the instrument (Lean with elbow position) is to measure the new power of the wrist joint, and it is a training protocol to increase the range of joint operation and muscle strength with the force of the wrist.

· Both arms can be measured at the same time, and it is designed with a stable structure that does not shake even when the support is loaded.

· The cushion of the forearm supports completely restrained the forearm so that the wrist can be fully reflected. It is designed to measure only the strength of the patient's wrist joint by fixing the body span of the patient sitting on the chair.

· The input device was considered to apply the FSR sensor, which can be applied simply because the back of the hand is pushed close to the sensor part, but it was judged that it was not suitable for this study with a rough measurement and a short life span. Therefore, we design a load cell with a long lifespan and capable of measuring precise values.

· Two road cells that can withstand up to 20kg of load are attached to both wrist temple training equipment, and cushions are added to provide smoothness when the wrist is placed.

Since 1 SET of training equipment can be separated, it is easy to move and use, and the bars that are inserted into each groove can be easily loosened and tightened, making it easy to adjust depending on the length of the user's arm and the thickness of the arm.

· A load cell indicator that can be connected to the training equipment is installed separately so that it can be linked to the software and set the initial value.

- Development of wrist extension training software

· Data is measured by sensors from connected input devices, collected through USB serial ports, and output to PCs. The program was built with Microsoft's Visual C++, and signals were collected at 50 Hz. All data is collected, processed, and analyzed by PC.

· Wrist temple software converts the maximum renal force of the wrist joint on the load cell to 100%, and expresses the left and right movements of the shape to make it easier for the patient to recognize the extent of the renal force applied. We set it to be "1 Count" when the target force (% of the new power) is applied, and a scenario is prepared so that patients can receive visual feedback up to the target in real time.

Based on the wrist temple training software scenario, the program Hand Visual Feedback was developed, and the final version of Hand Visual Feedback Ver.3 was produced over bug fixes and supplements after several tests.

· The left window is basically a privacy input and protocol setting and setting window, a file saving and loading window, a compiler setting window, and an indicator and software initial value setting window.

· The right window shows the coordinate screen on which the protocol is executed and provides feedback to the target when the task is given. We input maximum new power (MVC), target left and right start ranges (Start, %), target minimum and maximum values (Min Range, Max Range, %), target time to be maintained (Hold, second), and target difficulty (SD, test strength).

· Both the total value and raw data value are recorded in one Result output sheet file (Excel File) per task.

2.3.2 Protocol 2 - Distal Part 2 (Forearm Supination & Pronation)

- Development of Forearm Supination & Pronation training equipment

· It is a training protocol that improves joint operation range and muscle strength through the exercise of the forearm and the in-house movement.

· The principle is to measure the range of joint operation of the forearm, and both arms can be measured at the same time. The back of both handles is connected by two chains, allowing both sides to move simultaneously without being biased in one direction, and controlling the degree of resistance.

· Except for the handle for training, the rest of the tightening parts were covered with cases after manufacturing, and empty spaces were made in the case to avoid interference with the antenna's signal.

· The outside of the handle was made of rubber to prevent the equipment from getting cold at low temperatures, and the edges of the handle were rounded. In addition, space was provided to adjust the width of each individual wrist, making it easier to loosen and tighten the handle.

· The rotation center axis of the handle is designed to be in the middle finger position, and the bottom plate of the handle is adjusted close to the center axis.

· Input device is a wireless inertial sensor designed to be attached inside the training equipment and measures the angle of movement. Measured data is collected to the PC via Bluetooth communication and linked to a visual feedback program to enable real-time feedback to patients.

- Development of Forearm Supination & Pronation Training Software

· The training software for forearm rotation and in-flight implemented the angle of motion entered by the wireless inertial sensor in a circular form of 360°, and expressed the left and right movements of the shape, just like the wrist temple training software.

· When the target movement angle (forward rotation, range of operation, °) is applied, it is set to be "1 Count", and the scenario is prepared so that the patient can receive visual feedback up to the target.

· The sensor attached to the back of the chain connected to both rotating handles is implemented as an orange and green screen that is easy to recognize so that it can be displayed on the real-time screen. The sensor on the damaged side is set as the main so that the non-damaged side can move along with the movement of the damaged side, and the sensor on the damaged side must enter the target zone to be recognized as a single test.

· The input window was made so that the time, distance, area of the target, etc. can be easily set according to the patient's perception and the condition of the wrist joint.

· Based on the in-flight and in-flight training software scenarios, the program (total) Hand Visual Feedback was developed, and the final version of Hand Visual Feedback Ver.3 was produced after several tests and bug fixes and supplements.

· The GUI of the hand visual feedback is designed to resemble the wrist temple training software program, with the left side the main input window and the right side the protocol execution window.

2.3.3 Protocol 3 - Proximal Part (Elbow Extension & Shoulder Flexion)

- Utilization of Elbow Extension (Shoulder Flexion) training equipment

· It is an equipment that can train the forward-backward movement of the upper extremity, based on the Reaching Task, and is a training protocol that enhances upper extremity function.

· The range of exercise can be gradually increased by adjusting the arm distance during training. The height of the stretch movement can be adjusted, allowing exercise parallel to the ground or up and down as much as the set angle, and the higher the slope, the more difficult it becomes.

· The switch was attached to the range of joint operation of the exercise equipment rail as much as possible considering the patient's condition. The switch is designed to be adjustable according to the patient's range of joint operation. In addition, when the patient performs stretching movements, the handle is attached separately instead of the handle attached to the existing equipment to provide a sense of stability when grasping.

· Input devices in the software can be recorded on the PC by touching the switch on the rail through the Reaching Task using Makey (Makey, USA).

- Leveraging Elbow Extension·Shoulder Flexion Training Software

· It is set to one time for both upper extremities to extend forward and return, and using the number of times the task was performed, visual feedback was provided that the block would fall off as many times as the screen did not provide anything.

· It was manufactured using Superlab Software (ver.4.5, USA) and has the advantage of recording the speed at which the task is performed. The order and steps can be randomly specified, and the date-by-date management in which the training is conducted is constructed to be useful.

· The training program consisted of a total of six stages, and the difficulty setting increased the number of blocks that make up the screen every time the stage was raised from the first stage to the sixth stage. It was set to Step 1-12 blocks, Step 2-24 blocks, Step 3-36 blocks, Step 4-48 blocks, Step 5-60 blocks, Step 6-72 blocks, and a program was designed to create new pictures every time and step of the way to make them interesting and not boring.

· If the task is not carried out, a message encouraging training was put into the event to provide visual feedback.

2.3.4 Protocol 4 - Weight Bearing Part (Weight Bearing Shift)

- Development of upper extremity weight bearing shift training equipment

· It is an equipment that trains weight support movement while moving left and right between the body while attaching the forearm to the instrument (Lean with elbow position), and is designed to perform the task with the force of pressing the forearm and the attached plate.

· It is a training protocol that induces shoulder extension and interbody muscle activation due to the force of pressing the plate with the forearm.

It is designed to load weight from side to side or both sides, and the training equipment is located in the front of the body to train with the force of pressing the upper extremity onto the plate.

· Because the input device measures the force of pressing with the forearm adhering to the sensor part, the load cell is used just like the wrist extension input device in protocol 1.

· Two road cells were attached that can withstand up to 100kg of load on both forearms, and the guard was added to prevent impact on the forearm when the pressing force was applied.

· The second design was produced to compensate for the disadvantage of large handle parts and the convenience of the indicator to be attached within the training device, and the second version of the upper body weight support training equipment was developed.

- Development of Upper Extremity Weight Bearing Shift Training Software

· Upper extremity weight support and movement training software, which receives load cell input signals on two plates, has the same GUI and principle as wrist training software, except for sensor-recognized compressor setting and inputting minimum and maximum adjustment to wrist extension training software.

2.3.5 Protocol 5 - Complex Part

- Use of wrist, elbow, shoulder movement training equipment

· It is a training protocol to improve upper extremity function and muscle strength by inducing complex movements of wrists, elbows, and shoulders through games.

· The Biobal Sensor (RM, France) was used for complex upper extremity movement training. Bioval Sensor is an inertial sensor that has three-axis acceleration, geomagnetic, and tilt sensors.

· With the bioval sensor attached to each segment of the body (Shoulder, Elbow, wrist), use the angle information of the sensor. Two sensors were attached to each shoulder-shoulder top, top-arm, and forearm-hand to create movement in each segment.

· During training, wrist straps were manufactured separately to prevent the sensor from falling off.

- Use of wrist, elbow, shoulder movement training software

· Game Mode of the Bioval Software (RM, France) is used, which is linked to the Bioval Sensor. Triaxial movement information of each shoulder, elbow, and wrist joint is utilized for complex upper limb movements.

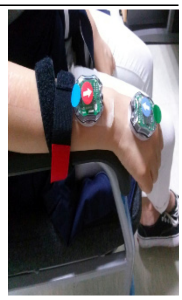
· Participant can choose the speed, difficulty, and type of game to control the intensity of the training.

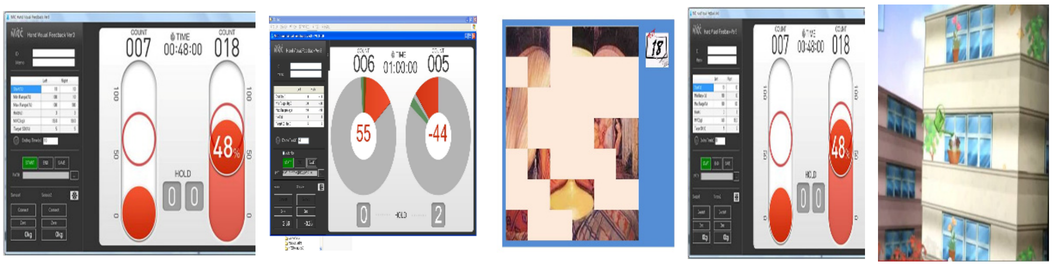
· To provide elements of interest in training, various games such as watering flowers, popping balloons, catching fish, picking up acorns, targeting and catching bugs were used.

2.4 Development of the visual feedback bilateral upper limb training programs

The opinions of the Advisory Committee of Rehabilitation Medicine Experiences, consisting of rehabilitation specialists and cranial nerve and spinal cord injury rehabilitation physical therapists; the principles of constructing treatment methods [33, 34], and the methods of rehabilitation exercises for preliminary bilateral upper limb rehabilitation [8-15] were combined for a stepwise procedure to develop a theory-, evidence-, and practice-based visual feedback rehabilitation training program. The equipment used in the program was composed of a hardware equipped with a sensor that can recognize the movement of each upper limb by force, position, and frequency and software that can receive feedback and reflect the movement through the computer screen. Performing several exercises, in the form of circuit exercises with several instruments, was considered efficient; thus, five kinds of equipment were developed for wrist extension, forearm supination/pronation motion, elbow extension/shoulder flexion exercise, upper limb weight support exercise, and shoulder/elbow/wrist complex movement (Table 2). When upper extremity movement occurs, compensation can occur or be tilted in one direction. Therefore, it was carried out with the trunk fastened with a belt to suppress compensation and prevent excessive weight leaning in one direction. The purpose of the program was to improve upper limb function through an accurate and repetitive motion of the upper limbs.

Table 2. Hardware and software used in bilateral upper limb training

Movement	(1) Wrist Extension	(2) Forearm supination and pronation	(3) Shoulder flexion and elbow extension	(4) Weight-bearing shift	(5) Shoulder, elbow, and wrist complex movement
Task	Performed by extending both wrists	Supination and pronation task performed by the hands on both sides of the angle information	Performed by counting the number of times the arm is extended and the shoulder is flexed	Performed by pressing the forearm downwards	Performed by moving the angle information of each joint of the upper limb (shoulder, elbow, wrist)
Time	7-8 min	7-8 min	15 min	15 min	15 min
Repetition	100-300 times	100-300 times	100-300 times	45-90 times	2-3 games
Hardware					
Input	Load cell	Tilt sensor	Makey Makey	Load cell	Inertial Sensor

Software	

2.5 Intervention

All exercises were performed in one session (60 min), and the intervention was carried out with 3 sessions per week in 4 weeks. For each program, the exercise time, rest time, and number of repetitions were set differently, and the intensity was based on the individual's maximum muscle strength, which was measured before the start of the program. The intensities of the range of motion exercise were set as follows: without resistance in the first week, 40% of the maximal strength in the second week, 60% in the third week, and 80% in the fourth week [33]. All exercises were performed in a sitting position, with the trunk fixed with a belt to prevent compensatory action and to avoid excessively unbalanced weight bearing. However, in the severe group, because of severity, the first and second exercises were excluded; the rest of the exercises were performed in 45 min per session.

2.5.1 Wrist extension

This was performed 100 to 300 times for 7-8 min to increase the range of motion and strength of the wrist with the force in extending the wrist joint, which is the principle of measuring the extension strength of the wrist joint. The forearm was attached to the hardware.

2.5.2 Forearm supination and pronation

This was performed 100 to 300 times for 7-8 min to improve the range of motion and muscle strength through forearm supination and pronation exercises.

2.5.3 Elbow extension and shoulder flexion

This was performed 100-300 times for 15 min to improve the upper limb function through elbow extension and shoulder flexion exercises or anterior-posterior stretching of the upper limb.

2.5.4 Weight-bearing shift

This was performed 45-90 times for 15 min to activate the muscles of the shoulder temple and trunk. Weight support movement training was performed by moving the trunk left and right while pressing the forearm downward.

2.5.5 Shoulder, elbow, and wrist complex movement

This was performed to improve the upper limb function and strength through the combined movement training of the upper limb. The game mode (e.g., watering flowers, blowing flowers, catching fish, picking acorns, and matching a target on screen) was used 2-3 times for 15 min.

2.6 Measurements

To measure the degree of upper limb function improvement, the following tests were performed: (1) motor performance tests of the upper extremities, using Fugl-Meyer Assessment of the Upper Extremity [12, 15, 22, 23][35-37] and Wolf Motor Function Test [12, 15], (2) trunk control ability test using Trunk Control Test [38], (3) resistance to passive movement test using the modified Ashworth Scale [39], (4) subjective pain test using the Visual Analogue Scale, and (5) fatigue test using the Fatigue Severity Scale. All measurements were performed by a physical therapist with at least 5 years of experience.

2.7 Statistical analysis

Data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). Nonresponse analysis was performed with Wilcoxon matched-pairs signed rank test, which is a nonparametric statistical test used when the number of samples is small (p<.05).

3. Results

The Fugl-Meyer Assessment of the Upper Extremity showed that the upper limb motor function significantly increased in both severe (17.8 → 21.4) and moderate (44.6 → 54.8) groups (p<.05) in the pre- and posttest and in the moderate group (44.6 → 52.2; p<.05) in the pre- and re-evaluation. The Wolf Motor Function Test revealed a significant increase in both severe (29.0 → 35.6) and moderate (56.2 → 64.6) groups (p<.05) in the pre- and posttest and in the pre- and re-evaluation (severe group: 29.0 → 34.4; moderate group: 56.2 → 66.6; p<.05) (Table 3).

Moreover, in the Trunk Control Test, both the severe and moderate groups had a slight increase in the pre-, post-, and re-evaluation, and trunk control was slightly improved; however, no statistical significance was observed. The modified Ashworth Scale showed that both the severe and moderate groups had a slight decrease in the pre-, post-, and re-evaluation, and elbow flexion rigidity also decreased; however, no statistical significance was noted. The Visual Analogue Scale revealed no difference between the pre- and post-evaluation subjective pain in the severe group; however, the pain decreased significantly during the post- and re-evaluation (2.4 → 1.6; p<.05). By contrast, in the moderate group, the Visual Analogue Scale showed a significant decrease (5.0 → 3.2; p<.05) in the pre- and post-evaluation; post-evaluation and re-evaluation results were similar (table 2). After the training, the Fatigue Severity Scale showed a low fatigue score in the severe group (2.4 points) and a normal fatigue score in the moderate group (4.4 points).

Table 3. FMA, WMFT, TCT, MAS, and VAS scores of SG and MG

Group	Variable	Mean±SD			p values		
		Pre	Post	Re	Pre [6] vs . Post [7]	Post [7] vs. Re [8]	Pre [6] vs. Re [8]
SG [9] (n=5)	FMA [1]	17.8±4.3	21.4±6.1	21.2±6.4	.042*	.783	.068
	WMFT [2]	29.0±2.0	35.6±5.0	34.4±4.6	.043*	.588	.041*
	TCT [3]	66.2±7.1	68.8±11.6	71.4±16.9	.317	.655	.414
	MAS [4]	1.4±0.9	1.2±0.8	1.0±0.7	.317	.317	.157
	VAS [5]	2.4±1.8	2.4±1.5	1.6±1.1	1.00	.046*	.285
MG [10] (n=5)	FMA [1]	44.6±3.3	54.8±3.6	52.2±5.0	.042*	.109	.041*
	WMFT [2]	56.2±4.2	64.6±5.9	66.6±4.8	.042*	.357	.043*

TCT [3]	61.0±13.0	74.0±15.9	76.6±14.2	.059	.317	.063
MAS [4]	1.0±0.7	0.8±0.4	0.6±0.5	.317	.317	.157
VAS [5]	5.0±4.0	3.2±3.4	3.2±1.8	.039*	1.00	.141

[1] FMA, Fugl-Meyer Assessment; [2] WMFT, Wolf Motor Function Test; [3] TCT, Trunk Control Test; [4] MAS, modified Ashworth Scale; [5] VAS, Visual Analogue Scale; [6] Pre, before the intervention; [7] Post, after the intervention; [8] Re, 4 weeks after the intervention; [9] SG, severe group; [10] MG; moderate group. *p<.05 by Wilcoxon signed-rank test

4. Discussion

In this study, we employed the Fugl-Meyer Assessment [12, 15, 22, 23][35-37] and the Wolf Motor Function Test [12, 15], which were used in several instruments that evaluate upper limb function in patients with stroke. Both the severe and moderate groups showed a significant upper limb function improvement after training (p<.05). The improvement during re-evaluation after 4 weeks tended to decrease compared with that in post-training, but remained higher, i.e., 3.4 points (severe group) and 7.6 points (moderate group), than that in pre-training. This finding is consistent with the results of a previous study [40] wherein the upper limb function improved by training the complex bilateral movements of the upper limb, indicating that repetitive and intensive training was associated with increased motor function. Moreover, in the Wolf Motor Function Test, both the severe and moderate groups showed a significant improvement after training (p<.05). Re-evaluation after 4 weeks showed a decrease by an average of 1.2 points in the severe group and an increase by 2 points in the moderate group; however, no statistically significance was observed. Similarly, in the Fugl-Meyer Assessment, we found that the upper limb function improved after the upper limb training program. Furthermore, similar to the study of Chae et al. [41], our study showed that repetitive exercise in functional training affects upper limb motor function recovery, and active, high-intensity training had positive results.

The trunk adjustment ability was not significant; however, it increased by 3.7% and 17.5% in the severe and moderate groups, respectively, after training. Compensatory movement restriction of patients with stroke contributes to the performance of the movement and to the improvement of the upper limb function [38]. Thus, in this study, the upper limb rehabilitation training program was performed with the trunk fixed. The restriction has apparently helped improve the trunk control ability, thereby preventing the leaning of the trunk.

In the Fatigue Severity Scale evaluation, the severe group had lower average fatigue points than the moderate group. During the training, the moderate group performed more exercises with higher motion intensity than the severe group and had greater motivation, due to the greater range of motion, through visual feedback. Moreover, the training was performed more actively by the moderate group.

A limitation of this study is the small number of subjects. Consequently, the results could not be generalized. Thus, subsequent studies should include more subjects and consider the general characteristics of the patient, including the etiology and location of their lesion and the level of disability. In addition, further studies including a control group are needed to verify the effectiveness of the training program.

Upper limb movement is essential in the activities of daily living. Thus, rehabilitation is crucial for patients with upper limb paralysis due to stroke. In patients with chronic stroke, a rehabilitation training program developed by combining complementary methods is necessary [18]. Our study showed that the newly developed bilateral upper limb rehabilitation training program using visual feedback method, which could be used as one of the training methods in community exercise programs, has a variety of advantages, including a positive effect on motor function recovery, the ability to control the intensity of the repeated and progressive training of complex upper limb movements, and the interest in adding game elements. Qualitative analysis using a variety of measurement tools to verify the effectiveness of the program revealed positive results. Fugl-Meyer Assessment of the Upper Extremity, Wolf Motor Function Test [12, 15, 22, 23][35-37], and Trunk Control Test [38] scores in this study were higher whereas the resistance to passive movement test (modified Ashworth Scale) [39] and subjective pain test (Visual Analogue Scale) scores were lower than those in pre-training, which is similar to the results in previous studies.

Future studies should explore training methods based on a systematic treatment to develop more efficient programs.

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