



Original Article

# Feedback training using a non-motorized device for long-term upper extremity impairment after stroke: a single group study

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**Abstract.** [Purpose] To investigate the effect of feedback training using a non-motorized device on the upper extremity kinematic performance of chronic stroke survivors. [Subjects] This study had a single group design. Thirteen chronic stroke survivors (onset duration: 11.5 years, 62.6 years, mini-mental state examination score: 26.0) were enrolled. [Methods] The feedback training system consisted of a non-motorized device that offered weight support, and a projective display device and loud speakers that provided suitable visual and auditory feedback to the user. Subjects participated in the feedback training for 40 min per day, two times a week for 4 weeks. Upper extremity kinematic performance (i.e., movement time) in three directions was confirmed twice (at baseline and post-intervention). [Results] After 4 weeks of the intervention, a significant improvement in upper extremity kinematic performance was observed in the three directions. [Conclusion] The present study demonstrated the positive effects of feedback training using a non-motorized device on the upper extremity kinematic performance of chronic stroke survivors. Therefore, the findings of this study may provide beneficial information for future studies on feedback training using a non-motorized device for chronic stroke survivors.

**Key words:** Feedback, Stroke, Upper extremity rehabilitation

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## INTRODUCTION

Stroke is a major cause of functional impairment, and problems with upper extremity function are present in >50% of patients with stroke<sup>1)</sup>. Therefore, restoring upper extremity function is an essential goal of stroke rehabilitation. Recently, assistive device training has been proposed to enhance the upper extremity functional movement of those with impaired upper extremity function after stroke<sup>2, 3)</sup>. In particular, robotic-assisted device training of the upper extremity can provide a repetitive, high-intensity, and interactive task<sup>4)</sup>. In addition, upper extremity training using a robotic-assisted device can provide objective and quantitative monitoring of the training process<sup>4, 5)</sup>.

In the field of stroke rehabilitation, provision of the feedback concept has been applied to enhance the motor learning process<sup>6)</sup>. In particular, the provision of feedback is useful for decreasing compensatory movements of the upper extremity<sup>6)</sup>. Recent technical advances can provide complex and realistic tasks using a visual and auditory feedback system, and this may lead to relearning of the motor process more efficiently<sup>7)</sup>. Although the effect of assistive devices and robot-assisted training with user interaction has been investigated<sup>4, 8, 9)</sup>, studies on assistive devices, especially non-motorized devices and robot-assisted training using visual and auditory feedback systems, with a focus on long-term upper extremity impairment after stroke are lacking.

The purpose of the present study was to assess whether visual and auditory feedback training using a non-motorized

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device that provides weight support can improve the upper extremity kinematic performance of chronic stroke survivors. The hypothesis of this study was that chronic stroke survivors would show improvement of upper extremity kinematic performance after 4 weeks of feedback training using a non-motorized device.

## SUBJECTS AND METHODS

A single group design was used to investigate the effects of feedback training using a non-motorized device on the upper extremity kinematic performance of chronic stroke survivors. Thirteen chronic stroke survivors (8 men, 62.6 years, minimal state examination [MMSE] score: 26.0, onset duration: 11.5 years) were enrolled in this study. The subjects were recruited from the local community. At the time of their recruitment, they were not receiving any rehabilitation services such as physical or occupational therapy. The subjects were screened according to the following inclusion and exclusion criteria. The inclusion criteria were hemiparesis from a single stroke occurring at least 6 months prior, sufficient cognition to follow simple instructions and understand the study's purpose (MMSE score >18 points)<sup>10</sup>, the absence of a musculoskeletal condition that could affect the subject's ability to sit safely, and the absence of hemispatial neglect. The exclusion criteria were participation in other studies or rehabilitation programs, shoulder subluxation or pain in the upper extremity, or spasticity (modified Ashworth scale score >2)<sup>11</sup>. Clinical and demographic data with the baseline assessment of subjects at enrollment are presented in Table 1.

The 13 subjects were briefed on the experimental procedure, and written consent to participation in the study was collected from all subjects prior to the experiment. Human subject ethical approval was obtained from the relevant committee of the Korea National Rehabilitation Center's Institutional Review Board (NRC-2012-05-035) prior to conducting the experiment.

Feedback training using a non-motorized device was conducted on a test bed. The training test bed consisted of a projective display device (Fig. 1-A), a non-motorized device that provided weight support (ReJoyce, Rehabtronics, Inc., Edmonton, Alberta, Canada) (Fig. 1-B), and loud speakers. The ReJoyce, a novel spring-loaded arm holding device that simulates activities of daily life, is an upper extremity rehabilitation device designed for neurological patients who exhibit impaired function of the arm. The ReJoyce can assist when either weight support or force is required to complete the task. A 120-inch projective display attached to the front of the test bed was used to provide suitable visual and auditory feedback to the user. On the handle of the ReJoyce, a magnetic motion tracking sensor (Patriot™ Wireless, Polhemus Patriot Wireless, Colchester, VT, USA) was attached to obtain the position information (Fig. 1-B-1). The position information was used to provide feedback to the subject. Once the training began, red and gray balls appeared on the projective display, and the subjects performed reaching movements toward targets in a three-dimensional space in three directions (i.e., targets 1, 2, and 3). The red and gray balls represented the target and hand point on the screen, respectively. The red ball was linked with the subject's upper extremity movements, and auditory feedback was provided when the red and gray balls matched. One task consisted of two phases: moving toward the target (approach) and returning from the target (return). While performing the training exercises, the

**Table 1.** General characteristics of the subjects (N = 13)

Subjects	Gender (M/F)	Age (years)	Time since stroke (years)	Height (cm)	Weight (kg)	Etiology (I/H)	Paretic side (L/R)	MAS (0/1/1+)	MRC (shoulder) (3/4/5)	MMSE (scores)
1	F	64	13	149.5	149.5	I	L	1	3	25
2	M	51	10	175.2	175.2	H	R	1	3	29
3	M	44	5	171.7	171.7	H	L	1+	4	29
4	M	71	16	166.3	166.3	I	R	1	3	29
5	F	71	17	156.2	156.2	H	L	1	4	24
6	M	72	3	158.0	158.0	I	L	0	5	25
7	M	71	12	163.7	163.7	H	L	1+	4	24
8	M	63	10	159.1	159.1	I	R	1	3	26
9	F	59	16	155.1	155.1	H	L	1+	3	30
10	M	58	13	169.4	169.4	I	L	1+	4	25
11	M	57	11	167.9	167.9	H	R	0	5	24
12	F	67	12	154.4	154.4	H	R	1	3	24
13	F	64	13	149.5	149.5	H	R	1	4	25
M (SD) or numbers	(8/5)	62.6 ± 8.5	11.5 ± 4.0	161.6 ± 7.9	67.5 ± 9.3	(5/8)	(7/6)	(2/7/4)	(6/5/2)	26.0 ± 2.3

Values are expressed as mean (SD) or numbers

H: Hemorrhage, I: Infarction, L: Left, R: Right, MAS: Modified Ashworth Scale, MRC (shoulder): Medical Research Council scale (Shoulder), MMSE: Mini-Mental State Examination

movement time from the starting point to the target position and from the target position to the starting point was recorded, and excessive trunk displacement was restricted by a trunk belt. All subjects participated in the feedback training using the non-motorized device two times a week for 4 weeks. A single training session was 40 min in duration. Upper extremity kinematic performance (i.e., movement time) was measured using the movement time of upper extremity reaching, and it was measured twice: at baseline and post-intervention. The movement time was defined as the time from the starting point to the target position and the time from the target position to the starting point. The movement time was recorded during the reaching movements toward the targets.

Data analysis was performed using SPSS, version 21.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used to confirm the normal distribution of all outcome variables. All variables (i.e., the movement time in all three directions) were normally distributed; therefore, paired t-test was used to compare the data between pre-training and after 4 week of training. All outcomes are expressed as mean values and standard deviations. Statistical significance was accepted for  $p < 0.05$ .

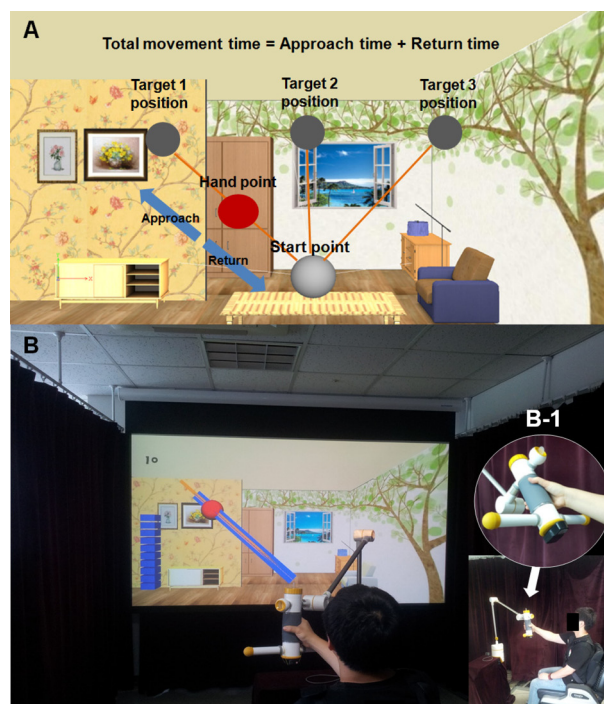
## RESULTS

A summary of the general characteristics of the 13 subjects who fulfilled the inclusion criteria is shown in Table 1. Changes of upper extremity kinematic performance were as follows; After 4 weeks of training, a significant improvement was observed in the upper extremity movement time in all directions (target 1: from  $5.4 \pm 2.4$  sec to  $3.1 \pm 1.0$  sec, target 2: from  $5.0 \pm 1.9$  sec to  $3.2 \pm 1.3$  sec, and target 3: from  $5.2 \pm 2.5$  sec to  $3.1 \pm 1.1$  sec;  $p < 0.05$ ).

## DISCUSSION

This study was conducted to investigate the efficacy of visual and auditory feedback training using a non-motorized device that provides weight support for upper extremity kinematic performance of chronic stroke survivors. After 4 weeks of feedback training using the non-motorized device, improvement in upper extremity kinematic performance was observed in the chronic stroke survivors.

Patients with stroke have abnormal movement on the affected side and a compensatory movement pattern due to abnormal motor function, paresthesia, and spasticity<sup>12</sup>. In addition, they commonly use inefficient or ineffective movement patterns due to compensatory movements<sup>6, 13</sup>. In particular, an inefficient or ineffective movement pattern does not provide appropriate feedback<sup>13</sup>. Therefore, various methods applying the feedback concept (i.e., intrinsic or extrinsic feedback) have been attempted in stroke rehabilitation<sup>6</sup>. Piron et al.<sup>14</sup> reported that feedback training using computer displayed virtual reality was useful for chronic stroke patients. In addition, the effectiveness of robot-mediated therapy on arm functions after stroke was



**Fig. 1.** Screenshot of the projective display (A), upper extremity assistive device training with visual and auditory feedback in the test bed (B) and a magnetic motion tracking sensor attached the handle (B-1)

investigated by Coote et al.<sup>15)</sup>, and they reported that robot-mediated therapy related to hand-to-mouse movement with visual feedback (visual feedback was provided on a screen) was helpful for improving upper limb functions after stroke. According to previous reports<sup>6, 7)</sup>, stroke survivors are able to preserve motor learning abilities through feedback training. Thus, therapeutic intervention using the feedback concept can improve the quality of movement through the motor relearning process<sup>16)</sup>.

In the present study, subjects were provided with visual and auditory feedback through interaction between a non-motorized device and the subject's arm movement. During feedback training using the non-motorized device, a red ball on the projective display was linked with the subject's upper extremity movements, and as an auditory feedback, ding-dong sounds were played when the red ball (hand point) and gray ball (target position) matched. Sigrist et al.<sup>7)</sup> reported that a visual and auditory feedback system can elicit a more efficient motor relearning process. In addition, visual and auditory feedback stimulus in rehabilitation is effective at increasing motivation and enjoyment, and decreasing the perception of exertion<sup>17)</sup>. In our study, after 4 weeks of training, improvement in upper extremity kinematic performance was observed, and we think that visual and auditory feedback during training acted as a motivating factor which helped to improve the upper extremity kinematic performance of chronic stroke survivors. Also, even though the device used in this study had no motorized function, gravity compensation with suitable feedback provided valuable results. Thus, we think that the non-motorized device with appropriate feedback has the potential to be applied usefully in stroke rehabilitation.

In conclusion, the findings of the present study demonstrated the positive effects of feedback training using a non-motorized device on the upper extremity kinematic performance of chronic stroke survivors. However, the present study had no control group, and only movement quality was assessed (i.e., kinematic movement), not the subjects' clinical outcomes. Thus, it cannot be determined whether the improvement was the result of the feedback training with a non-motorized device or participation alone. Further randomized controlled trials will be conducted to clarify this issue.

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