J. Phys. Ther. Sci.
24: 867–871, 2012

Arm Selection Behavior of Stroke Patients in Reaching: a Preliminary Study

Joong-Hwi Kim, PhD, PT[1)], Kyu-Ho Lee, PT[1)],
Wondae Kim, PhD[2)], Young Uk Ryu, PhD, PT[1)]

[1)] Department of Physical Therapy, College of Medical Science, Catholic University of Daegu: John Sye Hall 511, Geumrak-ro 5, Hayang-eup, Geongsan-si, Gyeongbuk, Republic of Korea.
TEL: +82 53-850-2533, FAX: +82 53-850-3292, E-mail: ryuyounguk@gmail.com
[2)] Department of Physical Education, Health, and Recreation, Prince Sultan University

Abstract. [Purpose] The purpose of the present study was to investigate arm selection behavior of stroke patients in a wide range workspace when they reached for an object. [Subjects] Twenty-three patients with stroke were recruited. The participants consisted of 10 right hemiplegic patients and 13 left hemiplegic patients. All participants were self-reported right-handed persons who were able to understand and respond to directions given by the experimenter. [Methods] Participants were instructed to reach to a target with the preferred hand at comfortable reaching speeds when nine targets randomly appeared on a table. The nine targets were located at the body midline (labeled 0°), –10°, –20°, –30° and –40° to the left of midline, and 10°, 20°, 30°, 40° to the right of the body midline. Each participant's upper-extremity sensorimotor, somatosensory, cognitive, and ADL functions were also attained. [Result] We found three distinct arm selection patterns. Sixteen patients who had relative good muscular strength and sensorimotor functions were characterized by a "normal-like" arm selection pattern. Five participants mostly used their non-paretic arm to reach to all targets, and three participants were characterized as having no pattern in arm selection behavior. [Conclusion] The most important factor that determines normal-like arm selection behavior of stroke patients in reaching is the integration of cortical sensory function and muscular strength. Purposeful use of the affected limb through with sufficient muscular strength will play a crucial role in achieving normal-like arm selection behavior.
Key words: Stroke, Reaching, Limb selection

(This article was submitted Mar. 27, 2012, and was accepted May 5, 2012)

INTRODUCTION

The handedness phenomenon has been much investigated in order to understand the specific characteristics of functional hemispheric differences in the control of upper limb movements[1–5)]. Handedness is defined as an unequal distribution of usage between the left and right arms, and it is the most distinct feature of brain lateralization and specialization. One of the key elements of handedness is the selection of a specific limb to achieve a task which requires a uni-manual action such as reaching or drawing. In normal adults, more than 90% of the population prefers to utilize their right hand for uni-manual actions[6)]. A setting used to investigate the issue of limb selection is one in which a patient has to reach an object placed on a wide-ranging workspace[7–11)]. Gabbard and colleagues explored this issue, and found that generally a limb transition from the dominant arm to the non-dominant arm among right-handers occurred around 20° past the body midline in the contralateral hemispace[7, 9)]. Similar findings were found for children and left-handers[8, 12)].

For patients who have suffered from a stroke, many studies have demonstrated that arm selection can be influenced by the side on which stroke occurrs[13–15)]. Harris and Eng[15)] showed that arm use was affected less in patients who had the dominant arm affected than in patients who had the non-dominant arm affected. A recent study showed that ipsilesional arm use was greater after right-side stroke, while patients with left-side stroke used both arms together more often than patients with the right-side stroke[16)]. However, the above-mentioned studies focused on the tendency of arm selection after a stroke. The issue of arm selection with regard to a wide ranging workspace has not been a focus of studies of patients with stroke.

The purpose of the present study was to explore arm selection behavior of stroke patients in a workspace. To address this research question, we asked right-handed stroke patients to reach to a target appearing on a table. Upper extremity sensorimotor functions of the participants were evaluated to gain an understanding of arm selection behavior.

METHODS

Twenty-three patients with stroke (17 men, 6 women, 54.7 ± 13.6 years old) were recruited from Gang Rehabilitation Hospital, Daegu, South Korea. All participants signed informed consent forms approved by the Institutional Review Board of the Catholic University of Daegu. Their average time form onset of stroke was 15.83 ± 14.35 months (range 2 to 60 months). Stroke location was identified by CT or MRI images of the brain. Thirteen patients were diagnosed as having cerebral infarction (56.5%) and 10 patients were diagnosed as having cerebral hemorrhage (43.5%). The participants consisted of 10 right hemiplegic patients (43.4%) and 13 left hemiplegic patients (56.5%). Patients with visual impairment were excluded from this study. Patients with Mini-Mental Status Examination (MMSE) scores of less than 23 were also excluded. All participants were self-reported right-handed persons who were able to understand and respond to directions given by the experimenter.

The participants sat on a flat seat (parallel to the floor) with a backrest that was perpendicular to the seat. While seated in the upright position, the chair height was adjusted to position the elbows level with the table. Each trial began with the participant's arms positioned on arm rests at the middle area of the body. All targets were presented at 75% of maximum arm length (semi-circular positioning), and they were presented randomly by a beam projector mounted on the floor at nine different positions: the body midline (labeled 0°), −10°, −20°, −30° and −40° to the left of midline, and 10°, 20°, 30°, 40° to the right of the body midline (Fig. 1). The target size was 1 cm in diameter. In the experiment, participants were instructed to reach to the target with their preferred hand at a comfortable reaching speed after one of the nine targets appeared on the table. Each participant was given three attempts to reach each target.

The present study used medical records of the patient's physical examination, that physical therapists kept from their examinations of each patient, in order to identify upper extremity sensorimotor functions. These records included the result of the manual muscle test (MMT), muscle tone, somatosensory tests, cognitive function test, and ADL. MMT was evaluated on an eleven-point scale (Z = 0, T = 1, P– = 2, P = 3, P + = 4, F– = 5, F = 6, F+ = 7, G– = 8, G = 9, N = 10) at the shoulder, elbow, and wrist joints of the paretic side. Muscle tone was evaluated on a six-point scale (0 = normal tone, 5 = severe spasticity) based on the Modified Ashworth Scale (MAS) at the elbow joint of the paretic side[17]. Somatosensory tests consisted of the cortical sense test, the superficial sense test, the deep sense test, and the touch sense test. Cortical sense was measured by touch recognition of a specific figure on the dorsal side of the hand with the eyes closed. Superficial sense was measured by light touch and pressure, and deep sense was measured by positional sense of the elbow and wrist joints. These somatosensory tests were evaluated on a three-point scale (2 = normal, 1 = impaired, 0 = absent). Touch sense was evaluated with a 10-g Semmes-Weinstein monofilament (Touch-Test Sensory Evaluator, North Coast Medical, Morgan Hill, CA) at the middle finger tip on the paretic side[18]. Lower score suggests better touch sensation in the monofilament test. Cognitive function was evaluated with the Mini-Mental Status Examination (MMSE)[19]. ADL was

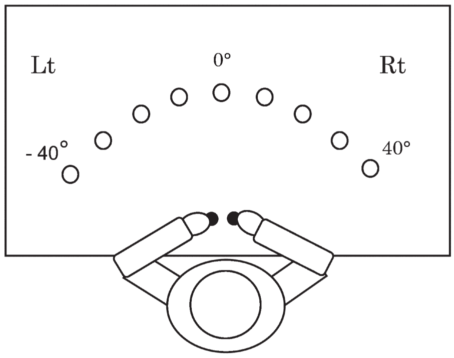

Fig. 1. View of the experimental set-up of the present study

evaluated using the Functional Independent Measure (FIM) (FIMTM Uniform Data System, Amherst, NY, USA) which consists of motor score items (maximum score 91) and social-cognitive score items (maximum score 35).

In order to analyze the data, we categorized participants into 3 arm selection patterns according to the results of the experiment. Based on these three categories, frequency data analysis and chi-square procedures were used to examine if a preference difference existed between the right and the left hand for each target. Because of the small number of observations among arm selection patterns, we used only descriptive analysis, instead of inferential statistics, to describe upper extremity sensorimotor functions based on the 3 arm selection patterns. The significance level for chi-square tests was chosen as $\alpha = 0.05$.

RESULTS

Sixteen participants were categorized by arm selection patterns characterized by selection of the limb closest to the target regardless of the affected side (Pattern A, Fig. 2A and Fig. 2B). Eight participants with left hemiparesis changed from the dominant right-hand to the non-dominant left hand mostly around a target position of −10° past the body midline (0°) in the contralateral hemispace (Fig. 2A), while six participants with right hemiparesis changed mostly at the body midline (Fig. 2B). Chi-square analysis confirmed the obvious differences between arm responses to targets appearing in the right and left-hemispace positions ($ps < 0.0001$). Table 1 shows that participants categorized as showing Pattern A had around P+ to F- in muscular strengths and these were relatively high compared to those of the other arm selection patterns. In the sensory function tests, the cortical sense and touch sense (monofilament test) of participants showing Pattern A were relatively sensitive compared to the other patterns (Table 1).

Five participants with right hemiparesis and one participant with left hemiparesis used mostly their non-paretic arm to reach to all targets in the workspace (Pattern B, Fig. 2C and Fig. 2D). Chi-square tests found obvious differences between hand responses to targets appearing in the right and left-hemispace positions ($ps < 0.0001$). The participants

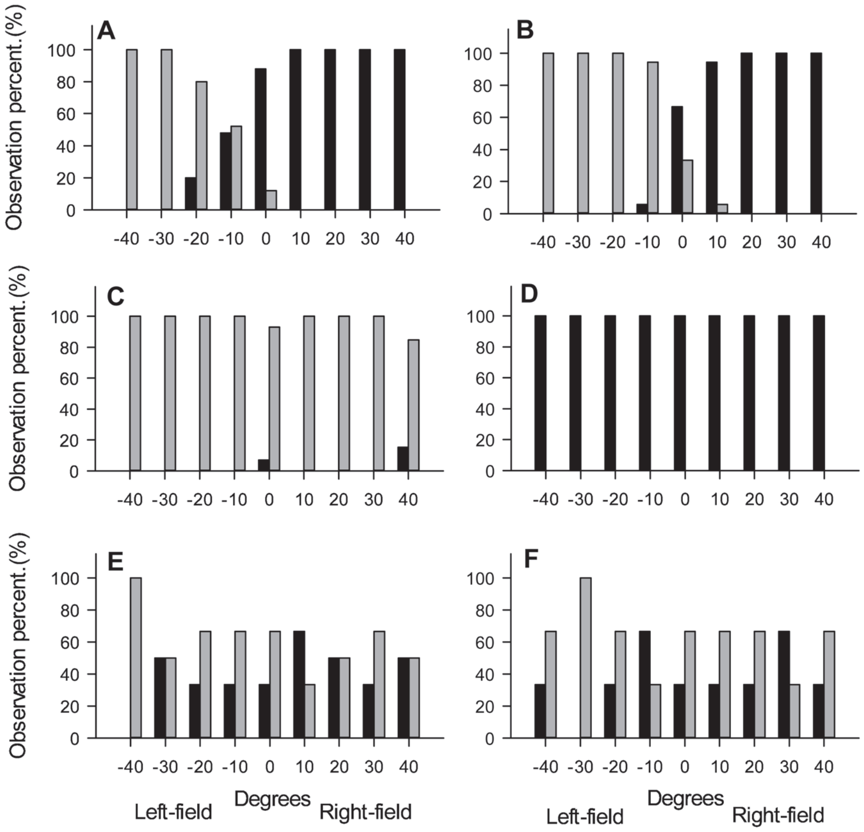

Fig. 2. Response profiles for each arm selection pattern (Pattern A = A and B, Pattern B = C and D, Pattern C = E and F) by type of hemiparesis (right hemiparesis = A, C, and E; left hemiparesis = B, D, and F). Black bars represent percentages of right arm use and gray bars represent percentages of left arm use.

Table 1. Characteristics of clinical tests of participants categorized by arm selection pattern (mean ± standard deviation)

	N=23	Pattern A (n=14)	Pattern B (n=6)	Pattern C (n=3)
Motor function (MMT)	Shoulder	4.71 ± 1.98	2.92 ± 2.54	2.50 ± 0.50
	Elbow	5.14 ± 2.14	2.67 ± 2.34	3.00± 1.00
	Wrist	4.04 ± 2.32	1.83 ± 2.14	1.33 ± 0.58
Muscle tone	MAS	1.00± 0.96	1.67 ± 1.21	0.67 ± 0.58
Somatosensory function	Cortical	1.64 ± 0.5	1.50 ± 0.55	1.00± 0.00
	Superficial	1.57 ± 0.51	1.50 ± 0.55	1.67 ± 0.58
	Deep	1.43 ± 0.65	1.50 ± 0.55	1.33 ± 0.58
	Monofilament	3.67 ± 0.99 (cm)	4.24 ± 1.2 (cm)	4.00 ± 0.87 (cm)
ADL	FIM	90.71 ± 13.76	99.33 ± 17.91	8.00 ± 18.52
Cognitive function	MMSE	26.57 ± 2.9	27.33 ± 2.5	25.67 ± 4.51

showing Pattern B arm selection had poor MMT scores compared to Pattern A (Table 1). Based on the results shown in Table 1, their ADL ability was relatively high compared to the other patterns.

Three participants (2 left hemiplegic patients, 1 right hemiplegic patient) were characterized as having no particular pattern of arm selection behavior (Pattern C, Fig. 2D and Fig. 2E). The chi-square tests confirmed our supposition (ps>0.05). The participants categorized into this arm selection pattern had poor sensorimotor function scores compared to the other arm selection patterns (Table 1). Especially, these participants had the lowest scores of wrist

MMT, cortical and deep sense, MAS, MMSE, and FIM (Table 1).

DISCUSSION

The purpose of the present study was to investigate the arm selection behavior of stoke patients on a wide range workspace when they reached for an object. Based on the results of the experiment, we found three distinct arm selection patterns: Patterns A, B, and C.

The majority of the participants in the present study were categorized as showing Pattern A. Regardless of the affected side, these participants tended to use their dominant right-hands to reach for a target in the right field of the workspace and up to a target position of −10° past the body midline (0°) in the contralateral hemispace. This arm selection pattern is similar to the findings of previous studies of healthy adults, in that arm selection changed to the non-dominant left hand at a target position of −10° in the contralateral hemispace of the workspace[7, 9, 20]. Thus, Pattern A can be called as a "normal-like" arm selection.

Sensorimotor function tests of Pattern A subjects showed that MMT scores of the shoulder, elbow, and wrist on the paretic side were those of the subjects higher than showing other patterns. The cortical sensory score was the highest with the narrowest sensory perceptive distance in the monofilament test. This means that the cortical sensory functions of the Pattern A subjects were the best. These findings suggest that the most important factors behind normal-like arm selection behavior are sound muscular strength and cortical sensory function. Specifically, Pattern C subjects who showed no particular pattern, had poor muscular strength and the lowest cortical sensory score. Unlike superficial or deep sensation that simply distinguishes sense, cortical sensation is important because it is associated with high cognitive processing including implicit and explicit memory[21, 22]. Therefore, cortical sensation is the most important sensory function for efficient sensory motor integration.

In this study, Pattern B subjects, who used only the non-paretic side arm showed the best ADL ability. This means that the participants of Pattern B had dependently used the non-paretic side in daily activities. Hofgren[23] said that improvement in the stroke patients' ADL is affected by the recovery of motor skills. Interestingly, the ADL ability of Pattern A, which showed normal-like arm selection, was lower than Pattern B. We assume that the Pattern A subjects intentionally used the paretic side in daily life because it had sufficient extremity strength. The ADL ability of Pattern C subjects, who showed no consistent pattern in arm selection, was the lowest.

In conclusion, the results of this study show that the most important factor that determines normal-like arm selection behavior of stroke patients in reaching is the integration of cortical sensory function and muscular strength. In addition, purposeful use of an affected limb with sufficient muscular strength, should play a crucial role in achieving normal-like arm selection behavior. The results of this study have some clinical implications for the functional rehabilitation of stroke patients. First, in functional rehabilitation, we should focus on the improvement of integration of muscular strength and cortical sensory function. Second, purposeful use of the affected limb if it has sufficient muscular strength should help the recovery even though there may be a decrease in ADL quality. Especially, reaching from the body midline to a workspace on the affected side at different angles would be helpful for the functional recovery of reaching ability. The present findings may also have a practical implication for the diagnosis of degree of recovery in stroke rehabilitation.

The number of subjects of this study was small, and the number of observations for each pattern was also small. Because of this, the inability to perform inferential analysis across the results of each pattern was a limitation of this study. Future studies should include more subjects so that the results can be generalized.

ACKNOWLEDGEMENT

This research was supported by a research grant from the Catholic University of Daegu in 2012.

REFERENCES

1) Oldfield RC: The assessment and analysis of handedness: The edinburgh inventory. Neuropsychologia, 1971, 9: 97–113. [Medline] [CrossRef]
2) Chapman LJ, Chapman JP: The measurement of handedness. Brain Cogn, 1987, 6: 175–183. [Medline] [CrossRef]
3) Hellige JB, Kee DW: Asymmetric manual interference as an indicator of lateralized brain function. Adv Psychol, 1990, 70: 635–660. [CrossRef]
4) Peters M: Handedness and its relation to other indices of cerebral lateralization. Brain Asymmetry, 1995, 183–214.
5) Stins JF, Kadar EE, Costall A: A kinematic analysis of hand selection in a reaching task. Laterality: Asymmetries of Body, Brain Cogn, 2001, 6: 347–367.
6) Coren S, Porac C: Fifty centuries of right-handedness: The historical record. Science, 1977, 198: 631. [Medline] [CrossRef]
7) Gabbard C, Iteya M, Rabb C: A lateralized comparison of handedness and object proximity. Can J Exp Psychol, 1997, 51:176.
8) Gabbard C, Helbig CR, Gentry V: Lateralized effects on reaching by children. Dev Neuropsychol, 2001, 19: 41–51. [Medline] [CrossRef]
9) Gabbard C, Helbig CR: What drives children's limb selection for reaching in hemispace? Exp Brain Res, 2004, 156: 325–332. [Medline] [CrossRef]
10) Choi HJ, Mark LS, Dainoff MJ, et al.: In: Hand use preferences in delimiting the boundaries of normal working area. Proceedings of the human factors and ergonomics society annual meeting; SAGE Publications, 2004, p. 1081–1085.
11) Kim W, Gabbard C, Buchanan JJ, et al.: Right-handers' reaching in contralateral hemispace: A kinematic observation. J Mot Behav, 2007, 39: 451–456. [Medline] [CrossRef]
12) Gabbard C, Rabb C, Gentry V: Attentional stimuli and programming hand selection: A developmental perspective. Int J Neurosci, 1998, 96: 205–215. [Medline] [CrossRef]
13) Mamolo CM, Roy EA, Bryden PJ, et al.: The performance of left-handed participants on a preferential reaching test. Brain Cogn, 2005, 57: 143–145. [Medline] [CrossRef]
14) Harris-Love ML, Waller SM, Whitall J: Exploiting interlimb coupling to improve paretic arm reaching performance in people with chronic stroke. Arch Phys Med Rehabil, 2005, 86: 2131–2137. [Medline] [CrossRef]
15) Harris JE, Eng JJ: Individuals with the dominant hand affected following stroke demonstrate less impairment than those with the nondominant hand affected. Neurorehabil Neural Repair, 2006, 20: 380–389. [Medline] [CrossRef]
16) Rinehart JK, Singleton RD, Adair JC, et al.: Arm use after left or right hemiparesis is influenced by hand preference. Stroke, 2009, 40: 545–550. [Medline] [CrossRef]
17) Bohannon RW, Smith MB: Interrater reliability of a modified ashworth scale of muscle spasticity. Phys Ther, 1987, 67: 206–207. [Medline]
18) Weinstein S: Fifty years of somatosensory research: From the semmes-

weinstein monofilaments to the weinstein enhanced sensory test. J Hand Ther, 1993, 6: 11–22. [Medline] [CrossRef]
19) Cockrell JR, Folstein MF: Mini-Mental state examination. Principles and Practice of Geriatric Psychiatry, 1988, 140–141.
20) Helbig CR, Gabbard C: What determines limb selection for reaching? Res Q Exerc Sport, 2004, 75: 47–59. [Medline]
21) Kim JS, Choi-Kwon S: Discriminative sensory dysfunction after unilateral stroke. Stroke, 1996, 27: 677–682. [Medline] [CrossRef]
22) Harris JA, Miniussi C, Harris IM, et al.: Transient storage of a tactile memory trace in primary somatosensory cortex. J Neurosci, 2002, 22: 8720–8725. [Medline]
23) Hofgren C, Björkdahl A, Esbjörnsson E, et al.: Recovery after stroke: Cognition, ADL function and return to work. Acta Neurol Scand, 2007, 115: 73–80. [Medline] [CrossRef]