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Original Article

Comparison of Upper Extremity Motor Recovery of Stroke Patients with Actual Physical Activity in Their Daily Lives Measured with Accelerometers

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Abstract. [Purpose] This study compared the upper extremity recovery of stroke patients with the amount of their upper extremity use in real life as measured by accelerometers. [Subjects] Forty inpatients who had had a stroke were recruited. [Methods] The subjects were divided into two groups by the Fugl-Meyer Assessment of Motor Function (FMA) score, a moderately recovered group and a well recovered group. The amount of upper extremity physical activity and its ratio in daily time periods were analyzed for the affected and unaffected sides. [Results] The well recovered group showed significantly higher affected arm use and use ratio than the moderately recovered group in all time periods. [Conclusion] The upper extremity recovery level of the affected side is similar to the physical activity level according to the amount of upper extremity physical activity in actual life measured with an accelerometer. Overuse of the normal side regardless of the recovery level of upper extremity proves the International Classification of Functioning (ICF) concept of differentiating between capacity and performance, and rehabilitation treatments should focus on improving performance.
Key words: Accelerometers, Physical activity, Rehabilitation

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INTRODUCTION

One of the most common motor deficits after a stroke is upper extremity impairment, and 30–60% of stroke sufferers report upper extremity disability and inability to use the paretic arm in their daily lives[1)]. Disability in the upper extremity limits overall physical function, and causes difficulties with daily activities, resulting in a decrease in quality of life[2)].

In order to help stroke patients functionally recovery their impaired upper extremity, a variety of assessment tools are used to assess upper extremity use in daily lives, and to analyze the factors related to its use and recovery. Even though standardized assessment tools to measuring grip strength, hand dexterity, sensation in hand and the performance of diverse tasks exist, these tools are mostly limited to assessing partial impairments and motor performance in a therapy room environment[3)]. The International Classification of Functioning, Disability and Health (ICF) of the WHO classifies activity into capacity and performance[4)]. A well known example of the difference between capacity and performance is learned non-use. In a study on constraint-induced movement therapy (CIMT), patients who had sufficient capacity to perform tasks did not use their affected arm and failed to utilize the affected arm in their daily lives[5)].

Recently, several studies have assessed the upper extremity use of patients with stroke in real life using accelerometers. Vega-Gonzalez et al. used accelerometers to analyze the upper extremity activities of 10 normal adults and 10 mild to moderate stroke patients at home and in the workplace[6)]. Their results showed normal adults used their dominant hand 19% more than the non-dominant one, and stroke patients used their non-paretic hand three to six times more than the paretic one. However, the age groups of the subjects were largely different, normal adults ranging from 22 to 35 years and stroke patients from 56 to 80 years, and the stroke patients participating in that study had onsets within a year.

Uswatte et al. analyzed the average movement maintaining time ratio of the upper extremity and both hands' use ratio for 169 subacute (three to nine months post-stroke) stroke patients with mild to moderate motor deficits[7)]. Neither the average movement maintaining time ratio of the upper extremity nor the both hands' use ratio showed significant differences. The distribution of upper extremity function showed that there were 64 subjects with high upper extremity function and 18 withlow function in the CIMT group, and 68 and 19 people in the non-treatment group. This fact limits the study to participants with higher functions.

This study classified subjects into two groups accord-

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ing to their motor recovery levels, and compared the results of ordinary capacity assessment of upper extremity motor function and the level of upper extremity use in real life using accelerometers, to measure the amount of upper extremity physical activity, in order to investigate affected arm use in the real lives of stroke patients.

SUBJECTS AND METHODS

The study subjects were forty patients with stroke in Gyeonggi province of Korea in 2013. Subjects who had experienced stroke for the first time and had no significant musculoskeletal or neurological condition other than stroke were recruited. The general characteristics of the subjects are summarized in Table 1. All of the protocols used in this study were approved by the University of Semyung. Before participation, the procedures, risks, and benefits were explained to all of the participants, who gave their informed consent. The participants' rights were protected according to the guidelines of the University of Semyung.

All subjects were assessed using the Fugl-Meyer Assessment of Motor Function, upper extremity (FMA, upper extremity) to classify them into two groups: a moderately recovered group with scores of 19 to 44, and a well recovered group with scores of 45 and above. An accelerometer was worn by subjects on both wrists for five days (from Monday to Friday, 8 am to 11 pm), except for sleeping hours, in order to measure the amount of physical activity of the upper extremities. The accelerometer was also worn while patients were participating in rehabilitation treatments such as physical and occupational therapy.

Table 1. General characteristics of the subjects

	Moderate group	Well group
Gender (male/female)	11/9	12/8
Age (year)	57.4±16.3	60.4±14.4
Lesion side (right/left)	9/11	6/14
Duration (month)	13.0±3.2	16.5±4.9
MMSE (score)	22.7±4.5	17.8±8.1
FIM (score)	65.8±25.2	76.3±21.2
FMA (score)	27.3±8.2	53.7±8.2
MFS (score)	39.8±23.2	78.9±13.2

All variables are mean±standard deviation (SD). moderate group: FMA score 9–45; well group: FMA score ≥ 45. MMSE: mini mental state examination test. FIM: functional independence measure. FMA: Fugl-Meyer assessment of motor function. MFS: manual function score.

The accelerometer (FITMETER 2010; KOREA) was a portable triaxial accelerometer with the size (35 × 35 × 13 mm^3) and weight (13.7 g) of a watch. The accelerometer was wireless and waterproof and was attached to both wrists with Velcro. The accelerometer sums the absolute values of accelerating and decelerating movements to record the subject's intensity of physical activity in units of cm/s^2. Accelerometer use has had its validity proven for assessing upper extremity activities and movements of stroke patients by many studies[8, 9]. In this study, the day was divided in to three time periods of 9 a.m.–12 noon, 2–5 p.m. (three-hour periods when subjects were receiving intensive rehabilitation treatment), and 7–10 p.m., three hours when mainly personal activities were being performed, and amounts of physical activity were analyzed.

SPSS ver. 12.0 was used to calculated averages and standard deviations. Descriptive statistics were used to analyze subjects' general characteristics and the independent t-test was used to test the significance of differences in amounts of physical activity in each time periods.

RESULTS

Amounts of upper extremity activity and use ratios of the moderately recovered group and the well recovered group in real life for each time period are shown in Table 2. The well recovered group showed significantly higher amounts of affected arm use than the moderately recovered group in all time periods. Both groups showed the highest activity level between 2 to 5 pm, 734±269 m/s^2 and 2,191±1,432 m/s^2. The non-paretic side of both groups showed similar amounts of activity. The use ratio was calculated by dividing the activity on the paretic side with that of the non-paretic side and was high in the well recovered group in all time periods. The time phase from 7 to 10 pm showed the highest ratio, 0.82±0.93.

DISCUSSION

This research analyzed the amount of upper extremity activity using an accelerometer to compare the upper extremity recovery level with the level of upper extremity use in the real lives of patients with stroke.

Stroke is a disease that can cause serious disability, and slow recovery of the paralyzed extremities often leaves patients with chronic disabilities. One of the most difficult problems in upper extremity rehabilitation of stroke patients

Table 2. Comparison of upper extremity physical activity and the use ratio of each group

	Amount of upper extremity physical activity (m/s^2)					
	Paretic side		Non-paretic side		Ratio	
Time phases	moderate group	well group	moderate group	well group	moderate group	well group
9 am − 12 pm	552±279	1,831±1,647*	3,296±1,880	3,669±3,159	0.20±0.12	0.50±0.18**
2 pm − 5 pm	734±269	2,191±1,432**	3,323±1,856	2,874±1,865	0.26±0.10	0.80±0.23**
7 pm − 10 pm	540±204	1,868±1,809**	4,456±2,738	2,973±2,679	0.17±0.12	0.82±0.93**

All variables are mean±SD. *p<0.05, **p<0.01, ***p<0.001

is learned non-use[10]. Learned non use is a motor impairment of stroke patients that is the result of learned suppression of movement rather than brain cell damage, and a vital factor of motor recovery is intensive and repetitive use[11]. However, training the affected arm mainly in therapy sessions and using the normal side outside therapy delays the recovery of the paralyzed extremities[12]. Our present study compared the use of affected upper extremity and the ratio of both hands use in therapy sessions and personal time periods. Our stroke in-patients were receiving rehabilitation treatments and were classified into groups according to their upper extremity recovery level. Although the amounts of activity on their non-paretic sides were similar, that of the paretic side was three times better in the well recovered group. De Niet et al. studied seventeen chronic stroke patients by monitoring their upper-limb activity. They reported that activity of the paretic side was 1.0±0.5 g/min, which was 39% of the non-paretic side value of 2.8±1.3 g/min, and less than half of the both hands use ratio of normal adults of 93.3%[13]. Even though the average time since onset of their study participants was 32 to 33 months was different from that of our study of 9.45±5.3 months, similar results were obtained. Previous studies have not performed analyses of time periods, but the well recovered group of our present study showed levels of use in the therapy sessions that were similar to that in their personal activity hours.

Regarding the amount of physical activity in personal activity hours, the moderately recovered group (4,456±2,738 m/s^2) used the normal side much more than the well recovered group (2,973±2,679 m/s^2). Also, the moderately recovered group did not show big differences in the amount of normal side activity among the time periods: 3,296±1,880 m/s^2, 3,323±1,856 m/s^2, and 4,456±2,738 m/s^2, respectively. This is because they used the normal side to perform activities since the paretic side was not functional enough, and even though they recognized that repetitive use of the paretic side is the key to motor recovery, the thought was not be linked to their behavior. Since most stroke sufferers do not recognize the effect of normal side overuse on upper extremity recovery, they cannot consciously control using their normal side, and problems such as impaired cognition, balance and fatigue and low self-efficacy hinder their performance of physical activities[14, 15].

As mentioned above, in the International Classification of Functioning model, a large gap exists between functional improvement and actual participation in physical activities[16]. Studies using accelerometers to monitor real life physical activities strongly support this ICF concept, and will lead the efforts to enhance performance in rehabilitation treatment. Accelerometers can also be utilized to collect useful data in future research to verify the effects of innovative interactive virtual reality games, like the Nintendo Wii system, CIMT, or home-based exercise programs for facilitating the paretic side.

Limitations of this study were its small sample size and the distribution of patients limited to being limited to subacute patients which limits the generalization of the results. Another limitation is the absent factorial analysis on the factors that limit the use of paretic extremity in real life and as a consequence, sufficient information were not provided to be referenced in planning for intervention of upper extremity recovery. This study analyzed only the amount of upper extremity activity and the use ratio of the normal and affected sides. Future studies should analyze a variety of variables, e.g. the total amount of physical activity, physical activity of the upper and lower extremities, time use (time using both hand, time using one hand, and total time use), to collect diverse data. Also diverse and systematic research should study large numbers of stroke patients in the subacute and chronic stages to trace the changes of activity level through self-monitoring of physical activities.

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