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The Comparison of Muscle Activation on Low-Reaching and High-Reaching in Patient with Stroke

MINCHULL PARK, PhD, PT[1)], MYOUNGHEE LEE, PhD, PT[2)], MINYOUNG SONG, MS, PT[3)], SANGYEOL LEE, PhD, PT[4)], JEMYUNG SHIM, PhD, PT[4)], BONGOH GOO, PhD, PT[5)], SUNGSOO BAE, PhD, PT[6)]

[1)]*Department of Physical Therapy, Pusan National University Hospital*
[2)]*Department of Physical Therapy, Daegu Health College: Taejeon 1–dong, Buk-gu, Daegu, 702-722 Republic of Korea. TEL: +82 53-320-1438, FAX: +82 53-320-1350*
[3)]*Department of Physical Therapy, Dong-eui Institute of Technology*
[4)]*Department of Physical Therapy, Gimhae College*
[5)]*Department of Physical Therapy, College of Health Sciences, Catholic University of Pusan*
[6)]*Department of Physical Therapy, College of Rehabilitation Science, Daegu University*

Abstract. [Purpose] The purpose of this study was to investigate the degree of muscle activation of the upper limb muscles during reaching movements in patients recovering from stroke. [Subjects] Nineteen hemiplegic patients participated in low-reaching and high-reaching tasks. [Methods] Changes in muscle activation resulting from performing low-reaching (reaching toward an object at the height of the knee) and high-reaching (reaching toward an object at the height of the shoulder) were measured using surface EMG. The surface electrodes were attached to the trapezius upper fibers, the deltoid anterior fibers, the deltoid middle fibers, the biceps, the triceps, the extensor carpi radialis and the flexor carpi radialis of both the paretic upper limb and the non-paretic upper limb. The independent *t*-test was used to compare muscle activation. [Results] Based on the results of measurements of muscle activation of the paretic upper limb, the muscle activation of the trapezius upper fibers and that of the deltoid anterior/middle fibers showed significant increases in high-reaching compared to low-reaching. However, for the non-paretic upper limb, significant increases were shown only in the trapezius upper fibers. These results indicate that, there is no difference between the muscle activation of the paretic side and that of the non-paretic side in high reaching while in low-reaching, the muscle activation values of the deltoid anterior fibers and the triceps of the non-paretic side are larger than those of the paretic side. [Conclusion] Muscle activation in reaching movements differs depending on the height of the target and we consider that these differences should be considered when therapeutic interventions are prescribed.
Key words: Muscle activation, Reaching, Stroke

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INTRODUCTION

The deficit of the upper limb function of hemiplegic stroke patients is a serious limitation on patients' voluntary participation in activities of daily living. In addition, the degree of disability among these patients reaches 55% to 75% in spite of intensive therapy[1,2)]. For these reasons, diverse treatment methods to improve the upper limb functions of hemiplegic patients have been

proposed, such as treatment methods using neuromuscular development treatment or functional electrical stimulation, constraint-induced movement therapy, task-oriented practice, resistance exercise, bilateral repetitive training, progressive resistance exercise, and proprioceptive neuromuscular facillitation. Most of these treatment methods focus on avoiding the learned disuse of the paretic upper limb and using it with minimal abnormal compensatory patterns[3]. Reaching is the most basic motion and it adjusts the upper limb so that the hand can reach targets[4]. It is also one of the methods of task training that are frequently used clinically. However, hemiplegic patients show stereotypical compensatory movement patterns when attempting reaching, and damage to the proximal upper limb muscle and abnormal coordination of upper limb motions can become important causes of trouble in reaching[4,5]. On account of this, in this study, the degree of muscle activation of the upper limb muscle while low-reaching (reaching toward an object at the height of the knee) and high-reaching (reaching toward an object at the height of the shoulder) were being performed were measured and compared in order to prepare basic data for efficient reaching exercises.

SUBJECTS AND METHODS

The conditions used to select the subjects of this study were as follows: 1) hemiplegic patients whose initial onset had occurred at least three months earlier; 2) grade 2 or lower upper limb spasticity on the Modified Ashworth Scale; 3) ability to reach a shoulder height target with the hand; 4) ability understand and follow instructions from the researcher; and 5) voluntarily agreement to participation in this study.

Changes in muscle activation resulting from performing reaching were measured using surface EMG (BioGraph Infiniti^{TM}, Thought Technology Ltd., Canada). After cleaning the points where the electrodes were to be attached using alcohol cotton, three poles (positive-ground-negative) surface electrodes (Triode^{TM} electrode) consisting of three poles were attached. The surface electrodes were attached to the trapezius upper fibers, the deltoid anterior fibers, the deltoid middle fibers, the biceps, the triceps, the extensor carpi radialis and the flexor carpi radialis of both the paretic upper limb and the non-paretic upper limb.

Each subject was instructed to lay the palm on the middle of the thigh and comfortably sit on a stool with no back support and then perform a motion to reach out the upper limb to touch a target 15 cm in front of the knee with the hand (low reaching), and a motion to reach out the upper limb to touch a target at the height of the shoulder with the hand (high reaching). The relative muscle activation of each of the reaching movements was calculated using the muscle activation at resting for 3 seconds as the reference.

When measuring the muscle activation values, the frequency range of EMG signals was set to 20–500 Hz and the analog EMG signals, input through 7 cable channels, were converted into digital signals using a 14 Bit Analog-Digital converter connected to a computer using TT-USB (BioGraph Infiniti^{TM}, Thought Technology Ltd., Canada) to collect data. The raw data, collected at 2 kHz, were analyzed using their %RVC (reference voluntary contraction) to the root mean square (RMS) value automatically provided through the BioGraph Infiniti (Thought Technology Ltd., Canada) software.

All data were statistically processed using SPSS Win. 12.0 software and a significance level $p=0.05$. The means, standard deviations, frequencies and percentages of the general characteristics and disease history characteristics of the subjects were calculated and recorded; and differences in muscle activation between low-reaching and high-reaching of the paretic upper limb, and differences in muscle activation between the paretic upper limb and the non-paretic upper limb in low-reaching and high-reaching were investigated using the independent *t*-test.

RESULTS

The nineteen patients who participated in this study were 8 males (42.1%) and 11 females (57.9%). Their average age was 46.89 ± 13.57 years, average height 162.53 ± 7.02 cm and average weight 58.31 ± 6.88 kg, and all the 19 patients were right handed. The causes of stroke were infarction in 13 patients (68.4%) and hemorrhage in 6 patients (31.6%); 11 had right hemiplegia (57.9%), 8 had left hemiplegia (42.1%), and the average duration since the onset of stroke was 31.82 ± 21.43 months.

The muscle activation of the trapezius upper fibers and that of the deltoid anterior/middle fibers

Table 1. Comparison of muscle activation (Mean ± SD)

Muscle		Low-reaching	High-reaching
Upper trapezius	Paretic arm	664.89 ± 532.82*	1689.36 ± 1659.24*
Upper trapezius	Non-paretic arm	418.82 ± 262.21*	1295.90 ± 936.36*
Deltoid anterior	Paretic arm	743.58 ± 412.59*[a]	1462.66 ± 983.92*
Deltoid anterior	Non-paretic arm	1193.98 ± 751.42[a]	1787.35 ± 1097.61
Deltoid middle	Paretic arm	637.73 ± 406.86*	1033.46 ± 665.87*
Deltoid middle	Non-paretic arm	794.94 ± 684.17	1157.53 ± 902.31
Biceps	Paretic arm	538.89 ± 355.21	703.49 ± 485.87
Biceps	Non-paretic arm	496.94 ± 327.36	612.42 ± 368.61
Triceps	Paretic arm	292.78 ± 191.34[a]	382.85 ± 218.57
Triceps	Non-paretic arm	541.99 ± 486.74[a]	494.55 ± 347.20
Extensor carpi radialis	Paretic arm	511.26 ± 483.86	521.01 ± 498.69
Extensor carpi radialis	Non-paretic arm	449.04 ± 312.28	435.81 ± 270.22
Flexor carpi radialis	Paretic arm	253.68 ± 174.35	286.25 ± 286.19
Flexor carpi radialis	Non-paretic arm	236.49 ± 130.09	216.84 ± 114.03

* : significant difference between low-reaching and high-reaching ($p<0.05$).
[a] : significant difference between paretic and non-paretic upper limb ($p<0.05$).

showed significant increases in high-reaching compared to low-reaching. However, in the non-paretic upper limb, significant increases were shown only in the trapezius upper fibers ($p<0.05$). This result indicates that there was no difference between the muscle activation of the paretic side and that of the non-paretic side in high reaching while in low-reaching, the muscle activation values of the deltoid anterior fibers and the triceps of the non-paretic side were larger than those on the paretic side ($p<0.05$) (Table 1).

DISCUSSION

EMG has been used since the middle of the 1900s as a tool to not only conduct studies on the functions of normal muscles but also to test and quantify the functions of muscles in morbid conditions[6]. In general, %MVIC (maximum voluntary isometric contraction) and %RVC are widely used in measuring muscle activation[7]. However, for patients with CNS problems such as stroke or cerebral palsy, if it is difficult to measure accurate MVIC values, the average values of EMG in resting can be standardized and used as reference values as an alternative measure[8]. In this study, the muscle activation during three seconds resting was used as the reference contraction to compare differences in muscle activation of the paretic upper limb and the non-paretic upper limb in low-reaching and high-reaching.

Acute hemiplegia patients show high muscle activation compared to healthy adults and their muscle activation decreases over time. This relative decrease in muscle activation reflects the recovery of the agonist[9]. Although the action of the deltoid anterior fibers is important for hemiplegic patients, the patients' arm elevation or reaching accompanies the activation of the deltoid middle fibers. Although this induces movements deviated from the sagittal plane, they could be a compensation strategy to accomplish the task[10]. In this study, based on the results of measurements of the muscle activation of the upper limbs, the muscle activation values of the trapezius upper fibers and the deltoid anterior/middle fibers in high-reaching were shown to be significantly higher than in low-reaching, while the non-paretic side showed significant differences in the trapezius upper fibers only. We consider that as the position of the object to be reached by the upper limb became higher, more excessive compensatory muscle recruitments occurred in the proximal upper limb muscles of the paretic side than in the non-paretic side. Also, in the comparison between the paretic side and the non-paretic side, there was no difference between the paretic side and the non-paretic side in high-reaching while in low-reaching, the muscle

activation values of the deltoid anterior fibers and the triceps of the non-paretic side were larger than those on the paretic side. This indicates that, whereas the non-paretic upper limb attempts movements close to the sagittal plane using selective movements toward the front, when attempting arm reaching to touch an object at the height of the knee, the paretic upper limb does not perform efficient arm reaching toward the front. Furthermore, low-reaching is a movement requiring higher muscle activation of the deltoid anterior fiber and the triceps than high-reaching. In conclusion, muscle activation in reaching movements differs depending on the height of the target and we consider that these differences should be considered when therapeutic interventions are prescribed.

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