2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Changes in Muscle Fatigue during Reaching Tasks Performed with Robotic Device by a Stroke Survivor: A Preliminary Study

Mi-Ran Hong, and Won-Kyung Song, *Member, IEEE*

***Abstract*—Electromyography was performed to investigate changes in muscle fatigue for the triceps brachii muscle in one stroke survivor. Results showed that the muscle fatigue increased initially, during robotic training for performing reaching tasks, for the first 500 seconds but became constant afterwards.**

I. Introduction

Rehabilitation therapy can form new neural networks for motor and sensory functions in the brain areas damaged by stroke through repeated training [1]. Muscle fatigue can be defined as a decrease in the ability to generate muscle strength due to exercise. During repetitive training, the muscle contracts several times. A rapid increase in fatigue can cause muscle damage, so proper exercise and rest are necessary [2]. Existing studies have investigated changes in muscle fatigue according to the contraction and relaxation of the biceps brachii muscle during isometric exercise [3] and the effect of muscle fatigue on proprioception in the biceps brachii muscle [4]. Usually, the task of reaching is not a very high intensity movement for stroke survivors. In this study, the effect on the triceps brachii muscle was analyzed when the stroke survivors performed the reaching task. In particular, changes in the ability to control motor function of the upper extremity were observed when the stroke survivors performed the reaching task using the robot for rehabilitation of the upper extremity.

II. Methods

In order to analyze the change in the upper extremity function of stroke survivors at the chronic stage of reaching training using a robotic arm, one male stroke survivor in his sixties was trained three times a week for four weeks (12 sessions in total), with 40 minutes of training per session. The upper extremity exercise module, NREH (National Rehabilitation Center End-effector based Rehabilitation arm at Home), and visual feedback were provided to perform the reaching task [5]. In order to find out whether muscle fatigue occurred even after four weeks of continuous training, one additional session was performed for measuring muscle fatigue. The distance from the home position to the target position of the reaching task was determined by measuring the maximum distance with the affected arm three times and taking the average value. A total of four sets of 480 reaching tasks were performed each day, 120 times per set. When the patient performed the reaching task, electromyography (EMG) signals were collected and analyzed to evaluate the changes in muscle fatigue of the triceps brachii muscle, the main muscle responsible for performing reaching movements of the arm. Data were collected and analyzed using Free EMG1000 (BTS Bioengineering, Quincy, MA, USA) and BTS EMG-Analyzer software. The sampling rate of the surface EMG signal was 1 kHz. The median frequency was extracted using a 20-second window at 20-second intervals [6]. The change in median frequency corresponding to fatigue of the triceps brachii muscle was analyzed during the reaching task.

This work was supported by the Translational Research Program for Rehabilitation Robots, National Rehabilitation Center, Ministry of Health and Welfare, Korea [NRCTR-IN20006, NRCTR-IN21005].

MR Hong (e-mail: hmiran1004@nrc.go.kr) and WK Song are affiliated with National Rehabilitation Research Institute, National Rehabilitation Center, 58 Samgaksan-ro, Gangbuk-gu, Seoul, Korea. (Corresponding author: WK Song, Phone: +82-2-901-1901; Fax: +82-2-901-1910; e-mail: wksong@nrc.go.kr).

III. Results

When observing the change in muscle fatigue of the triceps brachii muscle during the reaching task, we noticed a gradual increase in muscle fatigue in the first set. Muscle fatigue increased for 500 seconds from the start of the task. After that, even though the patient continued to perform the reaching task, there was no further increase in muscle fatigue as the patient adapted to the reaching task.

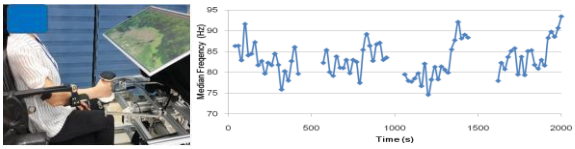

Figure 1. Upper extremity exercise module and change in muscle fatigue of the triceps muscle

IV. Discussion & Concluding Remarks

In this study, muscle fatigue was analyzed during reaching task performed using NREH, the upper extremity robot. The muscle fatigue of stroke survivors can affect their participation in rehabilitation using robotic arms. The degree of muscle fatigue can be used to adjust the training intensity as needed. Muscle fatigue showed a tendency to increase rapidly within the first 15 minutes of the reaching task. In order to exercise for a longer time, i.e., from 30 minutes to 1 hour, maintaining the intensity of exercise at an appropriate level seems to be necessary. This study was conducted as a preliminary study to examine the trend of muscle fatigue. Further studies on the effectiveness of training should be conducted by recruiting more patients undergoing training. In addition, based on the relationship between muscle fatigue and participation in training, we plan to develop a method that will enable efficient training using robotic rehabilitation.

References

[1] J.J. Wan, Z. Qin, P.Y. Wang, Y. Sun and X. Liu. "Muscle fatigue: general understanding and treatment," Experimental and Molecular Medicine, 49(10), pp. e384-e384, 2017.

[2] M.D.F. Ma'as, and A.Z.U. Azmi. "Real-time muscle fatigue monitoring based on median frequency of electromyography signal." In 2017 5th International Conference on Instrumentation, Control, and Automation (ICA), IEEE, pp. 135-139, 2017.

[3] B.L. Arnold and D.H. Perrin. "Effect of repeated isokinetic concentric and eccentric contractions on quadriceps femoris muscle fatigue," Isokinetics and Exercise Science, 5(2), pp. 81-84, 1995.

[4] M.L. Voight, J.A. Hardin, T.A. Blackburn, S. Tippett and G.C. Canner. "The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception," Journal of Orthopaedic and Sports Physical Therapy, 23(6), pp. 348-352, 1996.

[5] J.L. Patton, M. Kovic and F.A. Mussa-Ivaldi. "Custom-designed haptic training for restoring reaching ability to individuals with poststroke hemiparesis," Journal of Rehabilitation Research and Development, 43(5), p. 643-656, 2006.

[6] L. Arendt-Nielsen, N. Gantchev and T. Sinkjaer. "The influence of muscle length on muscle fibre conduction velocity and development of muscle fatigue," Electroencephalography and Clinical Neurophysiology, 85(3), pp. 166-172, 1992.