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Original Article

The effects of training using EMG biofeedback on stroke patients upper extremity functions

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Abstract.　[Purpose] While electromyography (EMG) biofeedback has been recently used in diverse therapeutic interventions for stroke patients, research on its effects has been lacking. Most existing studies are confined to functions of the lower extremities, and research on upper extremity functional recovery using EMG biofeedback training is limited. Therefore, this study examined the effects of training using EMG biofeedback on stroke patients' upper extremity functions. [Subjects and Methods] The subjects of this study included 30 hemiplegia patients whose disease duration was longer than six months. They were randomly divided into a control group (n=15) receiving traditional rehabilitation therapy and an experimental group (n=15) receiving both traditional rehabilitation therapy and training using EMG biofeedback. The program lasted for a total of four weeks. In order to examine the subjects' functional recovery, the author measured their upper limb function using the Fugl-Meyer Assessment and Manual Function Test, and activities of daily living using the Functional Independence Measure before and after training. [Results] A comparison of the study groups revealed that those in the experimental group experienced greater improvement in upper extremity function after training in all tests compared to the control group; however, there was no significant difference in terms of the activities of daily living between the two groups. The results of this study were as follows. [Conclusion] Thus, stroke patients receiving intensive EMG biofeedback showed more significant upper extremity functional recovery than those who only received traditional rehabilitation therapy.
Key words:　Electromyogram, Biofeedback, Stroke

INTRODUCTION

Over 85% of stroke patients undergo hemiplegia, and more than 69% among them experience functional motor disability of the upper extremities[1]. Functional motor disability noticeably appears in the upper extremities rather than in the lower extremities[2]. Damage to the middle cerebral artery, which supplies much blood to the brain part in charge of the motor functions of the upper extremities and the hands, accounts for 75% of the entire stroke; slight recovery of the lower extremities enables functional gait, whereas in the recovery of upper extremity functions, recovery of minute functions (e.g., grasp and manipulation) and that of the distal parts is needed[3]. As a result, the upper extremities look like they have recovered less than the lower extremities. Lang et al.[4] noted that upper extremity motor disability significantly affects stroke patients' performance of activities of daily living, such as having a meal, wearing clothes, or washing one's face. Purposeful movements of the upper extremities require adjustment of the arms and hands, and stroke patients may extend the upper extremities after a stroke but have difficulty in grabbing objects, with considerably reduced manipulation ability and decreased ability to perform purposeful movements[5]. The upper extremity functions of stroke patients play an important role in performing activities of daily living and in coming back to society; as a result, upper extremity functions have been emphasized as an important element in humans[6]. For the recovery of upper extremity functions in stroke patients, diverse treatment methods

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are being studied[7]. Recently, the area of information technology (IT) has provided techniques and services for rehabilitation as well as exercises for improving health[8]. Among such techniques, electromyography biofeedback is one of the industrially specialized contents related to the IT industry and exercise rehabilitation field. Therefore, it is provided as a specialized industry combined with the existing contents of such industries as sports/public health and silver[9]. Electromyography biofeedback provides visual and auditory information on muscular contraction or movements on a real-time basis, thereby effectively maintaining appropriate muscle contraction and body alignment and inducing normal movements. Feedback on electrical activities of the muscles is provided visually and auditorily, so that patients can learn how to adjust the level of the muscular tone themselves[10]. Nonetheless, until recently, treatment using electromyography biofeedback has been conducted diversely in therapeutic interventions for stroke patients[11–13], but research on its effects has been lacking. Therefore, additional research is necessary. Most existing research is confined to functions of the lower extremities, and research on upper extremity functional recovery using electromyography biofeedback training is limited. Accordingly, this study intends to examine the effects of training using electromyography biofeedback on chronic stroke patients' upper extremity functions.

SUBJECTS AND METHODS

The subjects were 30 stroke outpatients in M hospital located in Geollanam-do. They understood the purpose of this study and voluntarily consented to participate in this study. This study was approved by hospital, and all the participants provided their written informed consent. They were divided into a control group and an experimental group. The criteria for selection of the subjects were as follows: patients whose onset of a stroke was six months or longer prior, those whose Korean-mini mental state examination score was 24 points or higher, those whose arm and hand function was 4th stage or a higher level in Brunnstrom's motor recovery stages, and those who had no hemineglect. Before the initiation of this study, the general characteristics of the subjects were identified. No significant difference was found between the two groups in age (control group: 53.26 years old, experimental group: 56.93 years old, (p=0.40)), height (control group: 168.80 cm, experimental group: 160.40 cm, (p=0.22)), and weight (control group: 68.20 kg, experimental group: 60.93 kg, (p=0.08)).

In the pre-test post-test design of the study, the control group received traditional rehabilitation treatment (four weeks, five times per week, 30 min each time), and the experimental group received traditional rehabilitation treatment and training using electromyography biofeedback (four weeks, three times per week, 40 min each time). Myo-Ex of E-LINK system (biometrics Inc., UK) was employed for the intervention. Myo-Ex is composed of integral electrodes attached to the muscles using a double-sided tape. In the intervention, the recording electrode was attached to the center of the extensor digitorum muscle of the paretic side so that the two electrodes became a straight line[14], and the ground electrode that prevented electrical interference on the skin was attached to the distal ulna of the ipsilateral wrist. The reason why the electrodes are attached to the finger extensor in the upper extremity area is that finger extensor control is one of the hand functions that are recovered the latest and a motion to be preceded without failure for prehensile activity[7].

Four among 19 intervention programs (10 min for each program for a total of 40 min) with the highest interest levels, excluding those with speed and difficulty that could not be adjusted, were selected. For the implementation of the selected intervention program, the minimal value (when the muscles were relaxed) and the maximal value (when the muscles were contracted) of the extensor digitorum muscle of the subjects' paretic-side arm were measured, and then the experiment was conducted on the basis of the experimental results. In providing the biofeedback, the selected program was continued when the maximal value was reached and it was stopped when the minimal value was reached.

In the assessment, the Fugl-Meyer assessment (FMA), manual function test (MFT), and functional independence measure (FIM) were repeated twice, and the average value was used. In the data analysis, a paired samples t-test was conducted to compare the changes after the experiment with those prior to the experiment in each group. An independent samples t-test was applied to compare the changes in the score between the two groups after the experiment with those prior to the experiment. The significance level was set to $\alpha=0.05$.

RESULTS

The control group showed significant improvement in FMA ($p<0.01$) and MFT ($p<0.05$), but no significant difference was found in FIM between before and after the intervention. The experimental group showed a significant improvement in FMA ($p<0.000$), MFT ($p<0.000$), and FIM ($p<0.01$) after the intervention compared with before the intervention. According to the result of the analysis of the differences between the two groups, no significant difference was found in FMA ($p<0.05$) and MFT ($p<0.05$), but an increase in the average value of FIM was found in the experimental group (1.80) and the control group (1.27).

DISCUSSION

This study was conducted to verify the effect of electromyography biofeedback training on stroke patients' upper extremity functions and the influence of the recovery of stroke patients' upper extremity functions on their activities of daily living. In addition, this study intended to present a case of a convergent system in which exercise rehabilitation is conducted using

contents based on IT technology.

The electromyography biofeedback was applied to the finger extensor of the paretic side. The function of the upper extremities was evaluated with FMA and MFT, and patients' activities of daily living were assessed with FIN. Then, the results were compared.

According to the results, a statistically significant difference was found between the two groups (p<0.05). Chae et al.[15] and Lourencao, Battistella, de Vrito, Tsukimoto, and Miyazaki[16] also reported the same finding. According to the result of the examination of the effects of training using electromyography biofeedback on stroke patients, statistically significant differences were observed between the control group and the experimental group, consistent with the result of the present study. In addition, Shin[14] and Han, Choi, and Gam[3] found that training using electromyography biofeedback was effective for upper extremity functions in stroke patients. Similarly, electromyography biofeedback training had a positive effect on stroke patients' upper limb functions in the current study.

In addition, the present study comparatively analyzed the activities of daily living of the two groups, and no statistically significant difference was found between them. However, Francisco et al.[17] reported that electromyography biofeedback training on acute stroke patients led to a significant improvement in the experimental group's activities of daily living compared with the control group, inconsistent with the result of the present study. This inconsistent finding may be attributed to the difference in study designs and in the criteria for subject selection between the previous research and the present study. In the present study, the subjects selected were those whose stroke onset was six months or longer prior, whereas the subjects in Francisco et al.[17] were acute stroke patients whose stroke onset was six weeks or shorter prior. The result of the present study is consistent with that of Kim, Lee, Choi, Lee, and Kim[18] on chronic stroke patients. Unlike acute stroke patients, chronic stroke patients become accustomed to the compensation by the non-paretic upper and lower extremities in performing activities of daily living. Consequently, improvement in the upper limb functions of the paretic side does not greatly affect their activities of daily living.

The above study results show that electromyography biofeedback training positively affects stroke patients' upper limb functions. Nevertheless, this study has a few limitations. First, the onset period of study subjects was restricted to six months or longer prior. Thus, obtaining precise data on the training they had received more than six months ago was difficult. Prior training effect might have influenced the present study. Second, as the number of subjects was small, the result of the present study may not be generalizable to all stroke patients. The present study analyzed the results of the control group, which received traditional rehabilitation treatment, and those of the experimental group, which additionally received electromyography biofeedback. Electromyography biofeedback was found to improve stroke patients' upper extremity functions.

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