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Effect of Neuromuscular Electrical Stimulation Combined with Traditional Dysphagia Rehabilitation on Masseter Muscle Thickness and Bite Force in Stroke with Dysphagia Patient

Background: Patients with dysphagia after stroke are treated with neuromuscular electrical stimulation (NMES), but its effect on masseter muscle thickness and bite force in the oral phase is not well known.
Objectives: To investigated the effect of NMES on masseter muscle thickness and occlusal force in patients with dysphagia after stroke.
Design: Two group, pre-post design.
Methods: In this study, 25 patients with dysphagia after stroke were recruited and allocated to either the experimental or the control groups. Patients in the experimental group were treated with NMES to the masseter muscle at the motor level for 30 minutes and were additionally treated with traditional swallowing rehabilitation for 30 minutes. In contrast, patients in the control group were only treated with traditional swallowing rehabilitation for 30 minutes. Masseter muscle thickness was measured using ultrasonography before and after intervention, and bite force was measured using an bite force meter.
Results: The experimental group showed significant improvement in masseter muscle thickness and bite force compared to the control group.
Conclusion: NMES combined with traditional dysphagia rehabilitation is effective in improving masseter muscle thickness and bite force in patients with dysphagia after stroke.

Keywords: *Bite force; Dysphagia; Masseter muscle; Neuromuscular electrical stimulation; Stroke*

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INTRODUCTION

During the swallowing process, mastication primarily plays a role in crushing solid food in the oral cavity and contributes to bolus formation. Mastication involves four muscles—the masseter, temporalis, and lateral and medial pterygoid muscles.[1] Among these muscles, the masseter muscle is the largest muscle and can exert the strongest force; thus, it plays a major role in mastication.[2] Therefore, for normal swallowing in the oral cavity, myophysiological factors such as appropriate muscle strength and masseter muscle thickness are important.

However, neurological diseases such as stroke lead to the skeletal muscle weakness and atrophy. The masseter muscle is also adversely affected by neurological diseases. Weakness and atrophy of the masseter muscle make mastication of the solid food difficult during the oral phase of swallowing,[3] which in turn negatively affects bolus formation, resulting in oral dysphagia.[4] Therefore, there is a need for a therapeutic rehabilitation method for patients with chewing difficulty in the oral phase.

Neuromuscular electrical stimulation (NMES) is applied to the muscles to strengthen them, reduce spasms, prevent atrophy, and preserve muscles in which the nerve is distributed.[5,6] Muscle contraction is achieved by depolarizing the nerve fibers at the application site by transmitting the electrical stimulation to the muscles using surface electrodes.[7] In several previous studies, NMES has been used as a standard modality to restore and improve swallowing function in patients with dysphagia.[8,9] It not only activates the muscles involved in the pharyngeal phase but also is

effective in improving the oral phase of swallowing, thus reducing airway aspiration.[10] However, since most studies were performed with NMES targeting the suprahyoid muscles in the pharyngeal phase, its effect on patients with chewing problems in the oral phase is not well known. Because dysphagia mainly causes various problems in the pharyngeal phase and causes complications such as airway aspiration, relatively few studies have applied it to the masseter muscle including mastication in the oral phase.

Recently, Lee et al.[11] applied NMES to the masseter muscle for 2 weeks to investigate the effect of NMES on patients with dysphagia in the oral phase after stroke. They showed an overall improvement in the swallowing function in the oral and pharyngeal phases and recommended NMES as a rehabilitative tool for improving swallowing function in patients with dysphagia in the oral phase. However, the mechanism underlying this effect is unclear. Since only swallowing function was measured based on videofluoroscopic swallowing study (VFSS), the myophysiological effects of NMES on the masseter muscle could not be evaluated. Therefore, this study investigated the effect of NMES on masseter muscle thickness and bite force in patients with oral dysphagia after stroke.

SUBJECTS AND METHODS

Subjects

Participants were recruited (n=25) from the rehabilitation centre of the local hospital. Inclusion criteria were as follows: Those within 3 months of onset of stroke, dysphagia in oral phase confirmed through a videofluoroscopic swallowing study (VFSS); problem with the mastication function in the VFSS evaluation; Exclusion criteria were as follows: secondary stroke; presence of other neurological diseases. The study protocol was approved by the Institutional Review Board of Seoul Medical Center in South Korea (SEOUL 2019-03-001), and all participants provided written informed consent for study participation.

Methods

All subjects were assigned to either the experimental group (n=13) or the control group (n=12). In the experimental group, NMES was applied to the masseter muscle as follows. First, the target area was cleaned using TENS Clean-Cote skin wipes to firmly attach the electrode to the skin. Second, although the NMES unit could provide two channels of bipolar electrical stimulation at a 60 Hz pulse frequency and a pulse width of 500 μs, we applied only one channel to the paralyzed masseter muscle. Finally, the electric intensity was adjusted and applied. The electrical intensity was gradually increased in 0.5 mA increments until the motor level was reached. Different intensities of stimulation were applied in different patients according to their tolerance. The range of electrical intensity applied in the experimental group was 2.5-7.3 mA. Patients in the experimental group were treated with NMES for 30 minutes a day 5 times a week for 4 weeks and were additionally treated with traditional dysphagia rehabilitation for 30 minutes. In contrast, patients in the control group were only treated with traditional dysphagia rehabilitation without NMES for the same period. All intervention and evaluation were performed by a blind one occupational therapist who did not interact with the participants

Outcome measurement

The primary outcome measurement of this study was the change in the thickness of the masseter muscle. Muscle thickness was measured using a portable ultrasound device (SONON 300L; Healcerion, Seoul, Korea) with a 10 MHz linear- and convex array transducer. The contraction of the left and right masseter muscles was assessed during clenching. The linear type transducer was set to a frequency of 10 MHz, 66 dB for all participants. The transducer was placed at the same angle as the line between the external auditory meatus and acanthion, and then moved down 2-3 cm to meet the mouth tail and the midpoint between the zygomatic arch and mandibular angle. The transducer was moved back 2-3 cm to meet the outer canthus level and masseter muscle level.[1] The thickness of the masseter muscle was determined at the thickest part of the image.

The secondary outcome of the present study was the bite force on both sides, which was measured using an Occluzer device (ACCURA; Demetec, Gyeonggi-do, South Korea). Investigator who performed bite force assessment and analysis was blinded to all other parameters. The participants were instructed to sit on a chair in a relaxed, upright position, and then to bite the pressure-sensitive film (disposable pressure film, Gyeonggi-do, South Korea) as hard as possible. While in the seated position, the participants were instructed to place their incisor in the middle aspect of the bite sensor.[1] The bite force was measured for 5 s, and the mean of three measurements was used

for the analysis. The maximum bite force was expressed as an absolute value in newtons.

Statistical analysis

All statistical analyses were performed using SPSS version 15.0 (IBM Corporation). Descriptive statistics are presented as means with standard deviations. The Shapiro-Wilk test was used to check the normality of the outcome variables. To evaluate the intervention effects, Wilcoxon signed-rank and Mann-Whitney test were used to compare the pre- and post-intervention measures in each group and to compare the intergroup changes in outcome measures, respectively. The statistical significance level was set at $P<.05$.

RESULTS

Participants

25 people were enrolled in this study, and there was no dropout until the intervention was completed. Therefore, data from 25 people were analyzed (Table 1). There were no significant differences between the groups based on general characteristics, masseter muscle thickness and bite force ($P>.05$)

Masseter muscle thickness

Within-group comparisons showed that the experimental group had a statistically significant increase in masseter muscle thickness ($P<.05$). In contrast, the control group had no significant increase in masseter muscle thickness ($P=.18$). Post-intervention between-group comparisons showed that the experimental group had a statistically significant increase in masseter muscle thickness than the control group ($P<.05$) (Table 2).

Bite force

Within-group comparisons showed that the experimental group had a statistically significant increase in bite force ($P<.05$). In contrast, the control group had no significant increase in bite force ($P=.48$). Post-intervention between-group comparisons showed that the experimental group had a statistically significant increase in bite force than the control group ($P<.001$) (Table 2).

Table 1. Demographic characteristics of the patients

	Experimental group	Control group
Number of subject	13	12
Gender (man/woman)	6 / 7	6 / 6
Age (years)	65.7 ± 7.6	66.5 ± 4.8
Stroke type		
Hemorrhage	7	7
Infarction	6	5
Site of stroke lesion		
Middle cerebral artery	12	11
Medulla oblongata	1	1

Table 2. Changes of masseter muscle thickness and maximum occlusal force in parameters before and after treatment

	Experimental group			Control group			Intergroup *P*-values
	before	after	*P*-value	before	after	*P*-value	
MMT	4.5 ± .9	5.11 ± 1.1	<.05*	4.9 ± .8	5.0 ± .6	.18	<.05†
MBF	198.5 ± 18.5	220.3 ± 17.8	<.05*	187.8 ± 16.3	191.2 ± 17.5	.48	<.05†

*$P<.05$ by Mann-Whitney test, †$P<.05$ by Wilcoxon signed-rank, Mean ± standard deviation
MMT: Masseter muscle thickness, MBF: Maximum bite force

DISCUSSION

NMES is an effective tool used in the rehabilitation of muscle functions by improving muscle strength and muscle thickness in patients with neurological disease. In addition, it improves swallowing function and increasing muscle activation in patients with dysphagia after stroke. However, most studies have applied NMES only to the suprahyoid muscles involved in the pharyngeal phase of swallowing; hence, its effect on patients with dysphagia with chewing difficulty in the oral phase due to paralysis of mastication muscles is unclear. Therefore, this study investigated the effect of NMES on masseter muscle thickness and bite force in patients with dysphagia after stroke.

In this study, the experimental group showed a significant improvement in masseter muscle thickness compared to the control group. NMES is effective in inducing muscle activation and contraction through muscle fiber stimulation.[12] Increased muscle activation means an increase in motor unit activation in the peripheral nervous system, resulting in an increase in the number of motor units.[13,14] Therefore, the application of NMES causes increased activation of the target muscle, and its repeated application for 4-6 weeks or longer can increase muscle thickness and muscle strength. Recently, Chang et al.[15] reported a significant increase in masseter muscle thickness after NMES application to the masseter muscle in elderly individuals aged 〉65 years living in the community. Their findings are consistent with our study findings. In addition, our study investigated the effect of NMES on occlusal force, and the experimental group showed a significant improvement in occlusal force compared to the control group. Positive changes in muscle physiology, such as increase in muscle thickness due to NMES, are closely related to improvement in muscle strength. Increase in muscle thickness means an increase in the force that can be generated during muscle contraction, and increase in masseter muscle thickness is thought to contribute to the increase in the maximum bite force.

This study has several limitations. First, it is difficult to generalize the results of this study due to the small number of subjects. Second, the effect of NMES may vary according to its intensity, but since this study only increased the intensity till the motor level, the effect of intensity till the sensory level is unknown. Third, the long-term effect of NMES is unknown because follow-up was not performed.

CONCLUSION

This study confirmed that NMES is effective in increasing masseter muscle thickness and bite force in patients with dysphagia after stroke. Therefore, NMES combined with traditional dysphagia rehabilitation could be applied as a rehabilitative method in patients with dysphagia after stroke.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

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