J Korean Acad Rehab Med 2011; 35: 195-200
Original Article

The Effects of Neuromuscular Electrical Stimulation on Swallowing Function in Healthy Older Adults

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Objective To evaluate the effects of neuromuscular electrical stimulation on the swallowing function in healthy older adults without clinical dysphagia.

Method The subjects were 18 healthy older adults aged >70 years and 10 young adults aged <30 years without symptoms or a history of dysphagia. Both groups were evaluated by the functional dysphagia scale (FDS) and pharyngeal transit time (PTT), using a videofluoroscopic swallowing study with semisolid material. Only the healthy older adults group received neuromuscular electrical stimulation (NMES) on suprahyoid and infrahyoid muscles, 60 min/day, 5 days/wk, for 2 weeks. The healthy older adults group was then re-evaluated by FDS and PTT.

Results The average PTT in young adults was lower than in healthy older adults. FDS of the oral phase was larger in the older adults than in the young adults. After NMES for 2 weeks in older adults, there was a significant improvement in the averages for PTT and FDS.

Conclusion The results of this study showed that healthy older adults without clinical dysphagia had decreased swallowing function when they were compared with young adults. After NMES, the swallowing function, evaluated by FDS and PTT, was improved in healthy older adults.

Key Words Neuromuscular electrical stimulation, Swallowing, Pharyngeal transit time

INTRODUCTION

Dysphagia refers to difficulties in the process where a food bolus is sensed, put into the mouth, and transported into the stomach via the oral cavity, the pharynx, and the esophagus. Recently, dysphagia has included difficulties in all the actions and senses related to swallowing, and also the preliminary actions for swallowing.[1] In some serious cases, dysphagia causes aspiration pneumonia, malnutrition, dehydration, and sepsis, and thus may lead to death.[2] Ordinarily, dysphagia occurs in central nervous system diseases such as stroke, neurodegenerative diseases such as Parkinson's disease, peripheral nervous system disease, neuromuscular junction disorders, myopathies, and local lesions such as head and neck tumors or thyroid hypertrophy. Therefore, the incidence rate is higher in the aged than in the young because they are more sus-

Received March 30, 2010; Accepted October 19, 2010
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ceptible to stroke, dementia, and other causative diseases. It has been reported that the aged had the higher incidence rate of hypofunction of the oral phase, including masticatory force, inactive esophageal peristaltic movement, and induction of a swallowing reflex during inspiration, and that it took a longer time for each phase during swallowing with advancing years. Also, the hyoid bone becomes sluggish in the pharyngeal phase.[3-9]

Though the reduction of swallowing speed is not the cause of dysphagia, it may be a risk factor to carry the food bolus in the wrong direction,[10] in which case the pharyngeal transit time (PTT) is delayed; especially, the food bolus may be sucked into the respiratory tract.[11]

Recently, electrical stimulation has been used in rehabilitative therapy for dysphagia.[12,13] A study reported that in patients with stroke, electrical stimulation strengthened muscles related to swallowing and reactivated nerve pathways, and thus was judged to be therapeutically effective.[2,14,15] Also, electrical stimulation offered somatic senses or stirred the laryngeal elevator muscle repeatedly, causing plastic changes in the brain.[16,17]

In view of the studies so far reported, the swallowing function tends to decline with advancing years, and dysphagia may be improved in stroke patients treated with electrical stimulation. Therefore, this study made a comparison between normal elderly adults aged ≥70 (older adults group) and normal young adults (young adults group) in swallowing function, and observed the changes of swallowing function in the asymptomatic elderly who underwent electrical stimulation.

MATERIALS AND METHODS

Subjects

Applicants were recruited between September and October 2009, and 28 applicants were selected to be the subjects of this study. They were composed of 18 elderly aged ≥70 subjects and 10 young subjects aged <30, who were without swallowing difficulties and could lead their activities of daily living without problems. Applicants, who had a history of neuromuscular system diseases, craniocervical diseases, or esophageal diseases, or who had them at the time of the screening test, were excluded as subjects. In addition, applicants who had cardiovascular diseases and who had a history of epilepsy or were under suspicion of epilepsy were excluded because electrical stimulation therapy is not allowed to be performed on them.[18]

The older adults group was composed of 8 men and 10 women, and their average age was 76.2. The young adults group was composed of 2 men and 8 women, whose average age was 21.2.

Methods

Videofluoroscopic swallowing study (VFSS): VFSS was performed on the two groups by a physiatrist and a resident, who applied the adapted Logemann's method.[19] A semisolid diet was prepared by a mixture of plain yogurt and 140 g/100 ml of liquid barium, and subjects were examined in a lateral sitting position by the videofluoroscope (Philips Omnidiagnost, Philips Medical Systems, Eindhoven, Netherlands) while swallowing the mixture 3 separate times (10 ml per swallow). In the older adults group, VFSS was performed again after the subjects underwent neuromuscular electrical stimulation (NMES) for 2 weeks. The video recordings were analyzed at intervals of 0.033 second by the use of the program, V1 Home 2.0 (V1 Sports, Plymouth, USA), and the results were evaluated by the Functional Dysphagia Scale (FDS) presented by Han et al.[20] PTT was measured from the time when the front part of a food bolus reached the bottom of the mandibular ramus, until the time when its rear part passed through the cricopharynx.[20]

Neuromuscular electrical stimulation (NMES): NMES

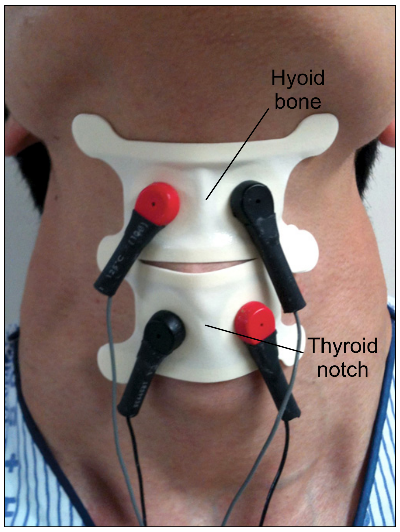

Fig. 1. Four pads of neuromuscular electrical stimulation were attached on the anterior neck. Two pads were applied to skin over the hyoid bone and another two pads over the both sides of the thyroid notch.

was performed only on the older adults group who underwent the primary VFSS, by the use of the electrostimulator (Stim Plus DP-200, Cyber Medic Corp., Iksan, Korea). It was performed for 60 minutes at a time, once a day, 5 times a week, for 2 weeks; 10 times in total. In 2 independent channels, pads were placed on both sides of the thyroid notch and two points on the hyoid bone, respectively (Fig. 1). The biphasic wave and pulse duration were determined at 80 Hz and 300 μsec, respectively, as described in the study of Freed et al.[2] To prevent laryngeal muscle spasm, electrical stimuli were given intermittently; specifically, a stimulation was given for 50 seconds, before and after which a rise time and a fall time were set for 1 second each, followed by a pause for 8 seconds. The intensity of stimulation was controlled between 3 mA and the maximum, which depended on a subject's compliance. Inquiries were made for whether subjects felt inconvenience or pain while undergoing NMES. In order to relax, we intended to lead our conversations to a free topic.

Using the program 'Statistical Package for the Social Science' (for Windows, version 14.0), the two groups were compared regarding their swallowing characteristics using the independent sample t-test. Additionally, FDS and PTT were analyzed before and after NMES on neck muscles using the paired sample t-test. The significance level was defined as a p-value <0.05.

RESULTS

PTT (Table 1)

In the older adults group, the average of PTT was 0.87±0.12 seconds, which was delayed compared to that of the young adults group (0.57±0.05 seconds) ($p<0.001$). After NMES on the neck muscles, PTT in the older adults group was 0.69±0.11 seconds, which was shorter than the previous value for that group ($p<0.001$).

The average of FDS (Table 2)

In the older adults group, the average FDS was 10.83±10.08, which was higher than that of the young adults group (5.30±6.04), but the difference was not statistically significant (p=0.127).

After NMES on the neck muscles, FDS in the older adults group was 5.08±6.82, which was lower than the previous value for that group (p=0.001).

FDS scores (Table 3)

Out of 11 items in FDS, just 6 were scored in all the groups, and average scores for the older adults group were higher than for the young adults group. Scores for 'Bolus formation' (BF) and 'Residue in oral cavity' (ROC), in the 2 groups were significantly different. However, scores for 'Triggering of pharyngeal swallow' (TPS), 'Residue in valleculae' (RV), 'Residue in pyriform sinuses' (RPS), and 'Coating of pharyngeal wall after swallow' (CPW), were not significantly different

Table 1. Pharyngeal Transit Time of Two Groups

	n	PTT (sec)	p-value
Young adults	10	0.57±0.05	<0.001
Older adults (before)	18	0.87±0.12	
Older adults (after)	18	0.69±0.11	<0.001

Values are mean±standard deviation.
PTT: Pharyngeal transit time

Table 2. The Average of Functional Dysphagia Scale of Two Groups

	n	FDS	p-value
Young adults	10	5.30±6.04	0.127
Older adults (before)	18	10.83±10.08	
Older adults (after)	18	5.08±6.82	0.001

Values are mean±standard deviation.
FDS: Functional dysphagia scale

Table 3. Functional Dysphagia Scale Score of Two Groups

	Young adults	Older adults (before)	Older adults (after)
Oral phase			
BF	0.30±0.95*	1.64±1.26	0.75±1.06*
ROC	0.20±0.63†	1.44±0.70	0.78±0.94*
Pharyngeal phase			
TPS	0.00±0.00	0.56±2.36	0.27±1.18
RV	2.60±3.13	3.19±3.89	1.11±1.70*
RPS	1.20±1.93	2.00±2.74	0.56±1.34*
CPW	1.00±3.16	2.78±4.61	1.00±3.83

Values are mean±standard deviation.
BF: Bolus formation, ROC: Residue in oral cavity, TPS: Triggering of pharyngeal swallow, RV: Residue in valleculae, RPS: Residue in pyriform sinuses, CPW: Coating of pharyngeal wall after swallow
*$p<0.05$, $^{\dagger}p<0.001$

between the 2 groups.

In the older adults group, a comparison of scores before and after NMES, showed statistically significant differences for BF, ROC, RV, and RPS, but scores for TPS and CPW were not significantly different.

DISCUSSION

VFSS has been the standard method used to evaluate the swallowing function of normal subjects and stroke patients,[19] and interesting information has been accumulated concerning the quantitative measurement of the oropharyngeal phase.[21-23] Regarding PTT, the terminology and measurements vary slightly depending on the study. Johnson et al.[24] defined kinematic pharyngeal transit time as the time the epiglottis needs to return to the original position after transport of a food bolus begins, and reported that normal subjects required a maximum of 1 second, while stroke patients showed a remarkable delay by requiring 6.2 seconds. Han et al.[25] measured this parameter in the same way as Johnson et al. and reported that stroke patients who did not have aspiration signs or symptoms required 1.5±0.4 seconds. Chon et al.[26] measured kinematic pharyngeal transit time in accordance with the definition given by McConnel et al.,[27] i.e., the time the hyoid bone needs to return to the original position after being elevated, and reported that the normal subjects took 1.2±0.3 seconds. Daniels and Foundas,[28] who defined it as the time the larynx needs to be elevated after a food bolus reached the lingual root, reported that it was normal to take $<$0.45 seconds. Han et al.[29] measured it in adults aged 26±4 who swallowed 4 diets of different viscosities, using the method suggested by Logemann,[10] and reported it took $<$0.49 seconds. In this study, PTT was 0.57±0.05 seconds and 0.87±0.12 seconds in the young adults group and the older adults group, respectively. PTT in the older adults group was within the normal range, but statistically, it was regarded as delayed, which was consistent with the report of Robbins et al.[5] that PTT, the cricopharyngeal opening time and the total swallowing time, got longer with advancing years. It is thought that the central nervous system becomes insensitive in the aged.

NMES is used to treat dysphagia. It strengthens the laryngopharyngeus related to swallowing, reactivates nerve pathways in the oral cavity, and thus improves the swallowing reflex. Additionally, NMES acts simultaneously with the mylohyoid muscle, the geniohyoid muscle, the stylohyoid muscle, and the surrounding tissues that elevate the larynx, and thus shortens the distance between the hyoid bone and the thyroid cartilage, where swallowing is expected to be improved.[2,13,14,30,31] The study of Yoon et al.[32] indicates that functional electrical stimulation improves the function of the pharyngeal phase and thus is effective to improve swallowing. In this study, PTT and FDS in the older adults group were significantly improved after 2 treatments with NMES. We thought that the result might be caused by functional strengthening of the pharyngeal phase through reactivating the delayed nerve pathways rather than strengthening the atrophied laryngopharyngeus.

In the case of FDS, the older adults group was given higher scores compared to the young adults group before NMES, but the difference was not statistically significant. This result implies that natural aging does not affect swallowing function to the level of disability. Actually, both groups did not have the clinical symptoms of dysphagia.

To itemize FDS, statistically significant differences were observed in BF (p=0.007) and ROC (p=0.000), which indicates that the older adults group had problems within the oral phase rather than within the pharyngeal phase. Facial muscles, masticatory muscles, soft palate muscles, intrinsic lingual muscles, and extrinsic lingual muscles are needed to form food boluses and leave no food residue in the oral cavity. However, the problem is that such muscles weakened with advancing years. As a result, the aged may have more problems with swallowing.

In the older adults group whose members underwent NMES, statistically significant changes were observed in 4 items, i.e., BF (p=0.008), ROC (p=0.006), RV (p=0.015), and RPS (p=0.008) out of 6 FDS items given scores.

The results of this study showed that oral and pharyngeal phases functionally weakened in the older adults group rather than the young adults group, but that PTT and FDS were improved after NMES was administered to neck muscles for 2 weeks, which might be caused by the reactivation of nerve pathways. Altogether, NMES is expected to be effective against decreased swallowing function caused by natural aging.

Limitations of this study are the small number of subjects, use of 2-week NMES (too short a period to follow the progress), and the type of diet. Such being the case, it was problematic to derive various results. Furthermore, inquiries were not made concerning the dental conditions of the older adults group, and therefore, the influence on the oral phase was constrained. In this regard, there is a need to conduct a further study.

CONCLUSION

In this study, VFSS was performed on an older adults group (n=18) and a young adults group (n=10), and the parameters of PTT and FDS were measured. In addition, NMES was performed on the older adults group for 2 weeks. The results indicated that swallowing function decreased more in the older adults group than in the young adults group, and that swallowing function was improved by NMES.

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