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Home Based Dysphagia Rehabilitation for Stroke Patients Using Information and Communication Technology

Background: Recently, a new home-based dysphagia rehabilitation method using information and communications technology (ICT) has been reported, but clinical evidence is still lacking.
Objectives: To investigate the effects of home-based dysphagia rehabilitation using ICT on tongue muscle strength and volume in patients with developed dysphagia after stroke.
Design: Randomized controlled trial design.
Methods: Twenty patients who developed dysphagia after stroke were enrolled. The experimental group received dysphagia rehabilitation in the form of ICT-based home care. In contrast, the control group received traditional rehabilitation based on swallowing under the supervision of occupational therapists. All interventions were conducted five times a week for four weeks.
Results: Both groups showed statistically significant increases in tongue muscle strength and volume after the intervention ($P<.05$, both). However, there were no significant differences in tongue strength or volume between the two groups after the intervention ($P>.05$, both).
Conclusion: Home-based dysphagia rehabilitation using ICT showed effects similar to those of conventional swallowing rehabilitation in patients who developed dysphagia after stroke. These findings suggest that dysphagia rehabilitation can be conducted at home without the help of a therapist.

Keywords: *Dysphagia; Information and communications technologies; Stroke; Tongue*

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INTRODUCTION

Tongue-strengthening exercises are effective in improving the swallowing function and eliciting physiological changes in the tongue muscles.[1] This therapeutic exercise, and variations thereof, are commonly used in clinical practice. Previous studies have reported that tongue exercises using a depressor and tongue resistance exercise against the hard palate on the roof of the oral cavity can help improve tongue strength and thickness and improve swallowing in healthy adults and patients with dysphagia.[2-5]

However, these methods have certain limitations. First, one must visit a hospital to perform them under the supervision of a speech-language pathologist or occupational therapist. Second, one important aspect of resistance exercise is the selection of proper resistance, which is generally based on 1-RM testing.[3] However, traditional tongue exercise methods have the disadvantage of not being able to control the intensity of resistance. Third, because resistance exercise requires significant physical effort, adherence is challenging. Therefore, visual feedback is important for active participation in rehabilitation.[6] In light of these limitations, an effective home-based dysphagia rehabilitation method is needed.Information and communication technology (ICT), smart home technologies, and the Internet of Things are becoming an important and ever-growing aspects of eHealth, which includes the use of hardware, computing devices, physical objects, and software that interact with each other and their users.[7] ICT has contributed to the development of healthcare and is widely used in rehabilitation. ICT is particularly prevalent in home-based rehabilitation.[8]

In rehabilitation, games are a common method of applying ICT and in clinical practice through the use of software and hardware. Several previous studies reported that the application of game-like ICT for dysphagia rehabilitation had a positive effect on improving function as well as motivating participants to participate in rehabilitation. Therefore, the application of ICT for home-based dysphagia rehabilitation can help minimize reliance on experts and the number of visits to the hospital. Therefore, this study investigated the effect of home-based dysphagia rehabilitation using ICT to improve swallowing function in patients who developed dysphagia after stroke.

SUBJECTS AND METHODS

Subjects

In this study, 20 patients diagnosed with dysphagia after stroke were enrolled. Inclusion criteria were as follows: diagnosis of stroke within the past 6 months; oropharyngeal dysphagia confirmed through a videofluoroscopic swallowing study (VFSS); coughing after completion of a 3-oz water swallow test; ability to follow study instructions; ability to swallow voluntarily; only liquid aspiration or penetration observed on a VFSS; presence of a nasogastric tube; absence of any cognitive deficits (a score of $>$ 24 points on the Mini-Mental Status Examination [MMSE]). Exclusion criteria were as follows: secondary stroke, presence of other neurological diseases, presence of a gastrostomy tube, and problems with the esophageal phase of dysphagia (e.g., achalasia or upper esophageal sphincter opening dysfunction), as confirmed by VFSS. 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

The study was conducted using two groups: a randomized control group and an evaluator-blinded experimental group. All participants were randomly assigned to one of the two groups using opaque envelopes containing a code that specified the group. The experimental group underwent home-based dysphagia rehabilitation using the TPS system (TPS 100, Cybermedic Inc., Iksan, South Korea). The TPS system is a device that applies ICT to tongue-strengthening exercises for the purpose of dysphagia rehabilitation and consists of a pressure sensor, an air bulb, and a display, such as that of a tablet PC or smartphone.[1] The air bulb is placed between the tongue and the hard palate, and external force generated as the tongue is elevated and squeezes the air bulb. The pressure against the air bulb was then transmitted to a pressure sensor via a connected tube. Thereafter, the pressure sensor readings are automatically displayed through the Bluetooth interface on the display of the tablet PC or smartphone in conjunction with the game. Prior to the initiation of the tongue-strengthening exercise, the TPS system was used to measure 1-RM in the experimental group. The 1-RM values were then used to determine the target value of resistance, which was set to 70% of the 1-RM. The exercises were divided into isotonic and isometric types. Isotonic exercise was performed by repeatedly contracting and relaxing the tongue musculature for three sets of 30 repetitions per day. The isometric exercises involved a sustained contraction of the tongue musculature for three sets of 30 seconds per day. All training undertaken by this group was performed at home with the help of a guardian and without visiting the hospital. The guardian was taught how to smoothly operate the equipment in advance.

Unlike the experimental group, the control group visited a rehabilitation hospital and underwent a tongue-strengthening exercise regimen using traditional dysphagia rehabilitation methods. An occupational therapist did not provide ICT. In terms of resistance exercise, the subjects were instructed to push the tongue against the hard palate according to the method previously presented by Park et al.[9] This exercise was performed both isometrically and isotonically. The exercise number and volume were the same as those of the experimental group, in which the isotonic exercise was performed by repeatedly contracting and relaxing the tongue musculature for three sets of 30 repetitions per day; isometric exercise involved a sustained contraction of the tongue musculature performed for three sets of 30 seconds per day. The intervention was performed by an occupational therapist.

Outcome Measurement

The tongue strength was measured using a TPS system. The measurement was performed by placing the air bulb between the tongue and the palate and then pressing the bulb firmly with the tongue.[5] The average value of three consecutive measurements was recorded. The numerical value of the results was automatically calculated and presented. Tongue muscle thickness was measured using a portable ultrasonography device (SONON300L, Healcerion, Seoul, Korea) with a 10 MHz and linear- and convex-array transducer. Tongue thickness was determined by measuring the distance between the upper and lower surfaces of the tongue muscles in the center of the plane perpendicular to the Frankfort horizontal plane of the frontal session. The vertical distance was measured from the surface of the mylohyoid muscle to the dorsum of the tongue.[1] Ultrasonographic measurement of muscle thickness was performed by an experienced rehabilitation physician.

Statistical Analysis

All statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL). 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-U tests 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

In this study, 20 patients with dysphagia after stroke were enrolled, and since three dropped out, the data of 17 patients were finally analyzed. No significant differences in baseline characteristics were observed between the two groups ($P>.05$). The general characteristics of the participants are presented in Table 1.

Effect on Tongue strength

The experimental group showed a significant increase in tongue strength. The control group also showed a significant increase in tongue strength ($P<.05$). When comparing the two groups after the intervention, tongue strength improved more in the experimental group than in the control group (Table 2).

Effect on Tongue thickness

The experimental group showed a significant increase in tongue strength. The control group also showed a significant increase in tongue strength ($P<.05$). When comparing the two groups after the intervention, tongue strength improved more in the experimental group than in the control group (Table 2).

Table 1. General characteristics

	Experimental group	Control group
Sex (male/female)	4 / 5	4 / 4
Age (years)	63.3 ± 4.7	65.2 ± 5.8
Paralyzed side (Rt./Lt.)	6 / 3	5 / 3
Stroke onset (weeks)	16.3 ± 2.5	15.8 ± 3.2

Table 2. Changes in parameters before and after the treatment

	Experimental group		Control group		Between group P-values
	Pre	Post	Pre	Post	
Tongue strength (kPa)	21.4 ± 5.8	25.8 ± 4.5*	22.1 ± 6.3	25.8 ± 5.7*	.105
Tongue thickness (mm)	38.5 ± 4.2	41.1 ± 3.2*	39.1 ± 2.5	42.1 ± 3.2*	.41

The values are expressed as mean ± standard deviation
*$P<.05$ by Wilcoxon signed-rank test, †$P<.05$ Mann-Whitney U test

DISCUSSION

Recently, new rehabilitation methods using ICT have been introduced to improve the effectiveness and efficiency of the process. However, most of these methods focused on the recovery of cognitive and motor functions. Hence, evidence of the utility of ICT in the rehabilitation of patients with dysphagia is insufficient. This study investigated the effects of home-based dysphagia rehabilitation using ICT in patients who developed dysphagia after stroke.

A comparison of the pre- and post-intervention results showed statistically significant improvements in tongue muscle strength and volume in both groups. In addition, there was no statistical difference between the two groups following the intervention, suggesting that home-based rehabilitation using ICT and traditional rehabilitation methods performed in hospital clinics had similar effects.

The two exercise methods used the basic principles of resistance exercise to induce physiological changes in the skeletal muscles.[10] Although they may have had the same purpose, they differed in terms of their application. The control group received traditional rehabilitation treatment at the hospital with professional assistance from a therapist, whereas the experimental group received home-based dysphagia rehabilitation using ICT.

Home-based dysphagia rehabilitation using ICT has several advantages. The first ICT-based tongue-strengthening exercises systematically controlled the intensity of the resistance through visual feedback using a table. In addition, systematic resistance exercise is possible because the force is self-adjusting, thereby correcting errors immediately.[11] On the other hand, conventional tongue-strengthening exercises cannot objectively control the intensity of the resistance or be monitored effectively, making it difficult to determine the patient's exercise state. It is very important to apply an appropriate resistance intensity to induce physiological changes in the skeletal muscles through resistance exercise. The strength of the resistance varies slightly among researchers, but 60% to 80% of the patient's 1-RM is generally used.[12] While higher resistance intensities more substantially affect the skeletal muscle, higher intensities can cause rapid muscle fatigue and temporary muscle pain, thus limiting their long-term use.[11] Neurological diseases, such as stroke, may also impose physical limitations on the use of higher intensities. In general, such intensities are less appropriate for patients with dysfunction than are apparently healthy patients. On the other hand, low-resistance strength training may primarily help improve skeletal muscle endurance; however, it is difficult to induce physiological changes in the muscle, such as maximal muscle strength and hypertrophy, using this method.[11] Hwang et al.[3] reported a significant improvement in tongue muscle mass and volume as a result of applying tongue exercise for six weeks at a resistance intensity of approximately 70% of 1-RM in healthy adults. In addition, several studies have demonstrated significant improvements in tongue muscle strength and volume as a result of applying tongue exercises in elderly patients and those with dysphagia caused by stroke.[1,9,13] As was the case in our report, these prior studies used a resistance intensity of approximately 70% of 1-RM.

Secondly, ICT-based rehabilitation has various applications. Since this equipment uses games rather than mere active participation as a part of the rehabilitation process, compliance and motivation are achieved through fun and excitement.[14] Moreover, the equipment involved can potentially be easier and more intuitive to use. Several previous studies have reported that game-based swallowing rehabilitation training significantly reduces subjective perceptions of physical effort and fatigue while significantly improving rehabilitation motivation and enjoyment compared to conventional resistance exercise.[14,15] Therefore, the findings of this study indicate that ICT-based tongue-strengthening exercises may have contributed positively to the levels of active participation by patients in the dysphagia rehabilitation process by encouraging fun, interest, and motivation.

Finally, ICT-based rehabilitation has advantages in terms of both time and cost when performed at home, since it does not require hospital visits or the help of a professional therapist. In particular, since the experimental group can perform the rehabilitation themselves or with the help of a guardian from home, there is no therapeutic cost, whereas the control group would otherwise incur the cost of treatment. However, ICT-based home rehabilitation may be possible only when patients have the cognitive ability, physical function, and cooperation to perform exercises on their own without intervention from a therapist.

This study had some limitations. First, the sample size was small; therefore, the results of this study cannot be generalized to other populations. Second, the possibility of natural recovery cannot be ruled out because the participants in this study were subacute patients who experienced strokes less than six months prior. Finally, the long-term effect of the treatment remains unknown because follow-up was not performed after the intervention.

CONCLUSION

This study showed that home-based dysphagia rehabilitation using ICT is effective in improving tongue muscle strength and volume in patients who develop dysphagia after stroke. This intervention method can be applied without time and space constraints and does not require the help of a professional therapist. Moreover, it offers the advantage of reducing medical expenses.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

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