The Effects of Combined Action Observation and Tongue Sensory Feedback Training on Bolus Transit and Swallowing Safety in Patients with Chronic Stroke-Related Dysphagia

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Purpose The present study examined whether Tongue Sensory Feedback Training (TSFT) combined with action observation improves tongue strength, swallowing performance, and penetration–aspiration severity in patients with chronic post-stroke dysphagia (PSD). ***Methods*** A randomized controlled pretest–posttest design was applied to twenty patients with chronic PSD who were hospitalized at a hospital in Gyeonggi-do, Republic of Korea. Participants were randomly assigned to either an experimental group (EG) receiving TSFT combined with action observation (n = 10) or a control group (CG) receiving tongue motor exercise training combined with action observation (n = 10). Over a period of five weeks, participants received 30-minute treatment sessions on three occasions each week. Effectiveness of the intervention was determined by changes in maximal tongue strength, swallowing transit times derived from VFSS analysis, and Penetration –Aspiration Scale ratings. ***Results*** Following the intervention period, the experimental group demonstrated significantly greater gains in maximal tongue strength and oral transit time than the control group ($p < 0.05$). Although no significant between-group differences were observed in pharyngeal transit time or penetration–aspiration scale scores, overall trends toward improvement were noted in the EG. ***Conclusion*** These findings suggest that TSFT combined with action observation is an effective intervention for enhancing tongue strength and oral-phase swallowing efficiency in patients with chronic PSD. Furthermore, the results indicate that an occupational therapy-based approach integrating sensory-based intervention and action observation may contribute to swallowing function recovery even in the chronic stage after stroke.

Key words Action observation, Chronic stroke, Dysphagia, Tongue proprioceptive biofeedback, Tongue strength

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Ⅰ. Introduction

Post-stroke dysphagia (PSD) is a common and serious complication following stroke and is associated with aspiration, aspiration pneumonia, malnutrition, dehydration, prolonged hospital stays, and poorer functional outcomes.[1,2] Swallowing is a complex sensorimotor process that integrates central nervous system control, peripheral sensory input, and highly coordinated activity of multiple muscle groups.[3] Neurological damage caused by stroke disrupts voluntary motor control and sensory processing of the swallowing musculature, leading to impairments in oral bolus control, pharyngeal reflex initiation, and overall airway protection efficiency.[4]

Rehabilitation interventions for PSD have traditionally employed multifaceted approaches, including sensory stimulation to facilitate the swallowing reflex, therapeutic exercises targeting oropharyngeal muscles, and therapist-provided feedback to guide motor performance.[5,6] Among these components, the tongue plays a critical role in bolus formation and intraoral transport. Reduced tongue strength and pressure generation are directly associated with decreased oral-phase efficiency and increased oral residue. Consequently, interventions specifically targeting tongue function have gained increasing clinical attention. Previous studies have demonstrated that resistance and pressure-based tongue training can lead to significant im-

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provements in tongue strength and reductions in oral residue, ultimately enhancing swallowing function.[7,8)]

From a motor learning perspective, performance change is driven not merely by repetition but by error-based learning and goal-directed modulation supported by augmented sensory feedback.[9)] In this context, TSFT enables patients to precisely monitor their motor output, thereby enhancing training quality and facilitating functional adaptation.[10)] Recently, action observation (AO) has been proposed as a novel adjunctive intervention capable of promoting motor cortical activation and neuroplasticity through visual stimulation. AO engages the mirror neuron system, facilitating motor planning and execution, and accumulating evidence suggests its potential contribution to functional recovery in swallowing rehabilitation.[11,12)]

Given that TSFT primarily enhances peripheral sensory–motor feedback and action observation facilitates central motor network activation, combining these interventions may provide complementary mechanisms for promoting swallowing recovery. The integration of peripheral muscle strengthening with central motor facilitation may produce synergistic effects on functional swallowing outcomes. However, to date, limited studies have examined the combined effects of TSFT and action observation, particularly in individuals with chronic post-stroke dysphagia.

Although post-stroke recovery is known to be time-dependent, with heightened plasticity during the acute and subacute phases, emerging evidence indicates that meaningful functional changes can still occur in the chronic stage through sustained training–plasticity interactions.[13)] Moreover, the gradient of treatment responsiveness has been reported to extend beyond one year post-stroke.[14)] These findings underscore the therapeutic relevance of targeted rehabilitation even in chronic populations. Therefore, the purpose of this study was to investigate the effects of TSFT combined with action observation on tongue strength, swallowing timing parameters (oral transit time and pharyngeal transit time), and penetration–aspiration outcomes in individuals with chronic post-stroke dysphagia.

II. Methods

1. Participants

This study recruited patients with chronic post-stroke dysphagia who were hospitalized at B Hospital in Gyeonggi-do, Republic of Korea. Chronic stroke was defined as a six months or longer after stroke onset, in accordance with commonly accepted classifications in stroke rehabilitation research.[13)]

A total of 20 participants were enrolled through prior announcement and screening procedures. They were randomly assigned by a lottery method, with an equal chance of allocation to one of two groups: the TSFT plus action observation group (n = 10) or the tongue exercise training plus action observation group (n = 10).

Participants were included if they met the following criteria: (1) a confirmed diagnosis of stroke established by a neurologist or rehabilitation physician; (2) dysphagia verified by videofluoroscopic swallowing study (VFSS) with evidence of penetration or aspiration; (3) reduced tongue strength, defined as a maximum tongue pressure of ≤ 20 kPa, indicating impairment in oral-phase propulsion; (4) a MoCA-K score of ≥ 23, reflecting sufficient cognitive ability to under-

Table 1. General characteristics of the subjects. (N = 20)

Variables		EG (n=10)	CG (n=10)	/z	p
Gender	Male	4	3	0.220	0.639
	Female	6	7		
Time since stroke (months)		18.16±3.09	18.27±3.21	0.007	0.935
Age (years)		60.20±6.66	59.10±6.40	0.142	0.711
K-MoCA (score)		26.1±1.52	25.80±1.48	0.200	0.660

EG: experimental group; CG: control group, K-MoCA: Korean-Montreal cognitive assessment

stand and follow study instructions; and (5) written informed consent obtained after a thorough explanation of the study procedures

Participants were not eligible for inclusion if they met any of the following criteria: (1) primitive oral reflexes that could interfere with treatment, such as tongue thrust or biting reflex; (2) structural dental abnormalities or a prior history of head and neck cancer surgery; (3) inability to maintain an upright seated posture during VFSS assessment; (4) evidence of silent aspiration; or (5) severe cognitive impairment or unstable psychiatric conditions that would limit participation in assessment or intervention.

2. Study design and intervention

This study employed a randomized controlled pre-post design. Treatment was provided for 30 minutes per session, scheduled three times weekly throughout the five-week intervention phase. Intervention effects were assessed by comparing pre- and post-intervention outcomes. Outcome measures included tongue pressure, swallowing timing parameters oral transit time(OTT) and pharyngeal transit time(PTT), and penetration-aspiration severity. All assessments were conducted under standardized environmental conditions. Baseline assessments were performed prior to the initiation of the intervention, and post-intervention assessments were completed following the conclusion of the five-week intervention period. To minimize assessment bias, outcome evaluations were conducted by two independent evaluators who were blinded to group allocation. The therapists who administered the intervention were not involved in the outcome assessment.

2.1 Action observation program

In this study, an action observation program was implemented using a three-dimensional (3D) animated video illustrating tongue movements, which was provided through an application developed by HealthBreeze Service Co., Ltd. with prior authorization (Figure 1). The video consisted of the following tongue movements: tongue protrusion, elevation of the tongue tip, depression of the tongue tip, lateral tongue movements, molar massage using the tongue tip, bilateral cheek pressing with the tongue tip, elevation and depression of the tongue against the gums, and curling the tongue upward along the palate. Participants viewed the video on a laptop computer in a quiet treatment room (Figure 2). The action observation session was conducted for 5 minutes after a 25-minute intervention session, which consisted of TSFT in the experimental group and tongue exercise training in the control group. Participants were instructed to observe the movements attentively without performing them during the video presentation.

2.2 Tongue sensory feedback training (TSFT)

The TSFT protocol applied in this study was adapted and expanded from the intervention approaches reported by Nakamura and Fujishima (2013) and Hwang et al. (2019)[15,16]. An ice stick was prepared by freezing bottled water in gauze measuring 10.16 cm in length and 1.27 cm in width. The base of the tongue was rubbed and lightly compressed with the ice stick

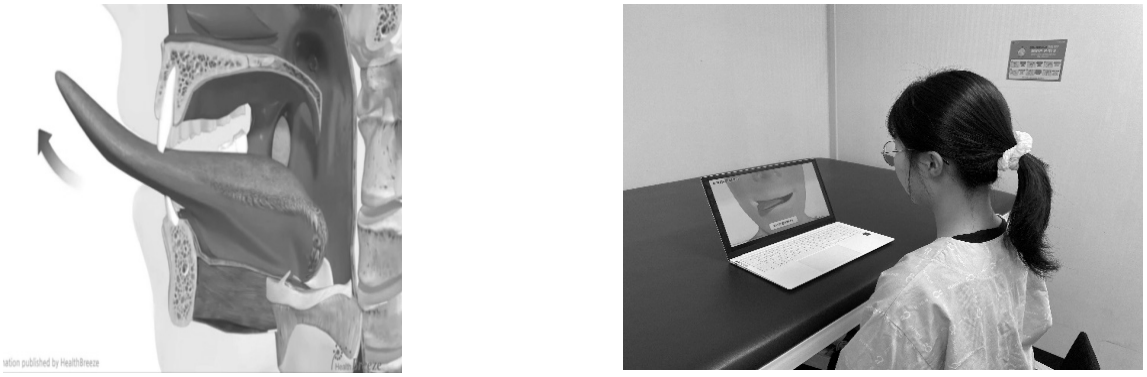

Figure 1. Action observation program and action observation training protocol

for 10 seconds to provide sensory stimulation. Subsequently, a powered toothbrush was applied to various regions and directions of the tongue to deliver tactile, vibratory, and pressure stimuli. Following sensory stimulation, the participant's tongue was gently grasped using gauze and subjected to both static and dynamic stretching in multiple directions to facilitate increased tongue mobility. Static stretching was maintained for 2–3 seconds, whereas dynamic stretching was performed for 20 seconds. After providing multimodal sensory input, including tactile, pressure, vibratory, and proprioceptive stimuli, participants were progressively guided to perform tasks requiring active tongue movements. Participants received 30-minute intervention sessions three times per week for five weeks.

2.3 Tongue exercise training

The tongue exercise training used in this study was administered by the same occupational therapist, who provided the intervention for 30 minutes per session. The intervention focused on active tongue movements aimed at improving swallowing function. Participants performed active tongue exercises centered on tongue mobility and control. The training consisted of activities in which participants imitated or executed tongue movements in response to verbal instructions or demonstrated movements provided by the therapist.

3. Outcome Measures

3.1 Measurement of maximum tongue strength

In this study, tongue strength was defined as the maximum isometric pressure exerted by the tongue against the palate. Tongue pressure was measured using a tongue pressure measurement device (JMS Co., Ltd., Japan). To ensure measurement accuracy and consistency, participants were instructed to keep their lips closed while the pressure bulb was positioned between the anterior palate and the tongue. Participants were instructed to compress the bulb with maximal effort for 7 seconds, and the measurement was repeated three times at 1-minute intervals. Measurement consistency was ensured by selecting the peak value from the three consecutive trials for subsequent analysis. The measurement site was set at the anterior portion of the tongue, where primary pressure generation occurs during swallowing. Tongue pressure values were recorded in kilopascals (kPa).[17]

3.2 Oral and pharyngeal transit time

Oral transit time (OTT) and pharyngeal transit time (PTT) were measured from videofluoroscopic swallowing study (VFSS) recordings A frame-by-frame analysis of the VFSS recordings was conducted at a temporal resolution of 0.033 seconds per frame. OTT referred to the time required for the bolus head to travel from beneath the tongue to the inferior margin of the mandible. PTT referred to the interval between the moment the bolus head passed the inferior margin of the mandible and the moment the bolus tail cleared the cricopharyngeal muscle. Participants were administered 5 mL of water and 5 mL of yogurt for the assessment.[18,19] To enhance the credibility of the outcome assessment, VFSS data were analyzed separately by three clinically experienced occupational therapists. The agreement across evaluators showed excellent reliability, reflected by an intraclass correlation coefficient of 0.97.

3.3 Penetration–aspiration scale

The Penetration–Aspiration Scale (PAS) was used to assess changes in the severity of penetration and aspiration before and after the intervention. The PAS is a standardized, valid, and reliable method for describing and quantifying the degree of airway penetration and aspiration during swallowing. The scale consists of eight ordinal levels based on the relationship of the bolus to the vocal folds and the presence or absence of airway aspiration. Lower scores indicate safer swallowing, whereas higher scores represent increasing severity of penetration and aspiration.[20] VFSS assessments from the two dietary conditions were scored separately by three clinically experienced occupational therapists in order to maintain evaluation reliability. The consistency among evaluators was confirmed by a high intraclass correlation coefficient (ICC = 0.97).

4. Statistical analysis

All statistical analyses were performed with SPSS software (version 18.0; IBM Corp., Chicago, IL, USA).

Baseline demographic characteristics were summarized using descriptive statistics. Differences in categorical variables, including sex, were assessed with the chi-square test, while continuous variables such as age, time since stroke onset, and cognitive function were compared using the Mann–Whitney U.

Normality of continuous data was examined through the Shapiro–Wilk test. As the data did not satisfy the normal distribution assumption, nonparametric analyses were adopted. Within-group comparisons of pre- and post-intervention outcomes—including tongue strength, oral transit time (OTT), pharyngeal transit time (PTT), and Penetration–Aspiration Scale (PAS) scores—were conducted using the Wilcoxon signed-rank test. Between-group differences in change values were analyzed using the Mann–Whitney U test. A two-tailed p-value below 0.05 was considered statistically significant.

5. Ethical Considerations

All participants provided written informed consent prior to participation. The study procedures were fully explained before enrollment, and the research was performed in accordance with internationally accepted ethical standards for human subjects research, including the Declaration of Helsinki.

Ⅲ. Results

1. Changes in maximum tongue strength between groups after the intervention

The change in maximum tongue strength after the intervention was significantly greater in the tongue TSFT combined with action observation group (6.16 ± 1.60 kPa) than in the tongue exercise training combined with action observation group (4.90 ± 0.74 kPa) (p < 0.05) (Table 2).

2. Changes in oral transit time between groups after the intervention

During water swallowing, the reduction in oral transit time was significantly greater in the TSFT combined with action observation group (−0.55 ± 0.66 s) than in the tongue exercise training combined with action observation group (−0.36 ± 0.43 s) (p < 0.05). Similarly, during yogurt swallowing, the reduction in oral transit time was significantly greater in the TSFT combined with action observation group (−0.45 ± 0.57 s) compared with the tongue exercise training combined with action observation group (−0.32 ± 0.56 s) (p < 0.05) (Table 3).

3. Changes in pharyngeal transit time between groups after the intervention

During water swallowing, the change in pharyngeal transit time did not differ significantly between the TSFT combined with action observation group (−0.34 ± 0.49 s) and the tongue exercise training combined with action observation group (−0.11 ± 0.49 s) (p > 0.05). Between-group comparison of changes in pharyngeal transit time during yogurt swallowing showed no statistically meaningful difference, with comparable decreases observed in both the TSFT with action ob-

Table 2. Comparison of changes in maximal tongue strength between the two groups (N = 20)

Variables	Post test - pre test	z	p
EG	6.16±1.60 kPa	-2.098	0.043*
CG	4.90±0.74 kPa		

EG: experimental group; CG, control group, *p < 0.05.

Table 3. Comparison of change in OTT between the two groups after intervention (N = 20)

Variables		Post test- Pre test	z	p
Water	EG	-0.55±0.66 sec	-2.098	0.043*
	CG	-0.36±0.43 sec		
Yogurt	EG	-0.45±0.57 sec	-1.988	0.047*
	CG	-0.32±0.56 sec		

EG: experimental group; CG:control group, OTT: oral transit time *p < 0.05.

Table 4. Comparison of changes in PTT between the two groups after intervention (N = 20)

Variables		Post test- Pre test	z	*p*
Water	EG	-0.34±0.49 sec	-1.210	0.247
	CG	-0.11±0.49 sec		
Yogurt	EG	-0.36±0.49 sec	-.302	0.796
	CG	-0.30±0.89 sec		

EG: experimental group;CG: control group, PTT: pharyngeal transit time

Table 5. Comparison of changes in PAS between the two groups after intervention (N=20)

Variables		Post test- Pre test	z	*p*
Water	EG	-1.50±0.41 score	-1.340	0.218
	CG	-0.90±1.37 score		
Yogurt	EG	-1.20±0.92 score	-.039	0.971
	CG	-1.00±1.76 score		

EG: experimental group; CG:control group, PAS : penetration-aspiration scale

servation group and the tongue exercise training with action observation group ($p > 0.05$) (Table 4).

4. Changes in penetration-aspiration scale scores between groups after the intervention

During water swallowing, the change in Penetration-Aspiration Scale (PAS) scores did not differ significantly between the TSFT combined with action observation group (−1.50 ± 0.71) and the tongue exercise training combined with action observation group (−0.90 ± 1.37) ($p > 0.05$). No meaningful between-group difference was identified in PAS score changes observed during yogurt swallowing, with comparable reductions in both the TSFT plus action observation group (−1.20 ± 0.92) and the tongue exercise plus action observation group (−1.00 ± 1.76) ($p > 0.05$) (Table 5).

Ⅳ. Discussion

This study investigated the effects of TSFT combined with action observation on tongue pressure, swallowing speed, and PAS outcomes in individuals with chronic post-stroke dysphagia. The combined intervention significantly improved tongue pressure and oral transit time compared with the control group. Although favorable changes were observed in pharyngeal transit time and PAS, these differences were not statistically significant.

The significant increase in tongue pressure suggests that the present intervention represents a clinically valid strategy for improving oral-phase swallowing performance. The tongue plays a central role in bolus formation and intraoral propulsion, and reduced tongue pressure is directly associated with impaired oral-phase efficiency and increased oral residue.[3,4] Previous studies have reported that resistance- and pressure-based tongue training leads to improvements in tongue strength and swallowing function,[7,8] and the present findings are consistent with this body of evidence. Notably, the intervention protocol in this study incorporated multimodal sensory input including thermal, tactile, and vibratory stimulation followed by progressively active tongue tasks. This structure likely enhanced sensory-driven motor modulation, supporting more precise motor output.[6] From a motor learning perspective, functional improvements are facilitated not by simple repetition but by error-based learning and goal-directed control supported by augmented feedback.[9,10] It is plausible that the intervention components influenced the enhancement in tongue pressure observed in this study.

The improvement in oral transit time indicates that increases in tongue pressure and enhanced oral-phase motor control were successfully transferred to greater

efficiency of oral bolus transport. Oral transit time is closely associated with the tongue's ability to generate posterior propulsion of the bolus. Therefore, the improvements in oral transit time support the effectiveness of tongue-focused interventions in enhancing oral-phase propulsion. No significant group differences were identified for pharyngeal transit time; nevertheless, the pattern of change in the experimental group implies a potential contribution to improved temporal organization and coordination during the pharyngeal stage of swallowing.

Swallowing is a complex sensorimotor process that integrates central nervous system control with peripheral sensory input, and increased sensory input plays a critical role in triggering the swallowing reflex and regulating pharyngeal-phase coordination.[4,6] In particular, sensory stimulation of the tongue base and oral cavity may be associated with the initiation of the swallowing reflex; therefore, the changes observed in pharyngeal transit time in the present study can be interpreted as the suggesting the potential validity of sensory-based interventions. As post-stroke dysphagia is a major contributor to poor clinical outcomes, including aspiration pneumonia, swallowing safety remains an important clinical target. Although no statistically significant difference was found in PAS outcomes, the observed improvements may suggest a potential enhancement in swallowing safety.

The changes in PAS observed in this study may be interpreted as the combined effects of increased tongue pressure, sensory biofeedback–based motor regulation, and activation of swallowing-related motor networks through action observation.[11,12] This study suggests that TSFT combined with action observation can induce significant improvements in tongue pressure and oral transit time, with potential benefits in other swallowing-related outcomes in individuals with chronic post-stroke dysphagia. Importantly, the findings indicate that functional recovery remains achievable even in the chronic stage through the interaction between targeted training and neuroplasticity. Caution is advised when interpreting the present findings. The small cohort size restricts broader applicability, and without post-intervention follow-up data, conclusions regarding the persistence of treatment benefits cannot be drawn. Future studies should employ randomized controlled designs with larger sample sizes under standardized assessment conditions and incorporate additional outcome measures, such as pharyngeal residue indices and functional oral intake levels, to more comprehensively evaluate the effects of the intervention. Several limitations should be acknowledged. First, no a priori sample size calculation was conducted due to the exploratory nature of this study, which may have limited the statistical power. Second, effect size estimates and confidence intervals were not reported, restricting interpretation of the magnitude and clinical relevance of the findings. In addition, baseline equivalence between groups was not statistically examined, and this should be considered when interpreting the intervention effects. Finally, the relatively small sample size and absence of follow-up assessments limit the generalizability and long-term interpretation of the results.

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