

The Effects of a Mobile Healthcare Application on Speech, and Swallowing in Amyotrophic Lateral Sclerosis

Yeongju Cho, Hyunkyung Lim, Hyang Hee Kim, Sun Young Won, Sung-Rae Cho

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Abstract

Background: Amyotrophic lateral sclerosis (ALS) impairs oral motor function, negatively affecting patients' speech and swallowing abilities, as well as their quality of life.

Objective: This study aims to evaluate the effectiveness of the ASSET (A Successful Swallow with Effortful Training) program, included in the '365 Health Swallowing App,' in preserving speech and swallowing abilities in ALS patients through self-training.

Methods: Over an 8-week period, ALS patients in the treatment group performed self-training using the ASSET program, while the control group did not receive this intervention. Changes in alternating motion rate (AMR), sequential motion rate (SMR), and speech- and swallowing-related quality of life were assessed. Additionally, the study investigated the effects of Effortful Pitch Glide (EPG) training on acoustic voice quality.

Results: In the control group, which did not receive treatment, AMR /tuh/ ($P = .026$), AMR /kuh/ ($P = .026$), and SMR ($P = .034$) showed significant deterioration. Additionally, in the SHI, there was a significant increase in handicap in the psycho-social ($P = .042$) and total ($P = .046$) domains. In the Dysphagia Handicap Index (DHI), the emotional domain ($P = .027$) showed a significant increase in handicap. Furthermore, in the SWAL-QOL, significant declines in quality of life were observed in the mental health ($P = .027$), social function ($P = .042$), fatigue ($P = .034$), and total ($P = .027$) domains.

The results of the EPG training group were not statistically significant, which is presumed to be due to muscle fatigue in patients with ALS.

Conclusions: The findings suggest that the ASSET program could be an effective treatment for patients with motor neuron diseases. However, this study has limitations, including the absence of blinding and a small sample size. Future research should validate the ASSET program using a larger sample and a double-blind study design.

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Original Manuscript

The Effects of a Mobile Healthcare Application on Speech, and Swallowing in Amyotrophic Lateral Sclerosis

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Abstract

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The results of the EPG training group were not statistically significant, which is presumed to be due to muscle fatigue in patients with ALS.

Conclusions: The findings suggest that the ASSET program could be an effective treatment for patients with motor neuron diseases. However, this study has limitations, including the absence of blinding and a small sample size. Future research should validate the ASSET program using a larger sample and a double-blind study design.

Keywords: Amyotrophic Lateral Sclerosis; Speech; Swallowing; Quality of life; Rehabilitative therapy; Swallowing training; Mobile healthcare

Introduction

Amyotrophic lateral sclerosis (ALS) is a neurological condition that causes the nerve cells controlling voluntary muscle movements to degenerate gradually¹. Motor problems in ALS can impact respiratory and phonatory muscles, affecting speech production. Speech deterioration is common, with approximately 25% of all ALS patients showing speech

deterioration as their initial symptom and 100% for bulbar-onset ALS²⁻⁵. Many studies have been conducted speech related measures for ALS. The main speech analysis of ALS includes vowel or consonant distortion, hypernasality, slow speech rate, and reduced intelligibility^{2,6,7}. Swallowing dysfunction is one of the most severe symptoms for ALS patients, leading to malnutrition and aspiration pneumonia. Swallowing dysfunction progresses gradually and affects all stages of swallowing, including oral preparatory, oral transport, pharyngeal and esophageal phases⁸⁻¹⁰.

Meanwhile, the mobile healthcare application, 365 Healthy Swallow Health Coach APP, was designed to provide easy-to-use training content to the elderly population. It is based on the A Successful Swallowing with Effortful Training (ASSET) method developed by Kim et al. (2020), which combines effortful swallow and Mendelsohn maneuver to create the effortful prolonged swallow (EPS), effortful pitch glide (EPG), and effortful tongue rotation (ETR) techniques. The training aims to strengthen the muscles in the mouth and throat. The training protocol for one session includes EPS, ETR and EPG, which lasts about 20 minutes and contains 20 repetitions. Users are instructed to conduct the training program for 180 sessions (5 days a week, three times a day) for eight weeks in their homes using the app. After the start of the training, the researchers check the participant's use of the app, training method, and performance rate every week through remote monitoring. However, the purpose of the check is to confirm the participant's ability to operate the app and train independently without external assistance, so the intervention is minimized, and the researchers only aid during the training session and when the participant cannot operate the app or performs the exercises improperly. The remote check is conducted individually and lasts for about 20 minutes^{11,12}. ALS patients face significant challenges in swallowing and speech, which negatively affect their quality of life¹³⁻¹⁶. Existing speech-language interventions may not be adequate or easily accessible for all patients; lack of standardized or easily accessible treatment plans, limited access to trained staff, time constraints, and financial limitations^{17,18}. These findings highlight the need for novel and effective therapeutic strategies. This study aims to investigate the effectiveness of the ASSET method and the 365 Healthy Swallow Health Coach App in enhancing speech and swallowing functions in ALS patients, specifically focusing on the impact on dysarthria, and dysphagia.

The ASSET method, which combines effortful swallow and Mendelsohn maneuver to create EPS and ETR techniques, has shown potential in enhancing swallowing function in the general older population and Parkinson's disease patients^{11,12,19-21}. However, its

effectiveness for ALS patients remains unexplored. While the use of controversial maneuvers in ALS patients is limited, some studies have shown effectiveness. For instance, the effortful swallow maneuver has been reported to increase upper esophageal sphincter (UES) duration^{22,23}, and the Mendelsohn maneuver has been suggested as compensatory strategy for ALS patients²⁴. Data on tongue exercise in ALS are limited but few case studies^{4,24,25} and animal model investigations^{26,27} indicating increased tongue strength and endurance. By examining the applicability and potential benefits of the ASSET method for ALS patients, this study aims to fill a gap in current literature and contribute to the development of targeted interventions.

Self-training approaches have gained recognition for their potential to improve speech and swallowing functions in various patient populations, including older adults and those with Parkinson's disease^{11,19,28}. However, the use of self-training in ALS patients has not been extensively studied. A previous study suggests that individuals with ALS often attempt to manage dysphagia independently before seeking professional help, employing self-developed techniques such as modifying food textures and altering mealtime environments¹⁶. This research would offer valuable insights into the feasibility and efficacy of self-training for ALS patients, potentially providing a more accessible and convenient therapeutic option.

The use of mobile healthcare applications has yielded promising results in delivering self-training interventions for speech and swallowing therapy²⁹⁻³¹. The 365 Healthy Swallow Health Coach App, which incorporates the ASSET method, has demonstrated positive outcomes in older adults and patients with Parkinson's disease^{11,12,19-21}. Yet, its impact on ALS patients remains unexplored. This study would be the first to assess the potential benefits of using the 365 Healthy Swallow Health Coach App for ALS patients, supplying valuable information for developing and optimizing mHealth solutions in this population.

This study aims to address several gaps in existing literature on ALS patients' swallowing and speech therapy, self-training approaches, and the use of mobile healthcare applications. By investigating the effectiveness of the ASSET method, self-training, and the 365 Healthy Swallow Health Coach App in ALS patients, this research could contribute to developing more targeted and accessible therapeutic options, ultimately enhancing the quality of life for individuals with ALS.

In light of these findings, this study hypothesizes that, for individuals with ALS, the overall treatment group may show improvement or maintenance in speech, swallowing, and the quality of life-related to these functions. Conversely, the control group may experience a

decline in speech, swallowing, and the related quality of life. And there will be no significant differences in speech before and after treatment between the Treatments with EPG group and the Treatments without EPG group.

Methods

Participants

In total, 16 ALS patients were initially recruited for the study. However, three participants were excluded due to death, refusal to participate, and loss of contact. The remaining 13 participants were informed about the study, and all provided their consent by signing the Institutional Review Board (IRB) agreement. The participants (n=13) included nine males (69%) and four females (31%) with a mean age of 64.61 years (± 13.75) and a mean K-MMSE score of 28.08 out of 30 (± 1.69) (Table 1). After completing the evaluation, the participants were introduced to the mobile health application and the ASSET program. Given the intensive nature of the program, which involves three sessions per day, five days a week, for eight weeks, 6 participants declined to undergo the treatment. However, they agreed to participate in the second evaluation, and thus were designated as the control group. All treatment participants (n=7) participated in the first and second evaluations, eight weeks of self-practice, and once a week of online checkout sessions. All the participants (n=13) completed in the first and second evaluations (Figure 1).

The inclusion and exclusion criteria in this study are as follows. The inclusion criteria were 1) diagnosis of ALS, 2) signs, and symptoms of dysarthria, 3) signs and symptoms of dysphagia, and 4) the ability to fully understand and follow the researcher's verbal instructions. The exclusion criteria were 1) complaint of severe laryngeal or pharyngeal pain during the treatment process and 2) failure to complete the 8-week treatment program.

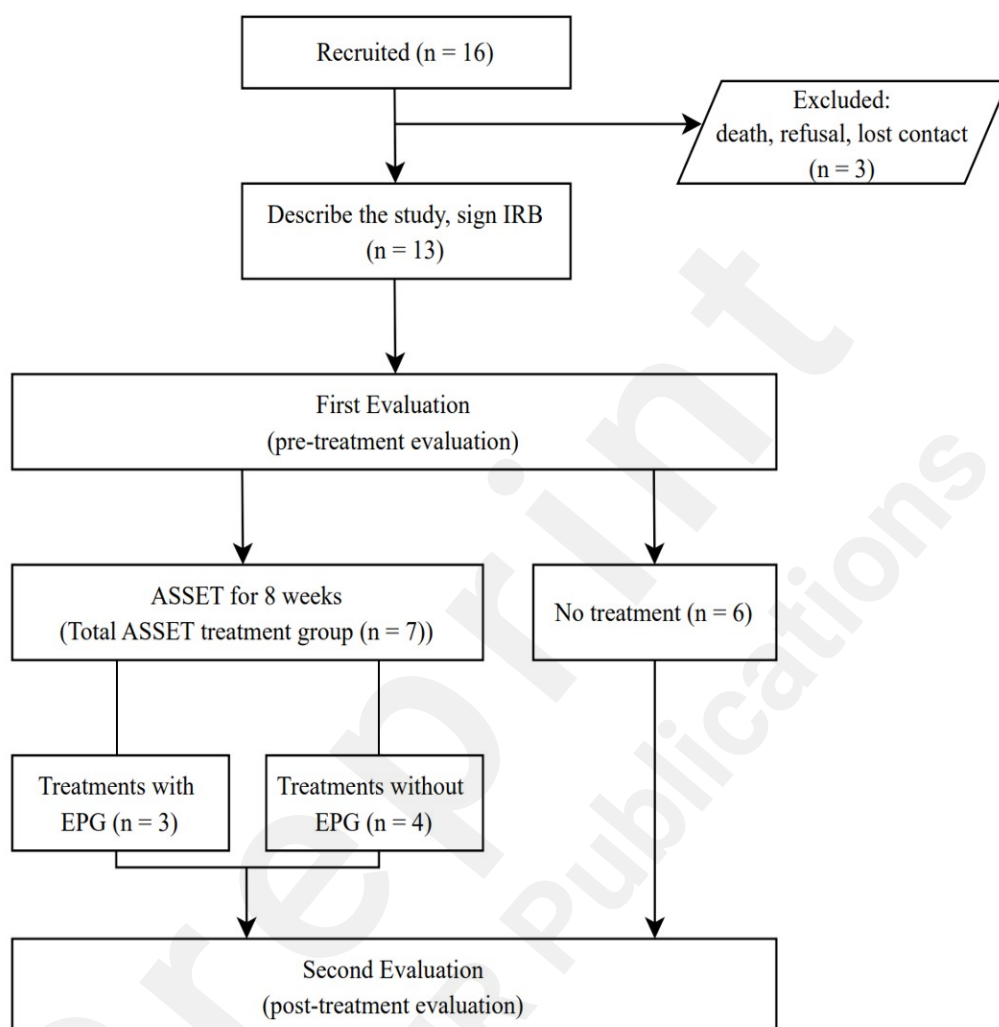
Figure 1. Participants Recruitment

Table 1. Participant Information

Group	No.	Sex	Age	K-MMSE	ALSSS Speech	ALSSS Swallow	ALSSS Lower extremities	ALSSS Upper extremities
Therapy (n = 7)	T1	Male	67	29	5	7	5	3
	T2	Male	80	27	1	7	5	8
	T3	Female	67	27	5	6	8	7
	T4	Male	60	28	6	7	7	7
	T5	Male	66	25	10	10	10	1
	T6	Male	68	30	4	9	6	4
	T7	Female	22	30	7	7	7	6
Average			61.43	27.86	5.42	7.57	6.86	5.14
Control (n = 6)	C1	Male	68	29	6	9	6	6
	C2	Male	75	28	9	9	9	8
	C3	Male	67	26	5	8	8	6
	C4	Female	70	30	7	6	1	3
	C5	Male	68	26	1	7	5	8
	C6	Female	62	30	10	7	2	6
Average			68.33	28.17	6.33	7.67	5.17	6.17

Abbreviation: K-MMSE, Korean Mini-Mental State Examination; ALSSS, Amyotrophic Lateral Sclerosis Severity Scale

Data collection

Participants underwent a sequence of steps: cognitive assessment, pre-treatment assessment, self-training treatment, and post-treatment assessment. The researcher guided participants to complete the quality of life questionnaires on their own or with the assistance of their guardians. A clinician was available to clarify any queries regarding the questionnaire items.

Cognitive assessment

A comprehensive assessment of the participant's cognitive abilities was deemed essential, considering the self-training nature of the treatment and its reliance on a mobile application. Consequently, researcher used the Korean Mini-Mental State Examination (K-MMSE) to assess cognitive function³². Thus, by measuring cognitive function using the MMSE, this study ensured that participants were well-equipped to engage in the self-training intervention and benefit from the program.

Amyotrophic Lateral Sclerosis Severity Scale

The Amyotrophic Lateral Sclerosis Severity Scale (ALS-SS) was utilized to assess participants' basic functional abilities, particularly speech and swallowing, which were the primary focus of this study. The ALS-SS measures various aspects of physical functioning,

including speech, swallowing, lower extremity function, and upper extremity function, making it suitable for evaluating individuals with ALS, given the shared symptomatology and focus on general motor functions³³.

Speech Functions

The speech assessment occurred in a quiet room with a controlled environmental noise level below 50 Db. The researcher captured the speech using a SONY ECM-MS907 condenser microphone (SONY Corp., Tokyo, Japan). The researcher held the microphone 10 cm from the participant's mouth and at a 90-degree angle consistently. This microphone is connected to an ICD-UX560F voice recorder (SONY Corp., Tokyo, Japan). The researcher configured the voice recorder settings to a sample rate of 44.1 kHz, a 16-bit depth, and a fixed recording level of 12 dB. The collected speech data were analyzed using Praat software, and the items collected are as follows.

Diadochokinetic rate (DDK) task, which comprises alternating motion rate (AMR), and sequential motion rate (SMR) components, is a widely used method for assessing speech motor control in dysarthric speakers. Both AMR and SMR tasks were administered by instructing participants to repeat the respective syllables or sequences as quickly and regularly as possible for five seconds.

Speech intensity, an important aspect of speech communication, was calculated based on the participant's vocal intensity during the utterance of an everyday functional phrase, [an̥jʌŋɦasʰejo], which translates to *hello* in Korean. Evaluating speech intensity using a familiar, functional phrase allows for a more ecologically valid and representative measurement, meaning that the assessment closely resembles the participant's real-life speaking situations and provides a better reflection of their natural communication patterns. By using a phrase commonly encountered in everyday conversations, the assessment captures the participant's speech intensity as it would typically occur outside of the clinical or research environment, offering a more accurate representation of their true speech performance³⁴. By including speech intensity assessment in the study, it was possible to obtain a comprehensive evaluation of the participant's speech characteristics and determine the impact of the intervention on this crucial aspect of speech production.

Acoustic Measures (Sustained /a/ Vowel for 5 Seconds) refers to a vowel that is not influenced by articulatory factors. It is commonly used in voice evaluations to analyze jitter (frequency perturbation) and shimmer (amplitude perturbation).

Speech-related quality of life

The participant completed standardized questionnaires related to speech and quality of life. Speech Handicap Index-15 (SHI-15) is a concise questionnaire that designed to gather self-reported information on the impact of dysarthria and other speech difficulties on the participant's psychosocial well-being. Comprising 15 items, this instrument allows for a relatively quick and efficient evaluation of the perceived of speech impairments on an individual's daily life and social interactions.

Swallowing-related quality of life

The participant completed standardized questionnaires related to swallow and quality of life. These questionnaires were chosen for their ability to provide a comprehensive understanding of participant's experiences with swallowing disorders and to assess the impact of the intervention on their swallowing-related quality of life.

The Swallowing Quality Of Life (SWAL-QOL) offers self-reported insight into swallowing capabilities and the presence of dysphagia symptoms. The SWAL-QOL also measures the subsequent influence of dysphagia on a participant's quality of life. There are 44 questions into 11 distinct sub-categories for comprehensive analysis³⁵.

The Dysphagia Handicap Index (DHI) offers self-reported insight into the impact of swallowing disorders on the participant's psychological well-being, divided into physical, functional, and emotional sections. Each section has ten items, for a total of 25 items³⁶. The Brief Inventory of Swallowing Assessment-15+ (BISA 15+) is a tool that can be utilized to detect the transition of swallowing function from normal to preclinical stages in patients³⁷. The administration of the BISA 15+ takes approximately 5-10 minutes.

Orientation

mHealth app (365 Healthy Swallowing Coach App)

365 Healthy Swallowing Coach app was developed as part of the 'Science and Technology Liberal Arts' by the National Research Foundation of Korea¹². In this study, version 1.4 was used. The app has not yet been released commercially and is only compatible with the Galaxy Tab A SM-P580 (Samsung Corp., Seoul, Korea) running on the Android operating system (ver. 9.1.0). Participants were provided with a tablet PC with the app installed for their training sessions. They used the swallowing training content of the app for the training. The swallowing training content consists of swallowing exercises, training guidance, and progress

tracking.

ASSET (A Successful Swallow with Effortful Training)

After the pre-assessment, the researchers conducted face-to-face orientation sessions to explain the tablet use, the intervention training process, and the methods involved. Subsequently, the patients completed self-training at home using the ASSET program app on the provided tablet for eight weeks, five days a week, three sessions per day. A student clinician checked the implementation of the ASSET through remote consultation with the patients once a week. The app automatically records the completion of each training day. The ASSET program is structured as shown in Table 2, with all exercises repeated in 2 sets^{11,12}(Table 2).

Remote monitoring

Remote monitoring was primarily conducted using the 'remote consultation' feature of the Swallow Healthy Coach app for video consultations. However, if this feature was not functioning smoothly, the 200 M Cloud Meetings (Zoom Video Communications Inc., San Jose, California) app was used as an alternative. During this stage, the researchers focused on verifying the completion rate of self-training and resolving technical difficulties, minimizing their intervention in the training process.

Statistical analysis

The statistical analyses for the pre-and post-treatment assessments were conducted using IBM SPSS (Statistical Package for the Social Sciences, version 28.0) for Mac.

First, a Wilcoxon signed-rank test and a two-way repeated measures ANOVA were conducted for all participants to examine whether there were differences in speech and swallowing functions between pre- and post-assessments. Second, a two-way repeated measures ANOVA was performed to investigate differences in speech, voice, and swallowing functions between pre- and post-assessments for the EPG treatment group and the control group, excluding those who received EPG treatment.

Table 2. The ASSET Protocol

Training Method	Instructions
Effortful Prolonged Swallow (EPS)	1. Hold water using a teaspoon.
	(For patients at risk of aspiration, dampen the oral cavity with water-moistened gauze and accumulate saliva instead)
	2. Engage all oral and laryngopharyngeal muscles while swallowing the water or saliva. Continuously apply force to maintain the swallowing moment for 3 seconds.
	3. Take a 5-second break after each swallow.
Effortful Pitch Glide (EPG)	4. Repeat steps 1-3 for a total of 10 swallows, forming 1 set.
	1. Maintain the vowel sound /i/ at a reasonable pitch.
	2. To get the highest pitch possible, raise the pitch gradually.
Effortful Tongue Rotation (ETR)	3. Try to stay on the highest pitch as long as you can.
	1. Press tongue forcefully against left cheek.
	2. Move tongue downwards with force, then towards right cheek, and finally back to left cheek.
	Reference the biofeedback provided by the app.
	3. Spend 5 seconds on each movement while exerting as much force as possible.
	4. Take a 5-second break after each rotation.
	5. Complete a total of 10 rotations, forming 1 set.

Results

Differences and changes in speech function

Amyotrophic Lateral Sclerosis Severity Scale (ALS-SS) Speech

To examine the differences between the overall treatment group ($n=7$) and the control group ($n=6$), a two-way repeated measures ANOVA was conducted to assess changes in ALS-SS Speech scores over time, between groups, and the interaction effect between groups and time. The results showed a significant main effect of time ($F(1, 11)=11.477$, $P=.006$) and a significant group-by-time interaction effect ($F(1, 11)=7.832$, $P=.017$), indicating meaningful changes in ALS-SS Speech scores between pre- and post-treatment assessments. However, the main effect between groups was not statistically significant, implying no clear differences in ALS-SS Speech scores between the treatment and control groups. Meanwhile, an analysis of differences in ALS-SS Speech scores between pretest and posttest for each group revealed no statistically significant difference in the treatment group ($n=7$), whereas the control group ($n=6$) showed a statistically significant difference ($P=.041$) (Table 3).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess changes in ALS-SS Speech scores over time, between groups, and the interaction effect between group and time. The results revealed no statistically significant main effect of time between pre- and post-treatment assessments. Similarly, the main effect between groups was not statistically significant, suggesting no notable differences in ALS-SS Speech scores either over time or between groups. The group-by-time interaction effect was also not statistically significant, indicating no meaningful differences in ALS-SS Speech between the treatment and control groups over time. Furthermore, when examining changes between pre- and post-treatment assessments within each group, no statistically significant differences were observed (Table 4).

Diadochokinetic rate (DDK)

To examine the differences between the overall treatment group ($n=7$) and the control group ($n=6$), a two-way repeated measures ANOVA was conducted to assess changes in DDK rates (AMR, SMR) over time, between groups, and the effect of the group-by-time interaction. The results revealed significant main effects of time for /puh/ ($F(1, 11)=7.952$, $P=.017$), /tuh/ ($F(1, 11)=6.897$, $P=.024$), and /kuh/ ($F(1, 11)=9.638$, $P=.01$), indicating

statistically significant differences over time. However, the main effect between groups was not significant, showing no notable differences between the treatment and control groups. The group-by-time interaction effect was significant for /tuh/ ($F(1, 11)=6.013$, $P=.032$) and /kuh/ ($F(1, 11)=5.200$, $P=.044$), indicating meaningful differences over time between the groups. For AMR tasks involving /puh/, /tuh/, and /kuh/, significant differences were found between the treatment and control groups. Meanwhile, when examining changes in AMR between pre- and post-treatment assessments for each group, no statistically significant differences were found in the treatment group ($n=7$). However, in the control group ($n=6$), statistically significant differences were observed for /tuh/ ($P=.026$), /kuh/ ($P=.026$), and /puh tuh kuh/ ($P=.034$). However, for SMR tasks involving /puh tuh kuh/, neither the main effects of time and group nor the group-by-time interaction effect were statistically significant (Table 3).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess changes in DDK rates (AMR, SMR) over time, between groups, and the interaction effect between group and time. The results revealed no statistically significant main effects of time between pre- and post-treatment assessments. Similarly, no significant differences were found between the groups, and the group-by-time interaction effect was also not statistically significant, indicating no meaningful differences in DDK rates over time between the treatment and control groups. Furthermore, when examining changes between pre- and post-treatment assessments within each group, no statistically significant differences were observed (Table 4).

Speech intensity

To examine the differences between the overall treatment group ($n=7$) and the control group ($n=6$), a two-way repeated measures ANOVA was conducted to assess changes in speech intensity over time, between groups, and the effect of the group-by-time interaction. The results revealed no significant main effect of time, indicating no substantial differences between pre- and post-treatment assessments. The main effect between groups was also not significant, indicating no significant differences in speech intensity between the treatment and control groups. Additionally, the group-by-time interaction effect was not significant, suggesting no meaningful differences between the groups over time (Table 3).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess

changes in speech intensity over time, between groups, and the interaction effect between group and time. The results showed no statistically significant main effects of time between pre- and post-treatment assessments. The main effect between groups was also not statistically significant. Furthermore, the group-by-time interaction effect was not statistically significant, suggesting no significant differences in speech intensity between the treatment and control groups over time. Furthermore, when examining changes in speech intensity between pre- and post-treatment assessments within each group, no statistically significant differences were observed (Table 4).

Acoustic Measures (Sustained /a/ Vowel for 5 Seconds)

To examine the differences between the EPG treatment group (n=3) and the EPG control group (n=4), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of jitter, shimmer, and NHR over time, between groups, and the interaction effect between group and time. The results showed no statistically significant differences over time, between groups, or for the group-by-time interaction, indicating that there were no meaningful changes in jitter, shimmer, and NHR between the treatment and control groups. Furthermore, when examining changes between pre- and post-treatment assessments within each group, no statistically significant differences were observed in the acoustic parameters (Table 4).

Difference and changes in speech related quality of life

Speech Handicap Index

To examine the differences between the overall treatment group (n=7) and the control group (n=6), a two-way repeated measures ANOVA was conducted to assess changes in SHI-15 scores over time, between groups, and the effect of the group-by-time interaction. The results showed a significant main effect of time for the psycho-social domain ($F(1, 11)=5.208$, $P=.043$), indicating a statistically significant difference over time. However, no significant main effect between groups was found, suggesting no meaningful differences in the speech-related handicap between the treatment and control groups. Additionally, the group-by-time interaction effect was not significant, indicating no meaningful differences in SHI-15 scores between the groups over time. Meanwhile, when examining changes in SHI-15 scores between pre- and post-treatment assessments for each group, significant changes were observed in the control group for the Psycho-social domain ($P=.042$) and the total score ($P=.046$) (Table 3).

To examine the differences between the EPG treatment group (n=3) and the EPG control group (n=4), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of SHI-15 scores over time, between groups, and the interaction effect between group and time. The results showed no statistically significant differences over time, between groups, or for the group-by-time interaction, indicating that there were no meaningful changes in SHI-15 scores between the treatment and control groups. Furthermore, when examining changes in SHI-15 scores between pre- and post-treatment assessments within each group, no statistically significant differences were observed in the acoustic parameters (Table 4).

Measure	Treatment (n=7)		Control (n=6)		Time		Group		Time*Group	
	Pre	Post	Pre	Post	F	P	F	P	F	P
ALS-SS										
Speech	5.43 ±2.76	5.29 ±2.75	6.33 ±3.20	4.83 ±2.99*	11.477	.006**	.020	.890	7.832	.017*
AMR										
/puh/	13.43 ±11.40	12.43 ±11.87	12.17 ±7.22	8.50 ±8.31	7.952	.017*	.219	.649	2.596	.135
/tuh/	11.86 ±11.54	11.71 ±9.43	11.67 ±8.14	7.50 ±7.71*	6.897	.024*	.180	.679	6.013	.032*
/kuh/	12.29 ±11.25	11.57 ±11.79	11.83 ±9.11	7.17 ±8.31*	9.638	.010*	.182	.678	5.200	.044*
SMR										
/puh tuh kuh/	5.71 ±4.89	4.57 ±3.05	4.33 ±3.27	2.83 ±3.13*	4.254	.064	.635	.442	.078	.786
SI										
/ənpjɪŋhəs'hejo/	74.78 ±6.91	74.70 ±4.36	72.62 ±5.44	70.22 ±6.01	.435	.523	.165	.225	.376	.552
SHI										
Speech	20.86 ±9.74	21.14 ±9.87	19.50 ±5.43	23.50 ±5.93	2.336	.155	.013	.910	1.755	.212
Psy-Cho	18.57 ±9.27	19.43 ±10.89	17.83 ±6.71	23.83 ±5.35*	5.208	.043*	.167	.691	2.930	.115
Total	39.43 ±18.68	40.57 ±20.26	37.33 ±12.04	47.33 ±10.75*	3.985	.074	.073	.792	2.461	.145

Table 3. Comparison of speech functions in first and second evaluation

Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; AMR, Alternating Motion Rate; SMR, Sequential Motion Rate; SI, Speech Intensity; SHI, Speech Handicap Index; Psy-co, Psychosocial

*p<.05, **p<.01

*Statistically significant differences were observed between the pretest and posttest evaluations.

Measure	EPG Treatment (n=3)		EPG Control (n=4)		Time		Group		Time*Group	
	Pre	Post	Pre	Post	F	P	F	P	F	P
ALS-SS Speech	7.00 ±3.00	7.33 ±2.52	4.25 ±2.22	3.75 ±1.89	.143	.721	3.107	.138	3.571	.117
AMR /puh/	19.67 ±16.80	19.67 ±16.50	8.75 ±1.89	7.00 ±2.94	3.000	.144	2.088	.208	3.000	.144
/tuh/	18.33 ±16.65	17.00 ±13.45	7.00 ±2.83	7.75 ±2.87	.115	.749	1.906	.226	1.464	.280
/kuh/	19.00 ±15.88	17.67 ±17.67	7.00 ±2.16	7.75 ±2.50	1.602	.261	1.865	.230	.750	.426
SMR /puh tuh kuh/	8.67 ±6.66	7.33 ±2.31	3.50 ±1.73	2.50 ±1.29	1.094	.344	4.658	.083	.022	.887
SI /aŋŋjŋhəs ^{hejo} /	75.51 ±9.50	72.30 ±4.83	76.49 ±5.12	76.49 ±3.53	.002	.966	1.121	.338	.002	.964
Jitter /a/	0.49 ±0.32	0.40 ±0.19	2.11 ±2.22	0.53 ±0.37	1.257	.313	2.154	.202	.999	.363
Shimmer /a/	5.59 ±2.64	4.08 ±1.13	8.51 ±5.24	5.62 ±3.28	1.585	.264	1.085	.345	.159	.707
NHR /a/	0.00 ±0.00	0.00 ±0.00	0.04 ±0.06	0.04 ±0.03	.024	.882	2.654	.164	.059	.817
SHI Speech	15.33 ±13.43	15.67 ±14.30	25.00 ±4.00	25.50 ±2.50	.020	.894	2.083	.209	.000	.985
Psy-Cho	11.67 ±10.41	11.33 ±13.32	23.75 ±4.03	25.50 ±2.08	.139	.724	5.168	.072	.301	.607
Total	27.00 ±23.39	27.00 ±27.00	48.75 ±7.93	50.75 ±3.59	.065	.808	3.524	.119	.065	.808

Table 4. Comparison of speech functions in first and second evaluation between the EPG treatment group and the EPG non-treatment group

Abbreviation: ALS-SS, Amyotrophic Lateral Sclerosis Severity Scale; AMR, Alternating Motion Rate; SMR, Sequential Motion Rate; NHR, Noise-to-Harmonics Ratio; SHI, Speech Handicap Index; SI, Speech Intensity; Psy-co, Psychosocial

Differences and changes in swallowing function

Amyotrophic Lateral Sclerosis Severity Scale (ALS-SS) Swallow

To examine the differences between the overall treatment group (n=7) and the control group (n=6), a two-way repeated measures ANOVA was conducted to assess changes in ALS-SS swallow scores over time, between groups, and the effect of the group-by-time interaction. The results showed no significant main effects of time or group, indicating no meaningful differences in ALS-SS swallow scores between the pre- and post-treatment assessments or between the treatment and control groups. Additionally, the group-by-time interaction effect was not significant, indicating no meaningful changes in ALS-SS swallow scores between the groups over time. Additionally, when comparing pre- and post-treatment assessments within each group, no significant changes were observed (Table 5).

To examine the differences between the EPG treatment group (n=3) and the EPG control group (n=4), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of ALS-SS swallow scores over time, between groups, and the interaction effect between group and time. The results revealed no statistically significant differences over time or between groups. Additionally, the group-by-time interaction effect was not significant, indicating no meaningful differences between the EPG treatment and control groups over time. Additionally, when comparing pre- and post-treatment assessments within each group, no significant changes were observed (Table 6).

Difference and changes in swallowing related quality of life

Dysphagia Handicap Index (DHI)

To examine the differences between the overall treatment group (n=7) and the control group (n=6), a two-way repeated measures ANOVA was conducted to assess changes in DHI scores over time, between groups, and the effect of the group-by-time interaction. The results showed a significant main effect of time in the Emotional domain ($F(1, 11)=10.617$, $P=.008$), indicating a meaningful change over time. However, no significant main effect of group was found, suggesting no substantial differences between the treatment and control groups in terms of swallowing-related handicap. Additionally, the group-by-time interaction effect was not significant, indicating no notable differences in changes between the groups over time. Meanwhile, when comparing changes between

pre- and post-treatment assessments for each group, a significant change was observed in the emotional subdomain within the control group ($P=.027$) (Table 5).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of DHI scores over time, between groups, and the interaction effect between group and time. The results revealed no statistically significant differences over time, between groups, or for the group-by-time interaction. This indicates that there were no meaningful changes in DHI scores between the EPG treatment and control groups. Additionally, when comparing pre- and post-treatment assessments within each group, no significant changes were observed (Table 6).

Swallowing related quality of life (SWAL-QOL)

To examine the differences between the overall treatment group ($n=7$) and the control group ($n=6$), a two-way repeated measures ANOVA was conducted to assess changes in SWAL-QOL scores over time, between groups, and the effect of the group-by-time interaction. The results showed significant main effects of time for the "eating duration" ($F(1, 11)=5.346$, $P=.041$), "eating desire" ($F(1, 11)= 10.317$, $P=.008$), "mental health" ($F(1, 11)= 18.287$, $P=.001$), "sleep" ($F(1, 11)= 5.520$, $P=.039$), "fatigue" ($F(1, 11)= 7.448$, $P=.02$), and "total" ($F(1, 11)= 21.977$, $P=.001$) subscales. However, no significant main effects were found between the groups, indicating that while there were time-related changes in swallowing-related quality of life, there were no substantial differences between the treatment and control groups. The interaction effect between groups and time was statistically significant for the "mental health" ($F(1, 11)= 9.462$, $P=.001$) and "total" ($F(1, 11)= 9.438$, $P=.001$) subscales. When examining changes in swallowing-related quality of life between pre- and post-treatment assessments for each group, no notable differences were observed in the treatment group ($n=7$). In contrast, the control group ($n=6$) showed statistically significant changes in the SWAL-QOL domains of eating desire ($P=.027$), mental health ($P=.027$), social function ($P=.042$), fatigue ($P=.034$), and the total score ($P=.027$) (Table 5).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of SWAL-QOL scores over time, between groups, and the interaction effect between group and time. The results showed a significant main effect of time and a significant interaction effect between groups and

time for the "eating duration" subscale ($P=.011$), indicating meaningful changes over time. Additionally, the main effect between groups was significant for the "food selection" ($P=.027$) and "fear" ($P=.047$) subscales. In contrast, when examining differences between pre- and post-treatment assessments for each group, no statistically significant differences were observed (Table 6).

Brief Inventory of Swallowing Assessment-15+ (BISA-15+)

To examine the differences between the overall treatment group ($n=7$) and the control group ($n=6$), a two-way repeated measures ANOVA was conducted to assess changes in BISA-15+ scores over time, between groups, and the effect of the group-by-time interaction. The results revealed a significant main effect of time ($F(1, 11)=7.923$, $P=.017$), indicating changes over time. However, no significant main effect of group was found, suggesting that while there were time-related changes in BISA-15 scores, there were no substantial differences between the treatment and control groups. Additionally, the group-by-time interaction effect was not significant, indicating no meaningful changes between the groups over time. In contrast, when examining differences between pre- and post-treatment assessments for each group, no statistically significant differences were observed (Table 5).

To examine the differences between the EPG treatment group ($n=3$) and the EPG control group ($n=4$), a two-way repeated measures ANOVA was conducted to assess changes in the acoustic parameters of BISA-15+ scores over time, between groups, and the interaction effect between group and time. The results revealed no statistically significant main effect of time between pre- and post-treatment assessments. Similarly, no significant main effect was found between the groups, and the group-by-time interaction effect was not significant. This indicates that there were no meaningful changes in BISA-15+ scores between the treatment and control groups over time (Table 6).

Table 5. Comparison of swallowing functions in groups in first and second evaluation

Measure	Treatment (n=7)		Control (n=6)		Time		Group		Time*Group	
	Pre	Post	Pre	Post	F	P	F	P	F	P
ALS-SS										
Swallow	7.57 ±1.40	7.86 ±1.07	7.67 ±1.21	6.83 ±1.17	1.039	.330	.555	.472	4.337	.061
DHI										
Functional	13.29 ±9.39	10.86 ±9.23	11.33 ±5.89	12.83 ±7.39	3.208	.101	2.476	.144	1.988	.186
Physical	10.43 ±7.21	10.00 ±6.22	17.67 ±10.91	23.67 ±5.61	.068	.800	.361	.560	.219	.649
Emotional	9.43 ±7.28	10.86 ±9.23	12.00 ±6.93	17.33 ±5.79*	10.617	.008**	1.255	.287	3.540	.087
Total	32.71 ±20.60	33.71 ±22.82	41.00 ±21.12	53.83 ±14.22	2.552	.138	1.867	.199	1.867	.199
SWAL-QOL										
Burden	6.29 ±2.93	6.43 ±3.05	5.67 ±3.08	4.83 ±2.14	.475	.505	.949	.351	.949	.351
Eating Duration	5.86 ±3.39	5.14 ±3.13	4.50 ±3.33	3.50 ±2.26	5.376	.041*	.804	.389	.149	.707
Eating Desire	12.43 ±2.94	11.14 ±3.29	11.83 ±3.43	7.50 ±3.39*	10.317	.008**	1.788	.208	3.035	.109
Symptom Frequency	50.71 ±12.47	50.57 ±13.48	50.33 ±13.91	46.33 ±14.91	1.012	.336	.877	.369	.877	.369
Food Selection	8.57 ±1.13	8.71 ±1.50	7.67 ±2.58	7.50 ±2.59	.001	.981	1.122	.312	.101	.757
Communication	4.43 ±2.70	4.71 ±2.87	5.00 ±3.10	3.83 ±2.48	1.239	.289	.011	.920	3.367	.094
Fear	16.86 ±4.74	15.29 ±4.15	18.50 ±2.81	16.00 ±30.68	5.708	.036	.336	.574	.297	.597
Mental Health	17.57 ±7.96	16.43 ±9.07	21.17 ±4.62	14.17 ±4.26*	18.287	.001**	.031	.863	9.462	.011*
Social Function	15.57 ±8.34	15.57 ±7.25	14.33 ±9.95	11.33 ±8.14*	1.783	.214	.363	.559	1.738	.214
Sleep	8.14 ±2.12	7.71 ±1.50	7.00 ±2.61	4.50 ±2.88	5.520	.039*	3.826	.076	2.762	.125
Fatigue	9.43 ±3.87	7.86 ±4.26	8.67 ±3.93	5.67 ±3.56*	7.448	.020*	.535	.480	.727	.412
Total	155.86 ±42.75	149.71 ±44.55	154.67 ±38.55	125.17 ±38.12*	21.977	.001**	.322	.582	9.438	.011*
BISA-15+										
Total	12.86 ±9.58	16.00 ±10.49	16.33 ±8.07	20.33 ±8.34	7.923	.017*	.613	.450	.114	.742

Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; DHI: Dysphagia Handicap Index; SWAL-QOL, Swallowing-quality of life; BISA-15+, Brief Inventory of Swallowing Assessment-15

*p< .05 ** p< .01

*Statistically significant differences were observed between the pretest and posttest evaluations

Table 6. Comparison of swallowing functions in first and second evaluation between the EPG treatment group and the EPG non-treatment group

Measure	EPG Treatment (n=3)		EPG Control (n=4)		Time		Group		Time*Group	
	Pre	Post	Pre	Post	F	P	F	P	F	P
ALS-SS										
Swallow	8.67 ±1.53	8.67 ±1.16	6.75 ±0.50	7.25 ±0.50	.714	.437	6.494	.051	.714	.437
DHI										
Functional	6.00 ±4.00	10.67 ±9.87	18.75 ±8.54	16.50 ±6.61	.322	.595	2.968	.146	2.638	.165
Physical	6.00 ±8.72	6.00 ±6.93	13.75 ±4.35	13.00 ±4.16	.014	.911	5.141	.073	.014	.911
Emotional	6.00 ±6.00	6.67 ±11.55	12.00 ±7.83	14.00 ±7.12	.497	.512	1.242	.316	.124	.739
Total	18.00 ±14.00	23.33 ±28.31	43.75 ±18.41	41.50 ±17.84	.056	.823	2.557	.171	.336	.587
SWAL-QOL										
Burden	8.00 ±1.73	8.00 ±3.46	5.00 ±3.16	5.25 ±2.50	.024	.884	2.103	.207	.024	.884
Eating Duration	7.67 ±2.08	5.67 ±3.06	4.50 ±3.79	4.75 ±3.59	9.545	.027*	.663	.452	15.779	.011*
Eating Desire	14.67 ±0.58	12.33 ±4.62	10.75 ±2.87	10.25 ±2.22	.803	.411	3.857	.107	.336	.587
Symptom Frequency	54.67 ±12.90	54.67 ±12.50	47.75 ±13.15	47.50 ±15.16	.002	.966	.493	.514	.002	.966
Food Selection	9.33 ±1.16	10.00 ±0.00	8.00 ±0.82	7.75 ±1.26	.201	.673	9.640	.027*	.971	.370
Communication	6.00 ±3.46	7.00 ±3.00	3.25 ±1.50	3.00 ±1.16	.714	.437	3.955	.103	1.984	.218
Fear	20.00 ±0.00	19.00 ±1.00	14.50 ±5.26	12.50 ±3.11	1.607	.261	6.857	.047*	.179	.690
Mental Health	22.67 ±4.04	22.33 ±4.62	13.75 ±8.38	12.00 ±9.45	1.464	.280	2.934	.147	.677	.448
Social Function	20.67 ±5.13	20.33 ±5.03	11.75 ±8.73	12.00 ±6.98	.001	.983	3.034	.142	.025	.880
Sleep	8.00 ±2.65	8.33 ±1.53	8.25 ±2.06	7.25 ±1.50	.260	.632	.097	.769	1.039	.355
Fatigue	10.33 ±4.51	9.67 ±6.11	8.75 ±3.86	6.50 ±2.38	2.182	.200	.603	.473	.643	.459
Total	182.00 ±32.51	177.67 ±37.45	136.25 ±41.88	128.75 ±40.82	1.322	.302	2.608	.167	.095	.771
BISA-15+										
Total	9.00 ±7.81	11.33 ±10.69	15.75 ±10.81	19.50 ±10.28	2.414	.181	1.001	.363	.131	.732

Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; DHI: Dysphagia Handicap Index; SWAL-QOL, Swallowing-quality of life; BISA-15+, Brief Inventory of Swallowing Assessment-15 / *p< .05

Discussion

Due to the disease, people with ALS often experience impaired oral motor function, leading to dysarthria and dysphagia. These difficulties can limit social interactions and negatively impact their quality of life^{1,38,39}. The swallowing problems increase the risk of aspiration pneumonia and chronic gastrointestinal issues^{14,24,40}. As a result, exploring various interventions to maintain speech, and swallowing abilities in ALS patients is essential to help preserve their quality of life as much as possible.

Self-training swallowing exercises, ASSET, offer a practical and accessible approach, allowing ALS patients to practice at their own pace and in their preferred environment. Remote interventions, such as mobile healthcare applications, could provide valuable tools for self-administered training, empowering ALS patients to maintain their speech, and swallowing functions^{11,12,41,42}. There has yet to be substantial evidence supporting ASSET as an effective treatment method for people with ALS.

Active therapies targeting the early stages of the disease have been explored to enhance swallowing abilities^{24,43}. While physical rehabilitation has traditionally been avoided^{9,44}, some studies suggest that moderate exercise may maintain motor functions. However, previous studies are minimal and need to show more information to say these methods significantly improve swallowing safety^{4,22-27}. In this study, the ASSET method, including effortful swallow and Mendelsohn maneuver, was employed along with tongue exercises as a rehabilitative treatment for swallowing function in ALS patients. This method's potential benefits and applicability were examined to fill a gap in the current literature and develop targeted interventions^{11,12}.

This study suggests that ASSET affects speech, and swallowing functions and quality of life indicators. In other words, ASSET may help slow the decline of essential speech and swallowing functions. As a result, this could lead to a slower progression of communication difficulties, a reduced rate of health risks associated with dysphagia, and a diminished impact on daily activities for ALS patients. This study showed two significant results.

Firstly, in the overall treatment group, AMR (Alternating Motion Rate) and SMR (Sequential Motion Rate) were relatively maintained, whereas the control group showed a marked decline. DDK (Diadochokinetic) tasks are closely related to oral motor function, which in turn is strongly associated with the severity of speech disorders depending on

performance⁴⁵. In particular, for patients with ALS, prolonged time and increased variability in jaw muscle movement tend to occur as the disease progresses. These factors can negatively impact the performance of DDK tasks⁴⁶. /puh/, /tuh/, and /kuh/ sounds involve the use of orbicularis oris, buccinator, styloglossus, palatoglossus, hyoglossus, and palatopharyngeal muscles. The SMR, /puh tuh kuh/, requires coordinated use of the tongue, lip, and soft palate muscles^{47,48}. EPS and ETR training strengthen these muscles, thus preserving or improving control of speech-related muscles in ALS patients. In previous studies, significant improvements were observed in tongue mobility, cheek and lip pressure, and diadochokinetic (DDK) rate after three weeks of orofacial myofunctional exercises and swallowing training for patients with dysphagia⁴⁹.

Furthermore, A previous study showed an increased or sustained ability in Parkinson's disease and head and neck cancer patients after performing swallowing exercises, including respiratory muscle relaxation, vocal folds relaxation, and laryngeal elevation⁵⁰. Another study demonstrated a significant increase in diadochokinetic rate after swallowing exercises such as deep breathing, opening and closing the mouth, tongue, and vocal exercises for three months⁵¹. The maintained performance in AMR and SMR in the current study aligns with previous research indicating that swallowing and tongue exercises are related to speech and accuracy of articulation. The maintenance of AMR and SMR performance in the treatment group, while the control group experienced a rapid decline, indicates that ASSET might be crucial in preserving speech-related muscle control and mobility in ALS patients. This improvement could be because the ASSET exercises involve the same muscle groups and structures responsible for producing AMR and SMR tasks. These exercises aim to strengthen and improve the mobility of the tongue, lips, and laryngeal muscles, essential for proper speech production. While the control group demonstrated a significant decline in their ability to perform AMR and SMR tasks, which can be interpreted as 'not doing the intervention led to worsening,' the treatment group showed no significant changes in these tasks. This suggests that 'doing the intervention did not result in deterioration.' Therefore, the ASSET intervention may help preserve or improve the performance of these tasks in ALS patients by strengthening the shared muscle groups involved in these movements.

Secondly, the treatment group maintained their speech, and swallow-related

quality of life, while the control group declined. Quality of life has a significant impact on patients with speech and swallowing disorders. These patients often experience difficulties in communication, which can lead to social isolation. Additionally, the extent to which they are aware of their own disabilities also plays a role^{52,53}. Since speech and swallowing issues due to ALS can significantly affect a patient's quality of life, addressing self-reported issues should be a primary criterion for evaluation and the goal of treatment^{13-15,43,54}. Previous research has shown improved quality of life for ALS patients after mobile music therapy, while no treatment resulted in a decline in quality of life⁴¹. ASSET has also been shown to affect the quality of life in other studies, such as in Parkinson's patients, where significant improvements were observed in SHI scores^{19,55}.

Other measurements, such as ALS-SS speech, speech intensity and ALS-SS swallow did not show significant differences between the treatment and control groups. However, the lack of significant differences might indicate that these functions were maintained in ALS patients, supporting the hypothesis that ASSET may contribute to preserving essential speech and swallowing functions in ALS patients. Further investigation is needed to understand the implications of these changes in the context of disease progression and the effectiveness of ASSET.

Additionally, there were no notable differences in most speech and swallowing variables between the EPG treatment group and the non-EPG treatment group. Vocal fatigue is associated with excessive use of the vocal cords, and the resulting muscle fatigue involved in phonation can be exacerbated by abnormal vocal cord movement⁵⁶. EPG is a training method that involves gradually increasing pitch through the use of vocal cord muscles. For ALS patients, this activity may have contributed to increased muscle fatigue. Studies on fatigue in ALS patients indicate that fatigue can be classified into two types: the first type is general systemic fatigue experienced even before diagnosis, while the second type is exercise-induced fatigue resulting from objective muscle weakness⁵⁷. In this study, it is assumed that the treatment group was not significantly affected by the EPG activity, likely due to the fatigue caused by muscle weakness.

Conclusions

This study has demonstrated the potential benefits of an 8-week ASSET program for ALS patients, particularly in preserving speech, and swallowing abilities. Compared to

the control group, the treatment group did not deteriorate its ability in AMR, SMR, and speech-swallowing-related quality of life. These results suggest that ASSET could be a viable intervention for ALS patients to help mitigate the negative impact of their condition on speech, and swallowing functions. However, the study has several limitations.

First, the limited sample size potentially constrains the generalizability of the results. Although some variables displayed significant differences in the Wilcoxon signed rank tests, they did not exhibit significance in ANOVA. Future research could involve larger sample sizes, which may yield more robust insights into the effects of ASSET on ALS patients. Secondly, the lack of blinding in the conduct of this study could introduce potential biases. The evaluators and patients were aware of the group allocations, potentially influencing the outcomes. Implementing a double-blind, or at least single-blind, design in subsequent studies could mitigate such biases, yielding more objective results. Additionally, the training duration could be determined through random assignment. This would allow for the observation of whether the treatment effects vary based on the duration of therapy, and it could provide objective results regarding at what point the treatment effects increase, decrease, or stabilize. Fourth, while objective swallowing evaluations were not conducted in this study, incorporating such assessments would be necessary to closely observe changes in swallowing function. For instance, methods such as the 3-oz water swallow test or VideoFluoroscopic Swallowing Study (VFSS) could be utilized. Fourthly, the lack of follow-up assessments makes it difficult to evaluate whether the intervention caused the reported effects. By conducting follow-up evaluations at different intervals, learning more about the efficacy and maintenance of the intervention's effects would be possible. Nonetheless, this study stands out as it presents new data on the impact of self-training mobile apps on speech, swallowing, and quality of life in people with ALS. These app-based training programs can offer more convenient treatment options for ALS patients who often balance multiple medical treatments and personal responsibilities. More studies replicating this one is needed to confirm ASSET as a practical approach for treating dysarthria and dysphagia in ALS.

Acknowledgements

Not applicable

Conflicts of Interest

None declared

Abbreviations

ASSET: A Successful Swallowing with Effortful Training

AMR: alternating motion rate

ALS: Amyotrophic lateral sclerosis

BISA-15⁺: Brief Inventory of Swallowing Assessment-15+

DDK: Diadochokinetic rate

DHI: Dysphagia Handicap Index

EPG: effortful pitch glide

EPS: effortful prolonged swallow

ETR: effortful tongue rotation

K-MMSE: Korean Mini-Mental State Examination

SMR: sequential motion rate

SHI-15: Speech Handicap Index-15

SWAL-QOL: Swallowing Quality Of Life

ALS-SS: The Amyotrophic Lateral Sclerosis Severity Scale

UES: upper esophageal sphincter

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