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The effects of a mobile healthcare application on speech and swallowing in amyotrophic lateral sclerosis

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Abstract

Background: Amyotrophic lateral sclerosis (ALS) impairs oral motor function, negatively affecting patients' speech and swallowing abilities, as well as quality of life. **Objective:** This study aims to evaluate the effectiveness of A Successful Swallowing with Effortful Training (ASSET) program, included in the 'The 365 Healthy Swallow Health Coach application' in preserving speech and swallowing abilities in ALS patients through self-training. **Methods:** In this 8-week quasi-experimental study, 13 participants were allocated to either the app-guided ASSET training group (n=7; three sessions per day, five days per week) or a usual-care control group (n=6) based on their clinical visit schedules. To evaluate changes over time and compare the two groups, linear mixed models were employed. Changes in ALS severity scale (ALSSS), Diadochokinetic (DDK) task, speech intensity, Speech Handicap Index-15, Dysphagia Handicap Index, Swallowing Quality of Life (SWAL-QOL), and Brief Inventory of Swallowing Assessment-15 were assessed. **Results:** ALSSS speech scores was relatively preserved from 5.43 (95% CI 3.01–7.84) to 5.29 (95% CI 2.87–7.70) in the ASSET treatment group, but declined from 6.33 (95% CI 3.73–8.94) to 4.83 (95% CI 2.23–7.44) in the control group, with a significant group-by-time interaction (p=.017). DDK/tuh/and/kuh/were relatively preserved from 11.86 to 11.71 and from 12.29 to 11.57 respectively in ASSET group, but declined from 11.67 to 7.50 and from 11.83 to 7.17 in the control group, with significant interactions in/tuh/(p=.032) and/kuh/(p=.044). SWAL-QOL total score was relatively preserved from 155.86 to 149.71 in ASSET group, but declined from 154.67 to 125.17 in the control group, with a significant interaction (p=.011). **Conclusions:** The findings suggest that ASSET program may help preserve speech and swallowing function in patients with ALS. Future research should validate the ASSET program with a larger, adequately powered sample size.

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Introduction

Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disorder characterized by the degeneration of upper and lower motor neurons that control voluntary muscle movements.[1] This loss of motor neurons leads to progressive muscle weakness, atrophy, and ultimately respiratory failure. A study published in 2020 estimated the global prevalence of ALS at 4.42 cases per 100,000 individuals (95% confidence interval, CI: 3.92–4.96), with an incidence rate of 1.59 cases per 100,000 person-years (95% CI: 1.39–1.81), highlighting the significant global health burden posed by this disease.[1]

Clinically, ALS is commonly classified into limb-onset and bulbar-onset types. Limb-onset ALS typically begins with weakness in the extremities and gradually progresses to involve respiratory musculature. In contrast, bulbar-onset ALS affects the muscles of the face, tongue, and pharynx, leading to early impairments in speech and swallowing. Many patients experience speech and swallowing difficulties during the course of ALS, which substantially affect communication and nutritional status.[2–5]

Motor impairments in ALS can affect respiratory and phonatory muscles, leading to progressive deterioration in speech production. Speech impairment is common, occurring as an initial symptom in approximately 25% of all ALS patients and in nearly 100% of those with bulbar-onset disease.[2,6–8] Numerous studies have examined speech-related markers in ALS, with frequently reported characteristics including vowel and consonant distortion, hypernasality, a slowed speech rate, and reduced intelligibility.[6,9,10] Swallowing dysfunction is another major and debilitating consequence of ALS, contributing to malnutrition and aspiration pneumonia. Dysphagia progresses gradually and affects all stages of swallowing including the oral preparatory, oral transit, pharyngeal, and esophageal phases during the course of the disease.[11–13]

The 365 Healthy Swallow Health Coach application delivers A Successful Swallowing with Effortful Training (ASSET) program in an accessible format for older adults. ASSET combines the effortful swallow and the Mendelsohn maneuver to create three structured exercises: effortful prolonged swallow (EPS), effortful tongue rotation (ETR), and effortful pitch glide (EPG). Each session lasts approximately 20 minutes and includes 20 repetitions of all three exercises. Participants completed the program at home for 8 weeks (three times per day, five days per week), and weekly remote monitoring was conducted to assess app use and adherence.[14,15]

The ASSET method has shown potential benefits for swallowing function in older adults and individuals with Parkinson's disease.[14–17] However, research on speech and swallowing interventions specifically targeting individuals with ALS remains limited. Most existing studies have been conducted with very small samples and often lack control groups, making it difficult to draw reliable or generalizable conclusions. Despite the high prevalence and clinical significance of speech and swallowing impairments in ALS, the amount of evidence-based therapeutic research is disproportionately small, and methodological limitations in prior studies further hinder interpretation of the findings.[18,19] Some preliminary evidence provides partial support for exercise-based interventions in ALS. For example, several studies suggest that the effortful swallow may increase upper esophageal sphincter opening duration,[20,21] and the Mendelsohn maneuver has been proposed as a compensatory strategy for ALS patients.[22] Although research on tongue exercises in ALS is sparse, several case studies and animal investigations have reported increases in tongue strength and endurance.[8,22,23]

Furthermore, one study noted that individuals with ALS often attempt to manage swallowing difficulties independently by modifying food textures or altering mealtime environments before seeking professional intervention.[24] This tendency highlights the need for accessible, self-directed therapeutic approaches and supports the rationale for exploring ASSET-based training in this population.

Although ALS patients experience significant impairments in swallowing and speech that adversely affect their quality of life,[24–27] access to speech-language interventions remains limited due to the lack of standardized and accessible treatment protocols, insufficient availability of trained professionals, time constraints, and financial burden.[28,29] These challenges underscore the importance of developing novel and scalable therapeutic strategies. Therefore, this study aims to investigate the effectiveness of ASSET-based training delivered through the 365 Healthy Swallow Health Coach App in supporting speech and swallowing functions in individuals with ALS, particularly focusing on dysarthria and dysphagia outcomes.

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. Furthermore, this study explored whether the addition of EPG to ASSET-based training is associated with differences in outcomes in individuals with ALS.

Methods

Study design and participants

In total, 16 ALS patients were initially recruited for the study. However, three participants were excluded due to death, refusal to participate in evaluations, and loss of contact. The remaining 13 participants were informed about the study, and all provided written informed consent approved by the Institutional Review Board (IRB). The participants (n=13) included nine males (69%) and four females (31%) with a mean age of 64.61±13.75 years and a mean Korean Mini-Mental State Examination (K-MMSE) score of 28.08±1.69 (out of a maximum of 30) (Table 1). After completing the evaluation, the participants were introduced to the mobile health application and the ASSET program. All treatment participants (n=7) completed the first and second evaluations, engaged in eight weeks of self-practice, and attended weekly online checkout sessions. Six participants were designated as the control group (Figure 1).

The inclusion and exclusion criteria in this study are as follows. The inclusion criteria were (1) a diagnosis of ALS, (2) signs and symptoms of dysarthria, (3) signs and symptoms of dysphagia, and (4) the ability to fully comprehend and follow the researcher's verbal instructions. The exclusion criteria included complaints of severe laryngeal or pharyngeal pain occurring during the treatment process.

Ethical considerations

The study protocol was approved by the Institutional Review Board of Yonsei University Health System (approval no. 4-2023-0040). All participants provided written informed consent. To protect privacy, the data used in this study were anonymized before analysis. Participants did not receive any compensation for their participation.

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 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, the researcher used K-MMSE to assess cognitive function.[30] Thus, by measuring cognitive function using the K-MMSE, this study ensured that participants were well-equipped to engage in the self-training intervention and benefit from the program.

Table 1. Participant information.

	Treatment (n = 7)	Control (n = 6)	p-value
Bulbar, n (%)	3 (42.86%)	3 (50%)	0.817
Non bulbar, n (%)	4 (57.14%)	3 (50%)	0.817
Sex			
Male, N (%)	0.872	4 (66.67%)	0.872
Female, N (%)	2 (28.57%)	2 (33.33%)	0.872
Age	61.43±18.38 [67 (22–80)]	68.33±4.23 [68 (62–75)]	0.279
K-MMSE	28.00±1.83 [28 (25–30)]	28.17±1.83 [28.5 (26–30)]	0.965
ALSSS Speech	5.43±2.76 [5 (1–10)]	6.33±3.20 [6.5 (1–10)]	0.510
ALSSS Swallow	7.57±1.40 [7 (6–10)]	7.67±1.21 [7.5 (6–9)]	0.890
ALSSS Lower extremities	6.86±1.77 [7 (5–10)]	5.17±3.19 [5.5 (1–9)]	0.427
ALSSS Upper extremities	5.14±2.54 [6 (1–8)]	6.17±1.83 [6 (3–8)]	0.628

Abbreviation: K-MMSE, Korean Mini-Mental State Examination; ALSSS, Amyotrophic Lateral Sclerosis Severity Scale.
Values are presented as mean ± standard deviation and median (minimum–maximum), and as number (%) for categorical variables.

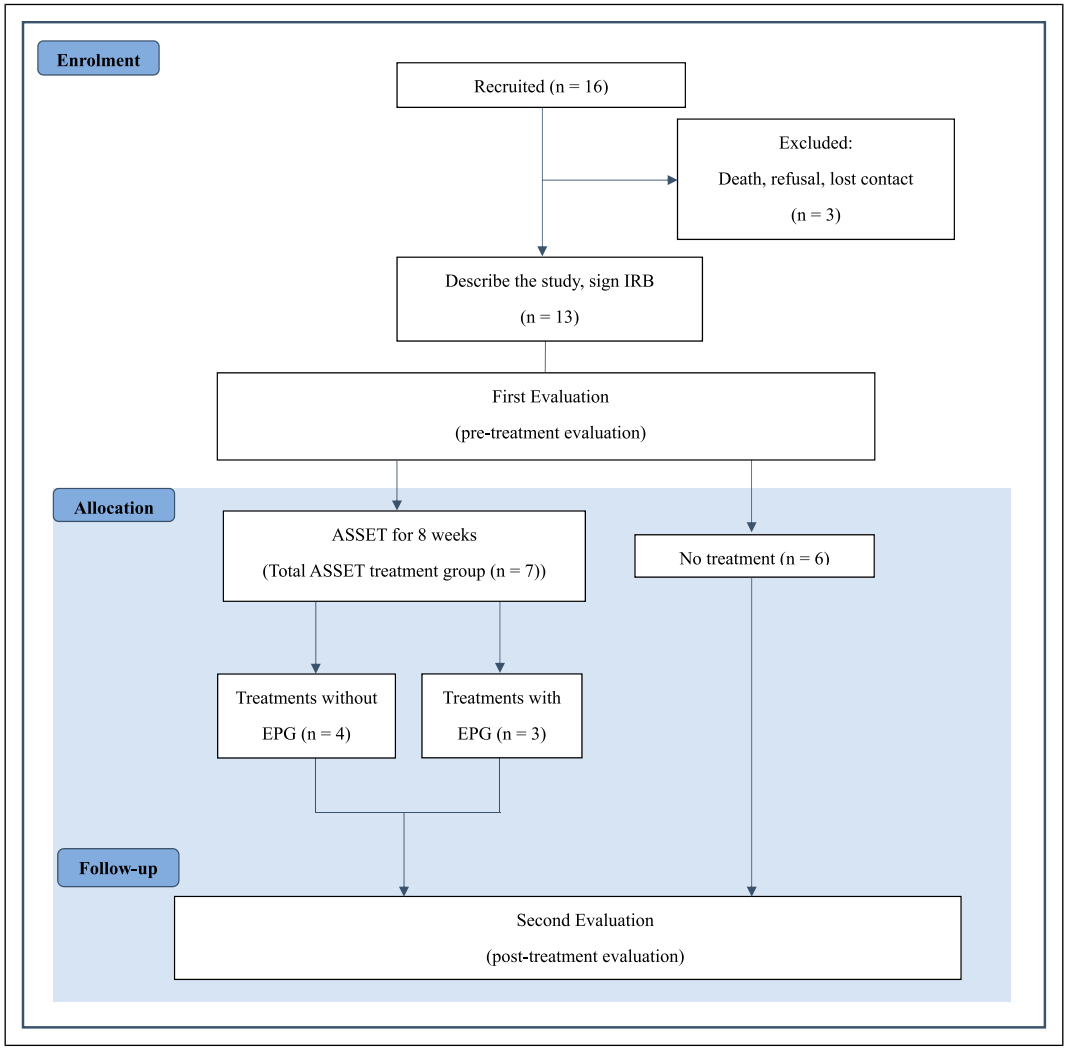

Figure 1. Participants recruitment.
Figure 1 Participant flow diagram of the ASSET intervention study. The flow diagram details the progress of participants through the screening, intervention, and follow-up phases. The study design was modified to a prospective quasi-experimental study, resulting in allocation based on individual consent and adherence capability.

ALS severity scale (ALSSS)

ALSSS was designated as the primary outcome measure for this study, as it directly assesses bulbar functions particularly speech and swallowing which were the main therapeutic targets of the ASSET intervention. The ALSSS evaluates multiple domains of physical functioning, including speech, swallowing, lower extremity performance, and upper extremity performance, making it a clinically relevant tool for characterizing disease severity in individuals with ALS.[31] Given its established use in monitoring bulbar decline, the ALSSS provides the most appropriate functional index for determining whether the intervention may influence disease-related changes.

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 consistently held the microphone 10 cm from the participant's mouth and at a 90-degree angle. This microphone was 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.

The diadochokinetic (DDK) task, including both alternating motion rate (AMR) and sequential motion rate (SMR), is commonly used to assess speech motor control in individuals with dysarthria. Participants were instructed to repeat specific syllables or syllable sequences as rapidly and consistently as possible over a five-second interval. In typical adult speakers, AMR performance for syllables such as/pʌ/,/tʌ/, and/kʌ/generally falls within a range of approximately 5 to 7 repetitions per second, with slightly reduced rates often observed for/kʌ/.[32]

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, [a̠ŋŋjʌ̩ŋɦa̠sʼʰe̞jo], 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 performance.[33] 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) refer to a vowel that is minimally influenced by articulatory factors. It is commonly used in voice evaluations to analyze jitter (frequency perturbation) and shimmer (amplitude perturbation). Higher values of both jitter and shimmer indicate greater instability in vocal fold vibration and are associated with poorer voice quality.

Speech-related quality of life

The participant completed standardized questionnaires related to speech and quality of life. The Speech Handicap Index-15 (SHI-15) is a brief questionnaire developed to collect self-reported data regarding the impact of dysarthria and other speech impairments on the psychosocial well-being of participants. Comprising 15 items, this instrument allows for a relatively quick and efficient evaluation of the perceived impact of speech impairments on an individual's daily life and social interactions. The SHI-15 yields a total score ranging from 0 to 60, with higher scores indicating greater perceived speech-related handicap.[34,35]

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.

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 in 11 distinct sub-categories for comprehensive analysis. Each domain score is transformed to a scale ranging from 0 to 220, with lower scores indicating poorer swallowing-related quality of life.[36]

The Dysphagia Handicap Index (DHI) provides self-reported insight into the impact of swallowing disorders on a participant's psychological well-being, encompassing physical, functional, and emotional domains. The instrument consists of 25 items (9 functional, 9 physical, and 7 emotional), with a total score ranging from 0 to 100, where higher scores indicate greater perceived dysphagia-related handicap.[37] The BISA 15+ is a screening tool used to detect the transition of swallowing function from normal to preclinical stages in patients. It consists of 15 items, with a total score ranging from 0 to 40, and can be administered in approximately 5–10 minutes. Higher scores indicate greater impairment in swallowing function.[38]

A mobile health application

365 Healthy Swallowing Coach app was developed as part of the 'Science and Technology Liberal Arts' funded by the National Research Foundation.[15] 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.

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. 4. Repeat steps 1-3 for a total of 10 swallows, forming 1 set.
Effortful Pitch Glide (EPG)	1. Maintain the vowel sound/i/at a reasonable pitch. 2. To get the highest pitch possible, raise the pitch gradually. 3. Try to stay on the highest pitch as long as you can.
Effortful Tongue Rotation (ETR)	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.

A successful swallowing with effortful training (ASSET)

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. All exercises in the ASSET program are performed in two sets[14,15] (Table 2).

Remote monitoring

Remote monitoring was primarily conducted using the 'remote consultation' feature of the 365 Healthy Swallow Health Coach application for video consultations. However, if this feature was not functioning smoothly, the Zoom 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. No adverse events or training-related discomfort were reported or observed during the 8-week intervention, indicating that the ASSET program and the mobile app were well tolerated by all participants.

Adherence

Adherence was assessed using daily performance logs automatically recorded on each participant's tablet. Daily performance data were collected from the logs recorded on each participant's tablet. The ASSET system defines a normal performance range of 80% to 120%.[14,15] In this framework, 100% represents the exact completion of the prescribed exercise target. Values exceeding 100% reflect additional sessions performed beyond the prescribed target (e.g., 144 sessions corresponding to 120% of the target). This range was defined to maintain adherence close to the target level while acknowledging proactive engagement by participants within a safe clinical margin.

Statistical analysis

The statistical analyses for the pre-and post-treatment assessments were conducted using IBM SPSS (IBM Corp., Armonk, NY, USA, Statistical Package for the Social Sciences, version 28.0) for Mac. Baseline comparability between the treatment and control groups was assessed using the Mann–Whitney U test to evaluate potential differences in pre-treatment measures. Post-hoc power for the time × group interaction was estimated in G*Power using the observed partial η^2 from the repeated-measures ANOVA. Effect sizes (Cohen's d) were calculated for within-group pre–post changes by dividing the mean change by the standard deviation of the change scores. Confidence intervals (95% CI) for Cohen's d were derived from the corresponding t-statistics. Linear mixed-effects models were applied to examine the main effects of group and time, as well as their interaction. Estimated marginal means with 95% CI were calculated for each group × time condition. Exploratory within-group comparisons were conducted using paired t-tests.

Results

Concerning study integrity, there were no missing data for adherence or outcome measures. All seven participants in the treatment group met the adherence criterion (>80% of scheduled sessions). Similarly, all six participants in the control group completed the scheduled assessments without any attrition, ensuring balanced data collection across both groups. Baseline characteristics are summarized descriptively in Table 1.

Differences and changes in speech function

Amyotrophic lateral sclerosis severity scale

ALSSS Speech showed change in the treatment group from baseline to post-intervention (from 5.429 to 5.286), whereas the control group showed a larger decline (from 6.333 to 4.833). This difference in change over time between groups was significant (time × group F (1,11)=7.832, p=.017). An overall time effect was also observed (F (1,11)=11.477, p=.006). Exploratory within-group comparisons showed a significant decrease in the control group, whereas no significant change was detected in the treatment group (Table 3).

Diadochokinetic rate

For DDK performance, values changed over time in both groups, with decreases observed in selected tasks in the control group. Significant between-group differences in change over time were observed for AMR/tuh/(from 11.857 to 11.714 vs from 11.667 to 7.500; F (1,11)=6.013, p=.032) and AMR/kuh/(from 12.286 to 11.571 vs from 11.833 to 7.167; F (1,11) =5.200, p=.044). Although AMR/puh/also decreased numerically in both groups, the between-group difference in change was not significant. Within-group exploratory comparisons revealed significant declines in the control group for AMR/tuh/ (p=.026), AMR/kuh/(p=.026), and the SMR/puh–tuh–kuh/sequence (p=.034), whereas no significant changes were detected in the treatment group (Table 3).

Speech intensity

Speech intensity showed decreases in both groups (from 74.784 to 74.679 in the treatment group and from 72.622 to 70.218 in the control group), with no significant between-group difference in change over time (p=.552) (Table 3).

Difference and changes in speech related quality of life

Speech handicap index

Regarding SHI-15 scores, significant overall time effect was identified for the psychosocial domain (F (1,11)=5.208, p=.043), and within-group exploratory comparisons showed worsening in the control group for the psychosocial domain (p=.042) and total score (p=.046), whereas no significant changes were detected in the treatment group (Table 3).

Differences and changes in swallowing function

Amyotrophic lateral sclerosis severity scale swallow

Analysis of the ALSSS swallow scores showed no significant main effects of time or group, and no significant group-by-time interaction was observed. Within-group comparisons also revealed no significant changes in either the treatment or control group (Table 4).

Difference and changes in swallowing related quality of life

Dysphagia handicap index

DHI scores did not show significant between-group differences in change over time. A significant overall time effect was identified for the emotional domain (F (1,11)=10.617, p=.008), and exploratory within-group comparisons indicated in the control group (p=.027), whereas no significant changes were detected in the treatment group (Table 4).

Swallowing-related quality of life

Analysis of the SWAL-QOL revealed significant main effects of time for the eating duration (F (1,11) = 5.376, 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=.020), and total score (F (1,11) = 21.977, p=.001) subscales. Significant group-by-time interactions were observed for the mental health (F (1,11) = 9.462, p=.011) and total (F (1,11) = 9.438, p=.011) subscales.

Table 3. Comparison of speech function trajectories between treatment and control groups.

	Treatment (n=7)		Control (n=6)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
ALSSS										
Speech	5.429 (1.103; 3.014-7.843)	5.286 (1.103; 2.871-7.700)	6.333 (1.191; 3.725-8.941)	4.833 (1.191; 2.225-7.441)#	11.477	0.006**	0.020	0.890	7.832	0.017*
AMR										
/puh/	13.429 (3.807; 5.093-21.764)	12.429 (3.807; 4.093-20.764)	12.167 (4.112; 3.163-21.170)	8.500 (4.112; -0.503-17.503)	7.952	0.017*	0.219	0.649	2.596	0.135
/tuh/	11.857 (3.569; 4.048-19.666)	11.714 (3.569; 3.905-19.523)	11.667 (3.854; 3.232-20.101)	7.500 (3.854; -0.935-15.935)#	6.897	0.024*	0.180	0.679	6.013	0.032*
/kuh/	12.286 (3.903; 3.729-20.842)	11.571 (3.909; 3.015-20.128)	11.833 (4.222; 2.591-21.076)	7.167 (4.222; -2.076-16.076)#	9.368	0.010*	0.182	0.678	5.200	0.044*
SMR										
/puh tuh kuh/	5.714 (1.399; 2.700-8.729)	4.571 (1.399; 1.557-7.586)	4.333 (1.511; 1.078-7.589)	2.833 (1.511; -0.422-6.089)#	4.254	0.064	0.635	0.442	0.078	0.786
Speech intensity	74.784 (2.175; 70.249-79.319)	74.679 (2.175; 70.162-79.231)	72.622 (2.349; 67.723-77.520)	70.218 (2.349; 65.320-75.117)	0.435	0.523	1.650	0.225	0.376	0.552
SHI-15										
Speech	20.857 (3.097; 14.181-27.533)	21.143 (3.097; 14.467-27.819)	19.500 (3.345; 12.289-26.711)	23.500 (3.345; 16.289-30.711)	2.336	0.155	0.013	03910	1.755	0.212
Psychosocial	18.571 (3.218; 11.641-25.502)	19.429 (3.218; 12.498-36.359)	17.833 (3.476; 10348-25.319)	23.833 (3.476; 16.348-31.319)#	5.208	0.043*	0.167	0.691	2.930	0.115
Total	39.429 (6.169; 26.135-52.722)	40.571 (6.169; 27.278-53.865)	37.333 (6.663; 22.975-51.692)	47.333 (6.663; 32.975-61.692)#	3.895	0.074	0.073	0.792	2.461	0.145

Note. Data are presented as estimated mean ± SE. All F-tests were based on numerator df = 1 and denominator df = 11.
Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; AMR, Alternating Motion Rate; SMR, Sequential Motion Rate; SHI-15, Speech Handicap Index-15.
#p < .05, ##p < .01 significant difference by Paired T-test.
*p < .05; **p < .01; ***p < .001 significant difference by linear mixed model.

Table 4. Comparison of swallowing functions in groups in first and second evaluation.

	Treatment (n=7)		Control (n=6)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
ALSSS										
Swallow	7.571 (0.461; 6.588-8.554)	7.857 (0.461; 6.874-8.840)	7.667 (0.498; 6.605-8.728)	6.833 (0.498; 5.772-7.895)	1.039	0.330	0.555	0.472	4.337	0.061
DHI										
Functional	13.286 (3.289; 6.265-20.306)	14.000 (3.289; 6.979-21.021)	17.667 (3.553; 10.084-25.250)	23.667 (3.553; 16.084-31.250)	3.208	0.101	2.476	0.144	1.988	0.186
Physical	10.429 (2.535; 5.124-15.733)	10.000 (2.535; 4.695-15.305)	11.333 (2.738; 5.603-17.063)	12.833 (2.738; 7.103-18.563)	0.068	0.800	0.361	0.560	0.219	0.649
Emotional	9.429 (2.833; 3.281-15.577)	10.857 (2.833; 4.709-17.005)	12.000 (3.060; 5.359-18.641)	17.333 (3.060; 10.693-23.974)[#]	10.617	0.008**	1.255	0.287	3.540	0.087
Total	32.714 (7.606; 16.478-48.950)	33.714 (7.606; 17.478-49.950)	41.000 (8.216; 23.463-58.537)	53.833 (8.216; 36.396-71.370)	2.552	0.138	1.892	0.196	1.867	0.199
SWAL-QOL										
Burden	6.286 (1.073; 3.975-8.596)	6.429 (1.073; 4.118-8.739)	5.667 (1.159; 3.171-8.162)	4.833 (1.159; 2.338-7.329)	0.475	0.505	0.546	0.475	0.949	0.351
Eating Duration	5.857 (1.164; 3.322-8.392)	5.143 (1.164; 2.608-7.678)	4.500 (1.257; 1.762-7.238)	3.500 (1.257; 0.762-6.238)	5.376	0.041*	0.804	0.389	0.149	0.707
Eating Desire	12.429 (1.230; 9.835-15.022)	11.143 (1.230; 8.550-13.736)	11.833 (1.328; 9.032-14.634)	7.500 (1.328; 4.699-10.301)[#]	10.317	0.008**	1.788	0.208	3.035	0.109
Sx Frequency	50.714 (5161; 39.541-61.888)	50.571 (5.161; 39.398-61.745)	50.333 (5.574; 38.265-62.402)	46.333 (5.574; 34.265-58.402)	1.012	0.336	0.100	0.758	0.877	0.369
Food Selection	8.571 (0.756; 6.969-10.174)	8.714 (0.756; 7.111-10.317)	7.667 (0.816; 5.935-9.398)	7.500 (0.816; 5.769-9.231)	0.001	0.981	1.122	0.312	0.101	0.757
Communication	4.429 (1.057; 2.137-6.721)	4.714 (1.057; 2.422-7.006)	5.000 (1.141; 2.524-7.476)	3.833 (1.141; 1.358-6.309)	1.239	0.289	0.011	0.920	3.367	0.094
Fear	18.571 (3.218; 11.641-25.502)	19.429 (3.218; 12.498-36.359)	17.833 (3.476; 10348-25.319)	23.833 (3.476; 16.348-31.319)	5.708	0.036*	0.336	0.574	0.297	0.597

(continued)

Table 4. (continued)

	Treatment (n=7)		Control (n=6)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
Mental Health	17.571 (2.637; 11.846-23.297)	16.429 (2.637; 10.703-22.154)	21.167 (2.849; 14.982-27.351)	14.167 (2.849; 7.982-20.351)#	18.287	0.001**	0.031	0.863	9.462	0.011*
Social Function	15.571 (3.183; 8.660-22.483)	15.571 (3.183; 8.660-22.483)	14.333 (3.438; 6.868-21.799)	11.333 (3.438; 3.868-18.799)#	1.738	0.214	0.363	0.559	1.738	0.214
Sleep	8.143 (0.867; 6.316-9.970)	7.714 (0.867; 5.887-9.541)	7.000 (0.937; 5.026-8.974)	4.500 (0.937; 2.526-6.474)	5.520	0.039*	3.826	0.076	2.762	0.125
Fatigue	9.429 (1.484; 6.259-12.598)	7.857 (1.484; 4.688-11.027)	8.667 (1.603; 5.243-12.090)	5.667 (1.603; 2.243-9.090)#	7.448	0.020*	0.535	0.480	0.727	0.412
Total	155.857 (15.619; 121.703-190.011)	149.714 (15.619; 115.560-183.869)	154.667 (16.870; 117.776-191.558)	125.167 (16.870; 88.276-162.058)#	21.977	<0.001***	0.322	0.582	9.438	0.011*
BISA-15+ Total	12.857 (3.497; 5.266-20.449)	16.000 (3.497; 8.408-23.592)	16.333 (3.777; 8.134-24.533)	20.333 (3.777; 12.134-28.533)	7.923	0.017*	0.613	0.450	0.114	0.742

Note. Data are presented as estimated mean ± SE. All F-tests were based on numerator df = 1 and denominator df = 11.
Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; DHI: Dysphagia Handicap Index; SWAL-QOL: Swallowing-Quality of Life; Sx Frequency: Symptom Frequency.
#p < .05, ##p < .01 significant difference by Paired T-test.
*p < .05; **p < .01; ***p < .001 significant difference by linear mixed model.

Within-group pre–post comparisons showed no significant changes in the treatment group. In contrast, the control group exhibited significant declines in eating desire (p=.027), mental health (p=.027), social function (p=.042), fatigue (p=.034), and the total SWAL-QOL score (p=.027) (Table 4).

Brief inventory of swallowing assessment-15

BISA-15+ scores increased in both groups over time, indicating worsening swallowing-related symptoms, but no significant between-group differences in change were detected. Although a significant overall time effect was observed ($F(1,11)=7.923$, p=.017), neither the group effect nor the time × group interaction was significant (Table 4).

Subgroup analysis of EPG intervention

To explore the additional impact of EPG, subgroup analyses were conducted between the EPG treatment group (n=3) and the control group (n=4). Across most parameters including ALSSS speech and swallowing scores, DDK tasks, acoustic measures (Jitter, Shimmer, and NHR), and SHI-15, no statistically significant main or interaction effects were observed (p > .05; Tables 5 and 6). While a significant interaction was noted in the SWAL-QOL eating duration subscale (p = .011), and significant between-group differences were identified in the food selection (p = .027) and fear (p = .047) subscales, the overall findings remain exploratory. Due to the limited sample size, these subgroup comparisons were not powered to detect small-to-moderate differences.

Table 5. Comparison of speech functions in first and second evaluation between the EPG treatment group and the EPG non-treatment group.

	EPG treatment (n=3)		EPG control (n=4)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
ALSSS										
Speech	7.000 (1.368; 3.513-10.487)	7.333 (1.368; 3.847-10.820)	4.250 (1.185; 1.231-7.269)	3.750 (1.185; 0.731– 6.769)	0.143	0.721	3.107	0.138	3.571	0.117
AMR										
/puh/	19.667 (6.181; 3.815-35.519)	19.667 (6.181; 3.815-35.519)	8.750 (5.353; -4.978-22.478)	7.000 (5.353; -6.278-20.728)	3.000	0.144	2.088	0.208	3.000	0.144
/tuh/	18.333 (5.673; 3.864-32.802)	17.000 (5.673; 2.531-31.469)	7.000 (4.913; -5.531-19.531)	7.750 (4.913; -4.781-20.281)	0.115	0.749	1.906	0.226	1.464	0.280
/kuh/	19.000 (6.222; 3.061-34.939)	17.667 (6.222; 1.727-33.606)	7.250 (5.388; -6.554-21.054)	7.000 (5.388; -6.804-20.804)	1.602	0.261	1.865	0.230	0.750	0.426
SMR										
/puh tuh kuh/	8.667 (1.944; 4.096-13.237)	7.333 (1.944; 2.763-11.904)	3.500 (1.683; -0.458-7.458)	2.500 (1.683; -1.458 -6.458)	1.094	0.344	4.658	0.083	0.022	0.887
Speech intensity	72.513 (3.382; 64.730-80.296)	72.303 (3.382; 64.521-80.086)	76.488 (2.929; 69.748-83.277)	76.491 (2.929; 69.752-83.231)	0.002	0.966	1.121	0.338	0.002	0.964
Jitter	0.490 (1.002; -2.084-3.065)	0.400 (0.179; -0.061-0.860)	2.105 (0.867; -0.125-4.334)	0.526 (0.155; 0.128-0.925)	1.538	0.267	1.673	0.249	1.222	0.316
Shimmer	5.585 (2.090; 0.904-10.266)	4.080 (2.090; -0.601-8.762)	8.512 (1.810; 4.458-12.566)	5.615 (1.810; 1.560-9.669)	1.585	0.264	1.085	0.345	0.159	0.707
NHR	0.002 (0.022; -0.047-0.051)	0.004 (0.022; -0.045-0.053)	0.043 (0.019; 0.001-0.086)	0.036 (0.019; -0.006-0.078)	0.026	0.879	2.645	0.165	0.057	0.821
SHI-15										
Speech	15.333 (5.279; 2.394-28.273)	15.667 (5.279; 2.727-28.606)	25.000 (4.572; 13.794-26.206)	25.250 (4.572; 14.044-36.456)	0.020	0.894	2.083	0.209	0.000	0.985
Psychosocial	11.667 (4.594; 0.456-22.877)	11.333 (4.594; 0.123-22.544)	23.750 (3.978; 14.042-33.458)	25.500 (3.978; 15.792-35.208)	0.139	0.724	5.168	0.072	0.301	0.607
Total	27.000 (9.625; 3.475-50.525)	27.000 (9.625; 3.475-50.525)	48.750 (8.336; 28.377-69.123)	50.750 (8.336; 30.377-71.123)	0.065	0.808	3.524	0.119	0.065	0.808

Note. Data are presented as estimated mean ± SE. All F-tests were based on numerator df = 1 and denominator df = 11.
Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; AMR, Alternating Motion Rate; SMR, Sequential Motion Rate; NHR, Noise-to-Harmonics Ratio; SHI-15, Speech Handicap Index-15.
*p < .05; **p < .01; ***p < .001 significant difference by linear mixed model.

Table 6. Comparison of swallowing functions in groups in first and second evaluation.

	EPG treatment (n=3)		EPG control (n=4)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
ALSSS										
Swallow	8.667 (0.543; 7.382-9.951)	8.667 (0.543; 7.382-9.951)	6.750 (0.470; 5.638-7.862)	7.250 (0.470; 6.138–8.362)	0.714	0.437	6.494	0.051	0.714	0.437
DHI										
Functional	6.000 (4.383; -4.521-16.521)	10.667 (4.383; 0.145-21.188)	18.750 (3.796; 9.638-27.862)	16.500 (3.796; 7.388-25.612)	0.322	0.595	2.968	0.595	2.638	0.165
Physical	6.000 (3.448; -1.684-13.684)	6.000 (3.448; -1.684-13.684)	13.750 (2.986; 7.096-20.404)	13.000 (2.986; .346-19.654)	0.014	0.911	5.141	0.073	0.014	0.911
Emotional	6.000 (4.742; -5.609-17.609)	6.667 (4.742; -4.942-18.275)	12.000 (4.107; 1.947-22.053)	14.000 (4.107; .947-24.053)	0.497	0.512	1.242	0.316	0.124	0.739
Total	18.000 (11.498; -9.068-45.068)	23.333 (11.498; -3.735-50.401	43.750 (9.958; 20.308-67.192	41.500 (9.958; 18.058-64.942)	0.056	0.823	2.557	0.171	0.336	0.587
SWAL-QOL										
Burden	8.000 (1.620; 4.127-11.873)	8.000 (1.620; 4.127-11.873)	5.000 (1.403; 1.645-8.355)	5.250 (1.403; 1.895-8.605)	0.024	0.884	2.103	0.207	0.024	0.884
Eating Duration	7.667 (1.907; 2.801-12.532)	5.667 (1.907; 0.801-10.532)	4.500 (1.651; 0.287-8.713)	4.750 (1.651; .537-8.963)	9.545	0.027*	0.663	0.452	15.779	0.011*
Eating Desire	14.667 (1.662; 10.964-18.370)	12.333 (1.662; 8.630-16.036)	10.750 (1.439; 7.543-13.957)	10.250 (1.439; 7.043-13.457)	0.803	0.411	3.857	0.107	0.336	0.587
Sx Frequency	54.667 (7.859; 35.233-74.100)	54.667 (7.859; 35.233-74.100)	47.750 (6.806; 30.920-64.580)	47.500 (6.806; 30.670-64.330)	0.002	0.966	0.493	0.514	0.002	0.966
Food Selection	9.333 (0.560; 8.077-10.589)	10.000 (0.560; 8.744-11.256)	8.000 (0.485; 6.912-9.088)	7.750 (0.485; 6.662-8.838)	0.201	0.673	9.640	0.027*	0.971	0.370
Communication	20.857 (3.097; 14.181-27.533)	21.143 (3.097; 14.467-27.819)	19.500 (3.345; 12.289-26.711)	23.500 (3.345; 16.289-30.711)	2.336	0.155	0.013	03910	1.755	0.212
Fear	20.000 (1.949; 15.451-24.549)	19.000 (1.949; 14.451-23.549)	14.500 (1.688; 10.560-18.440)	12.500 (1.688) (8.560-16.440)	1.607	0.261	6.857	0.047*	0.179	0.690

(continued)

Table 6. (continued)

	EPG treatment (n=3)		EPG control (n=4)		Time		Group		Time*Group	
	Pre (SE; 95% CI)	Post (SE; 95% CI)	Pre (SE; 95% CI)	Post (SE; 95% CI)	F	*p*	F	*p*	F	*p*
Mental Health	22.667 (4.298; 11.767-33.567)	22.333 (4.298; 11.433-33.233)	13.750 (3.722; 4.310-23.190)	12.000 (3.722; 2.560-21.440)	1.464	0.280	2.934	0.147	0.677	0.448
Social Function	20.667 (3.992; 11.027-30.307)	20.333 (3.992; 10.693-29.973)	11.750 (3.457; 3.402-20.098)	12.000 (3.457; 3.652-20.348)	0.001	0.983	3.034	0.142	0.025	0.880
Sleep	8.000 (1.128; 5.351-10.649)	8.333 (1.128; 5.685-10.982)	8.250 (0.977; 5.956-10.544)	7.250 (0.977; 4.956-9.544)	0.260	0.632	0.097	0.769	1.039	0.355
Fatigue	10.333 (2.430; 4.396-16.271)	9.667 (2.430; 3.729-15.604)	8.750 (2.104; 3.608-13.892)	6.500 (2.104; 1.358-11.642)	2.182	0.200	0.603	0.473	0.643	0.459
Total	182.000 (22.495; 125.170-238.830)	177.667 (22.495; 120.837-234.496)	136.250 (19.481; 87.034-185.466)	128.750 (19.481; 79.534-177.966)	1.322	0.302	2.608	0.167	0.095	0.771
BISA-15+ Total	9.000 (5.826) (-5.449-23.449)	11.333 (5.826) (-3.116-25.783)	15.750 (5.046) (3.236-28.264)	19.500 (5.046; 6.986-32.014)	2.414	0.181	1.001	0.363	0.131	0.732

Note. Data are presented as estimated mean ± SE. All F-tests were based on numerator df = 1 and denominator df = 11.
Abbreviation: ALSSS, Amyotrophic Lateral Sclerosis Severity Scale; DHI: Dysphagia Handicap Index; SWAL-QOL: Swallowing-Quality of Life.
*p < .05; **p < .01; ***p < .001 significant difference by linear mixed model.

Post-hoc power analysis and effect sizes

A post-hoc power analysis was conducted using G*Power for the time × group interaction of the linear mixed model. Based on the observed effect size (f=0.85, derived from partial η^2=0.417) and the total sample size (n=13), the achieved power was 0.58. Effect sizes were calculated using Cohen's d based on the pre–post change scores. The treatment group showed virtually no change in ALSSS Speech (d=−0.02; 95% CI −0.83 to 0.80), whereas the control group demonstrated a large decline (d=−1.28; 95% CI −2.72 to 0.13).

Discussion

This exploratory study demonstrated the clinical feasibility and potential efficacy of a mobile-based ASSET program in patients with ALS. While the progressive nature of ALS related bulbar dysfunction typically leads to rapid deterioration in speech and swallowing functions, our findings provide preliminary evidence that digital healthcare interventions can support functional preservation. In this study, several outcomes were relatively preserved in the treatment group than in the control group. 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. However, these findings should be interpreted cautiously because the study was not powered for confirmatory between-group inference. This study showed two significant results.

Firstly, in the overall treatment group, AMR and SMR were relatively showed limited observed change, whereas the control group showed a marked decline. DDK tasks are closely related to oral motor function, which in turn is strongly associated with the severity of speech disorders depending on performance.[39] 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 tasks.[40] The SMR,/puh tuh kuh/, requires coordinated use of the tongue, lip, and soft palate

muscles.[41,42] EPS and ETR training may help maintain or support the control of speech-related musculature in individuals with ALS by strengthening the muscles involved in these movements. In the present study, AMR and SMR performance was relatively preserved in the treatment group, while the control group showed a marked decline, suggesting a potential protective effect of the ASSET program on bulbar motor function. Previous studies have shown that swallowing and orofacial exercises can influence tongue mobility, cheek and lip pressure, and diadochokinetic performance in individuals with dysphagia.[43] It can sustain or improve articulatory ability in populations such as Parkinson's disease or head and neck cancer.[44,45] These findings generally support the notion that exercises engaging oral and pharyngeal musculature may contribute to maintaining speech-related motor function. AMR (/puh/,/tuh/) and SMR (/puh-tuh-kuh/) tasks recruit overlapping muscle groups—including the orbicularis oris, buccinator, styloglossus, palatoglossus, hyoglossus, and palatopharyngeal muscles—that are also activated during EPS or ETR–lip tasks included in the ASSET program.[15,41,42,46,47] The relative stability observed in the treatment group may therefore reflect some overlap in the functional systems targeted by ASSET and those required for performing DDK tasks.

However, this mechanistic interpretation remains speculative. The present study did not directly measure physiological parameters such as tongue pressure, muscle strength, or EMG activity; therefore, any inference regarding shared muscle activation or functional strengthening should be viewed as a hypothesis rather than evidence. Further work incorporating tongue pressure metrics, surface EMG, or kinematic analyses would be required to clarify whether ASSET directly contributes to the preservation of DDK performance in ALS.

Secondly, the treatment group showed relative preservation in 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.[25,48] 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.[25–27,49,50] 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 life.[51] 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.[16,52]

Other measurements, such as ALSSS speech, speech intensity, and ALSSS swallow, did not show significant differences between the treatment and control groups. Given the limited sample size and exploratory design, these findings focused on providing descriptive summaries and preliminary trends rather than making definitive claims. Further validation is required, and additional research is needed to clarify the implications of ASSET within the context of ALS disease progression and to better understand its potential effectiveness for this population.

Despite these promising patterns, the clinical significance of the observed changes remains limited. Minimal clinically important difference (MCID) thresholds for speech- and swallowing-related outcome measures have not been established specifically for individuals with ALS, making it difficult to determine whether the magnitude of change represents a meaningful clinical improvement. While the treatment group demonstrated relative stability compared to the decline observed in the control group, this preservation of function should be interpreted cautiously and cannot be considered definitive evidence of clinical benefit.

These findings must also be understood within the context of several methodological limitations, including the very small sample size and the absence of multiplicity correction across multiple comparisons. Such limitations restrict the generalizability of the results and underscore that the present study provides exploratory, rather than confirmatory, evidence. Larger, adequately powered randomized trials are required to validate the potential of ASSET-based interventions for individuals with ALS.

Conclusions

This study provides preliminary, exploratory evidence that the 8-week ASSET program may be associated with less observed decline in selected speech, swallowing, and quality-of-life outcomes in individuals with ALS. Compared with the control group, the treatment group demonstrated relative stability in AMR, SMR, and speech and swallowing-related quality of life, rather than the declines typically expected in this population. These exploratory findings suggest that ASSET could represent a promising approach for mitigating bulbar deterioration in ALS. However, given the small sample size and exploratory design, larger and adequately powered studies are needed to confirm the clinical effectiveness of this intervention.

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Yeongju Cho and Sun Young Won designed the model and the framework of the study, wrote the manuscript and analyzed the data. All authors reviewed and compiled the results. Yeongju Cho and Sun Young Won drafted and revised the manuscript. Hye Kyoung Lee performed statistical revisions and contributed to the data analysis. Sung-Rae Cho supervised the project, revised the manuscript, and provided financial support. All authors read and approved the final manuscript.

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Appendix

Abbreviations

ASSET	A Successful Swallowing with Effortful Training
AMR	Alternating motion rate
ALS	Amyotrophic lateral sclerosis
ALSSS	Amyotrophic lateral sclerosis severity scale
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
UES	Upper esophageal sphincter.