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CONTRACTING ORGANIZATION: The Pennsylvania State University

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## 1. INTRODUCTION

We propose a longitudinal home study of ALS patients to assess bulbar progression via a smartphone-based, self-administered remote speech and swallow assessment (rSSA). This application will be used to take a weekly 'snapshot' of bulbar health by recording the audio of speech and swallowing sounds. The overall hypothesis is that this monitoring protocol can be used 1) in a way that is satisfactory to the patient, 2) to provide a set of digital biomarkers that are sensitive to dysarthria and dysphagia, and 3) with higher temporal resolution than standard measures to allow for the study of speech and swallow pathology co-evolution in ALS. This proposal features the cross-discipline collaboration of content experts in ALS quality of life (Simmons), mobile health technologies (Geronimo), and the collection, analysis, and interpretation of speech/swallow sound data (Lee/Madhavan).

## 2. KEYWORDS

Amyotrophic lateral sclerosis, dysphagia, dysarthria, remote patient monitoring

## 3. ACCOMPLISHMENTS

### What were the major goals of the project?

- 1) Design, administer and describe weekly remote speech and swallow assessments (rSSA).
- 2) Validate rSSA against standard assessments for speech and swallow. Compare rSSA outcomes to clinical measures employed as part of standard bulbar management by the speech-language pathologist.
- 3) Analyze the association between dysphagia and dysarthria measures over the 24 weeks of the study.

See the statement of work and the progress meeting milestones in the next section.

### What was accomplished under these goals?

- 1) Design, administer and describe weekly remote speech and swallow assessments (rSSA).

This has been fully completed and is deployed to active research subjects. A copy of the statement of work for Aim 1 is provided below, along with the date items were completed, if applicable.

Table 1: Progress on SOW for Aim 1. Differentials are given between actual completion date and proposed completion date, with the grant period officially starting on 10/1/21. NC – not completed, NS – not started.

	Proposed Timeline (months)	Date Completed	Actual Timeline (months)	Differential (months)
<b>Major Task 1: Regulatory Approval</b>				
• Refine inclusion criteria and screening protocol	-7	2/24/2021	-7	0
• Finalize consent form and human subjects protocol	-7	2/24/2021	-7	0
• Consult with monitoring team to develop monitoring plan	-7	4/6/2022	6	13
• Departmental Scientific Review	-6	3/4/2021	-6	0
• Penn State Hershey IRB Review	-6	7/13/2021	-2	4
• Annual continuing renewal of study protocol with IRB	5,16	2/11/2022	4	-1
• Milestone Achieved: IRB Approval from PSHMC	-5	7/13/2021	-2	3
• Milestone Achieved: DoD HRPO regulatory approval	0	9/20/2021	0	0
<b>Major Task 2: Prepare Research Materials for Study</b>				
• Complete data use agreement with Aural Analytics	-1	NC		

• Application and Database development with Aural Analytics	-1	4/1/2022	6	7
• Acquire hardware for study	-1	10/27/2021	0	1
• Complete training course on MBSImP	-1	4/26/2022	6	7
• Develop rSSA kit and instructions	-1	4/6/2021	-5	-4
• Finalize data collection instruments in REDCap	-1	4/11/2022	6	7
• Pilot testing of rSSA kits	0	4/6/2021	-5	-5
• Milestone: Research materials ready for start of study	0	4/26/2022	6	6
<b>Major Task 3: Conduct Study</b>				
• Recruitment materials distributed	0	4/25/2022	6	6
• Study site training	0	10/14/2021	0	0
• In-person recruitment during ALS clinic visits	0-15	11/10/2021	1	1
• Schedule subject visits	0-21	5/9/2022	7	7
• Clinical Activities (ALSFRS-R, FVC, MIP, MASA completed at study visits 1-3)	0-21	4/8/2022	6	6
• Research Activities (SIT and MBS completed at study visits 1 & 3)	0-21	5/9/2022	7	7
• Home Activities (Surveys completed monthly and rSSA completed weekly)	0-21	5/17/2022	7	7
• Recruit listeners and conduct SIT intelligibility scoring	0-21	12/1/2022	14	14
• Conduct SSF analysis	0-21	8/19/2022	10	10
• Submit amendments, adverse events, protocol deviations as needed	0-21	Ongoing		
• Monitoring visits after 1st, 10th subject enrolled and study closeout	1,6,24	6/8/22, 6/13/2023	20	14
• Milestone: First subject Consented and Enrolled	1	4/11/2022	6	5
• Milestone: 10 subjects enrolled	6	5/31/2023	19	13
• Milestone: Fully enrolled (20 subjects)	12	NC		
<b>Major Task 4: Describe the study cohort</b>				
• Create analysis plan to describe study cohort	1	8/19/2022	10	9
• Interim analysis of Aim 1 for grant reporting and presentation	6-8	8/19/2022	10	4
• Final analysis for dissemination, final grant report	21-23	NS		
• Milestone: Present interim results of Aim 1 at ALS conference (NEALS 2022)	11	11/1/2022	13	2
• Milestone: Platform presentation of final results of Aim 1 at ALS conference (NEALS 2023)	23	NS		
• Milestone: Manuscript submission to clinical journal	24	NS		
• Milestone: Incorporate findings into grant proposals	18-24	NS		

- 2) Validate rSSA against standard assessments for speech and swallow. Compare rSSA outcomes to clinical measures employed as part of standard bulbar management by the speech-language pathologist

As of the time of this report, we have 13 subjects enrolled in the study who have each completed a clinical and radiographic examinations of swallowing, standard speech intelligibility recordings, and weekly home recordings of their speech and swallow. The plan for performing these analyses were formulated as part of the grant writing and study startup process. Preliminary analysis has been performed for the analysis of standard and remote swallowing assessments. For the remote spontaneous swallowing frequency

assessments, audio data is downloaded. WavePad software is used to listen to the audio files via Bose QC35 headphones. Swallows are identified as swallows per minute and a total over 10 minutes is calculated. SSF analysis has been completed as recordings become available.

In December 2022, data collection from listeners began. Listeners are recruited to perform intelligibility ratings of patient voice assessment. Prior to this, the audio recordings are edited and cleaned for each target word and sentence. As each recording naturally contains extraneous noises (e.g., coughing sound, clearing throat, etc.), careful and consistent editing needs to be done. To do so, Speech Production Laboratory lab members have had weekly to discuss any extraneous noises detected in files and handle them consistently. Once audio editing is done, the audio files are analyzed acoustically as planned, and listeners are enrolled to rate speech intelligibility. As of November 2023, 21 listeners have performed complete scoring of 10 patient's speech files.

Table 2: Progress on SOW for Aim 2. Differentials are given between actual completion date and proposed completion date, with the grant period officially starting on 10/1/21. NS – not started.

	Proposed Timeline (months)	Date Completed	Actual Timeline (months)	Differential
<b>Major Task 1: Analysis of rSSA compared to standard speech and swallow assessments</b>				
• Create analysis plan for extracting and comparing outcomes related to swallow (MBSImP, rSSA spontaneous swallow task)	-1	10/1/2021	0	1
• Create analysis plan to for extracting and comparing outcomes related to speech (SIT, rSSA speech battery)	-1	10/1/2021	0	1
• Interim analysis for grant reporting and presentation of results	6-8	8/19/2022	10	3
• Final analysis for grant reporting and presentation of results	21-23			
• Milestone: Complete analysis plan	-1	10/1/2021	0	1
• Milestone: Platform presentation submission to International Symposium on ALS/MND 2022	21-23	NS		
• Milestone: Manuscript submission for motor-speech findings	24	NS		

3) Analyze the association between dysphagia and dysarthria measures over the 24 weeks of the study.

Data collection to meet this goal is ongoing, although the sample size at this point is too small to warrant interim findings. Data collection is complete in 9 participants, with expected completion in 3 subjects currently enrolled in April 2024.

Table 3: Progress on SOW for Aim 3.: Differentials are given between actual completion date and proposed completion date, with the grant period officially starting on 10/1/21. NS – not started.

<b>Major Task 1: Describe the longitudinal relationship between assessments of dysphagia and dysarthria</b>				
• Create analysis plan to compare speech and swallowing outcomes	-1	10/1/2021	0	1
• Milestone: Complete analysis plan	-1	10/1/2021	0	1

**What opportunities for training and professional development has the project provided?**

See invited presentations and poster abstracts. The PI has been able to present this work in the context of larger remote monitoring efforts within the Hershey ALS clinic. Preliminary results from the swallowing analysis were presented at the Northeast ALS Consortium Annual meeting in November 2022. Preliminary speech results were presented at the annual meeting of the American Speech-Language-Hearing Association by Dr. Lee in 2023.

Carrie Reichwein was able to successfully complete the MBSImP training in April 2022, for which she earned 21 contact hours of continuing education credit. She applies this training to her work on the study and in her professional role as a speech-language pathologist.

**How were the results disseminated to communities of interest?**

Project conceptualization and preliminary results have been shared with the scientific community at international outlets for ALS and digital health research.

Additionally, we plan to share ongoing results of the study at an upcoming patient research group meeting hosted by the Hershey ALS clinic.

**What do you plan to do during the next reporting period to accomplish the goals?**

We are approximately 60% complete in our recruitment goals. Because of this, *we requested and were granted in September 2023 a 12-month no-cost extension with a final end date of 8/31/2024.* We plan to continue recruiting ALS subjects for the study at our site at Hershey, and initiating the listener phase of the study procedures at University Park. Our goal remains to enroll 2-3 participants per quarter. A revised enrollment plan is given below. Continued meetings with the study team will be used to troubleshoot ongoing data collection, analysis, and dissemination.

*Table 4: Enrollment table including the original schedule of enrollments, actual enrollment, and a revised plan completing data collection in 17 participants by the end of the award.*

	2021	2022				2023				2024				Total
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Planned		5	5	5	5	0	0	0	0					20
Actual		0	4	1	2	1	2	2	1					13
<b>Revised Plan</b>		<b>0</b>	<b>4</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>0</b>	<b>0</b>		<b>17</b>

**4. IMPACT**

**What was the impact on the development of the principal discipline(s) of the project?**

A significant care gap exists in tracking bulbar pathology in the traditional and tele-ALS clinics. A tailored assessment that can be self-administered regularly to monitor bulbar changes is needed. Access to speech and swallowing data measured at such a fine timescale allows us to better respond to clinical changes. It also serves a research purpose to determine the co-evolution of dysphagia and dysarthria due to bulbar neurological involvement in ALS.

### **What was the impact on other disciplines?**

Presentation of this work at the local, national, and international level has garnered much interest both in the field of ALS and other neuromuscular disease and dementia.

### **What was the impact on technology transfer?**

N/A

### **What was the impact on society beyond science and technology?**

N/A

## **5. CHANGES/PROBLEMS**

### **Changes in approach and reasons for change**

There have been three substantial changes to the protocol since initial approval:

- 1) Change in the platform used for performing smartphone-based recordings of speech. The original platform quoted in our proposal was through a company called Aural Analytics. When reaching out to them after receiving the grant, they were no longer interested in pursuing a partnership at the discussed price point. We had to look for other options. We took the route of an alternative smartphone speech collection tool using the open-source Beiwe software (<https://www.beiwe.org/>). This allows us to design our own survey schedule, manage patients, and download data from the data server, which has been set up in Amazon Web Services. This pivot has led to the majority of delays (approximately 6 months), since the PI was responsible for preparing this database for production. *This change has little to no expected effect on the outcomes, as the data collection via smartphone and external microphone, as well as the prompts used to gather speech data, remain unchanged.*
- 2) Modification to allow for partial completion of the MASA. This was implemented because the best clinical practices for doing a swallowing assessment do not involve the elicitation of a gag or choking response or the evaluation of pharyngeal phase.
- 3) Removed original inclusion criteria which required a minimal rate of change in speech or swallowing. Addition of Inclusion to clarify that patients with feeding tube may be enrolled as long as they maintain consistent daily oral intake. We believe removal of these changes will allow us to recruit a greater proportion of patients seen in ALS clinic.

There have also been changes to the study team, including an updated monitor, new research coordinator, and student investigators.

### **Actual or anticipated problems or delays and actions or plans to resolve them**

The project experienced longer than expected startup time due to delays in software development and change of research coordinator. The project enrolled its first participants in May 2022.

Since collection of data from subjects went live in May 2022, we have experienced some inconsistencies with data upload from subject smartphone devices, particularly on those using the iOS operating system. While not ideal, this is affecting the minority of total speech recordings. Our study team is following up as necessary to ensure we have the most complete data possible. The PI is working with the Beiwe team to correct these issues and will push an update to the application to users when it is available.

In 2023, we transitioned to providing study-owned android smartphones to study participants. This has resulted in more consistent task completion and data transfer.

### **Changes that had a significant impact on expenditures**

We incurred minor additional cost with the purchase of 5 android smartphones (~\$200 each phone)

### **Significant changes in use or care of human subjects**

None, other than the modified inclusion criteria mentioned above.

### **Significant changes in use or care of vertebrate animals**

N/A

### **Significant changes in use of biohazards and/or select agents**

N/A

## **6. PRODUCTS**

### **Conference Abstracts**

Lee, J., Geronimo, A., Krajewski, E., Mazzola, D., Taylor, K., Padt, M., Jackson, E., Reichwein, C., & Simmons, Z. (2023). Remote monitoring of speech function in individuals with dysarthria secondary to amyotrophic lateral sclerosis. Poster presentation at American Speech-Language-Hearing Association Convention, Boston, MA.

Geronimo, A.M., Reichwein, C., Madhavan, A., Simmons Z, "Tracking dysphagia in ALS with audio recordings of spontaneous swallowing", Poster presentation at Northeast ALS Consortium Annual Meeting 2022, Clearwater, FL, November 1, 2022.

### **Invited Presentations**

Geronimo, A.M. (May 19, 2022) "Inhale, exhale, upload: Digital Health in the ALS Clinic," "Experiences in Digital Health from the ALS Clinic" AFTD Holloway Summit 2022, Miami, FL, 75 in attendance, Invited. International.

Geronimo, A. M. (March 15, 2022). "Inhale, exhale, upload: Digital Health in the ALS Clinic," MDA Clinical & Scientific Conference, Muscular Dystrophy Association, Nashville, TN, USA, 100 in attendance, Invited. International.

Geronimo, A. M. (October 7, 2021). "Pioneering decentralized multidisciplinary ALS care using digital health and targeted remote monitoring technologies," Northeast ALS Consortium Annual Meeting 2021, Virtual, peer-reviewed/refereed, Invited. International.

## **7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

### **What individuals have worked on this project (*new study team members emphasized*)**

PI: Andrew Geronimo, Ph.D.

Co-I: Zachary Simmons, M.D.

SLP: Carrie Reichwein, M.S., CCC-SLP

Coordinator: Cristie Crawford, BS

Statistician: Erik Lehman, M.S.

Data Monitor: Kelly Nye, B.S.

Co-I: Ji Min Lee, Ph.D., CCC-SLP

Co-I: Aarthi Madhavan, Ph.D., CCC-SLP

Graduate Student (Lee Lab): Elizabeth Krajewski

Undergraduate Student (Lee Lab): Erica Jackson

***Undergraduate Student (Lee Lab): Heather Killian***

***Undergraduate Student (Lee Lab): Merel Padt***

**Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?**

Yes

Dr. Geronimo has transitioned his primary appointment within the Penn State College of Medicine from the Department of Neurosurgery to the Department of Neurology. He is still supported at 100% effort for research.

**What other organizations were involved as partners?**

N/A

**8. SPECIAL REPORTING REQUIREMENTS**

Not Applicable

**9. APPENDICES**

## Background

The COVID-19 pandemic brought to light the necessity of providing services to vulnerable populations through alternate, remote means. One such population is individuals with amyotrophic lateral sclerosis (ALS), the majority of whom will experience dysarthria throughout the progression of their disease (Ball et al., 2007). Broadly, the current study focuses on exploring home monitoring of speech function in people with dysarthria secondary to ALS.

To remotely monitor speech function, optimal speech measures and tasks first need to be identified. Previous research has sought to identify speech measures that are sensitive to dysarthria severity in people with ALS (PALS), such as speaking rate. Most of these studies, however, were cross-sectional in nature and did not include longitudinal observations. In order to find speech measures sensitive to dysarthria progression, longitudinal observations of speech changes and their impact on functional verbal communication, such as speech intelligibility, need to be investigated.

## Current research aim

The current study aimed to examine longitudinal patterns of speech changes and identify speech tasks that have a potential as clinical measures for remote monitoring of speech function in people with dysarthria secondary to ALS.

## Methodology

**Participants:** 8 individuals with ALS (4 males; mean age 68 yrs) were recruited from the Penn State ALS Research Center and Clinic. The inclusion criteria were 1) be older than 18 years of age, 2) be diagnosed with ALS, 3) have symptom onset within the last three years, and 4) demonstrate a score of 2 or 3 in either the speech or swallowing components of the ALSFRS-R at the time of enrollment. They were assigned to two severity groups (Severe and Mild) based on their speech intelligibility test (SIT) score and speaking rate (SR) in week 1 (Lee & Bell, 2018). Severe Group SIT and SR were 40% and 90 words per minute (wpm). Mild Group SIT and SR were 94% and 160 wpm.

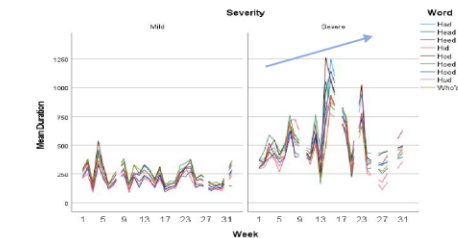
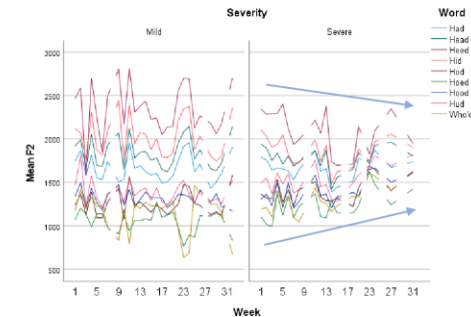
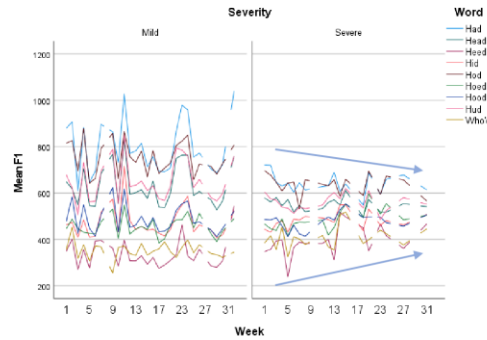
**Procedures:** Each participant used a cellular phone application, Beiwe (Connaghan et al., 2019; Onnela et al., 2021) to record themselves performing various speech tasks once a week for approximately 24 weeks. Due to unpredicted data loss on Apple phones, all participants were provided with an Android phone. Participants also completed speech tasks during three clinic visits (~ weeks 1, 12, and 24). Completed recordings were downloaded by the research team, edited, and acoustically analyzed. Audio files were also prepared for speech intelligibility data collection. Speech and vowel intelligibility of the clinic visit recordings were obtained from 15 naive listeners.

### Speech Tasks and Measurements

1. Speaking and articulation rates: 1) SIT, 2) Grandfather passage, and 3) Rainbow passage.
2. Counting in one breath (highest number reached/sec)
3. Diadochokinetic rate (DDK; syllable/sec): 1) puh-tuh-kuh and 2) ta-ta-ta (Rong, 2020)
4. Sustained phonation of "ah"(sec): duration and voice measures using Praat
5. Acoustic working space (Lee & Fischer, 2019): 1) I owe you a yoyo, 2) Will Robin wear a yellow lilly, and 3) Iowa Iowa Iowa (Lee & Fischer, 2019), 4) 4 corner vowels, and 5) 9 vowels (all monophthongs)
6. Vowel formants (F1 & F2) and duration (Lee et al., 2019): 9 American English monophthongs were produced in a phrase, "I say a \_\_\_ again," in a /h/-Vowel-/d/ contexts (e.g., "I say a HEED again"). All speech tasks were analyzed using TF32 acoustic analysis software (Millenkov, 2001), except for the voice measures.

### Statistical Analyses

Pearson correlation analyses were completed to examine the relationship between speech measures and intelligibility. In addition, a linear mixed model was used to test the effect of time (weeks) and severity and their interactions on vowel measures. An alpha level of 0.05 was used.



## Results

**Correlation coefficients (r values) against Speech and Vowel Intelligibility Scores** (pooled data; \* $<0.05$ ; \*\* $<0.01$ )

- Strong relationship between intelligibility and: speaking rate, articulation rate, DDK, and acoustic working space
- Higher coefficients in speaking rates than articulation rates
- Four and 9 vowel acoustic working space showed higher coefficients than other sentence working spaces
- No significant correlation coefficients in voice measures

	Speaking Rate			Articulation Rate			DDK		
	SIT	Grandfather	Rainbow	SIT	Grandfather	Rainbow	Counting	PTK	TTT
Speech Intell.	.823**	.817**	.825**	.792**	.780**	.807**	0.483	.810**	.825**
Vowel Intell.	.634*	.565*	.624*	.576*	.488	.576*	0.336	.530*	.764**

	Acoustic Working Space				
	4 corner vowels	9 vowels	"yoyo" sentence	"Robin" sentence	"Iowa" repetition
Speech Intell.	.823**	.811**	0.362	.645*	.738**
Vowel Intell.	.902**	.906**	0.491	.705*	0.521

### Linear Mixed Model Results

- As seen in the figures on the left, centralization was observed in the longitudinal vowel changes, especially in the Severe group. Vowel-specific patterns were also observed.
  - **F1:** Faster centralization with time in Severe group than Mild group was observed in only Heed, Hid and Hoed.
  - **F2:** Faster centralization with time in Severe group than Mild group was observed in all vowels except Had and Head.
- **Vowel Duration:** Greater elongation of vowels with time in Severe group than Mild group.

## Discussion

- Material (e.g., passage, vowels, sentences) impacted the relationship of acoustic working space measures with speech intelligibility. Monophthong-based working space area showed strong relationships with speech and vowel intelligibility.
- Material did not make a notable difference in the relationship between rate and intelligibility. Speaking rate showed a stronger relationship with intelligibility than articulation rate when using the same materials.
- Counting rate and voice measures were not significantly correlated with speech intelligibility.
- Acoustic working space reduction was observed longitudinally and also in people with more severe dysarthria. However, this pattern was vowel-specific (/i, I, o/). Thus, certain vowels might better detect longitudinal speech changes in people with dysarthria secondary to ALS.

The current study explores potential speech tasks and measures for detecting speech function changes over time using remote monitoring. The analyses will continue with newly enrolled participants with ALS.

### Acknowledgements

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Lee, J., Geronimo, A., Krajewski, E., Mazzola, D., Taylor, K., Padt, M., Jackson, E., Reichwein, C., & Simmons, Z. (2023). Remote monitoring of speech function in individuals with dysarthria secondary to amyotrophic lateral sclerosis. Poster presentation at American Speech-Language-Hearing Association Convention, Boston, MA.



## Tracking dysphagia in ALS with audio recordings of spontaneous swallowing

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### Introduction

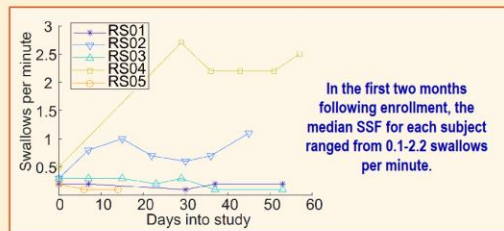
Dysphagia in ALS may lead to severe complications such as malnutrition, dehydration, and aspiration pneumonia. Spontaneous swallowing frequency (SSF) has been found to be an easily accessible biomarker for airway clearance health, and has been shown to be reduced in those with dysphagia.

### Objective

To determine the feasibility of conducting measurements of SSF using a smartphone application, and to determine the potential of SSF to reflect established clinical assessments of swallowing in persons with ALS.

### Results

Five participants (2 female, median age 70 years (range 66-80)) have been enrolled. Over 45-159 days on the study, participants completed SSF recordings at a median rate of 0.82 per week (range 0.71-1).



### Methods

Participants with a diagnosis of ALS and functional changes in speech or swallow were enrolled at the Penn State Hershey Medical Center.

At the initial study visit participants completed the following assessments:

- **ALS Functional Rating Scale – Revised (ALSFRRS-R)** – We report the swallowing score for this assessment (range 0-4, impairment decreasing with score).
- **Mann Assessment of Swallowing Ability (MASA)** - We report a modified MASA summary score since the items for "gag", "cough reflex", and "pharyngeal phase" were not assessed (range 34-180, impairment decreasing with score).
- **EAT-10** survey (range 0-40 impairment increasing with score).
- **Modified barium swallow study (MBSS)** - Scored using the MBS Impairment Profile (MBSImp, range 0-55, impairment increasing with score).

Subjects downloaded an application (Beiwe2, beiwe.org) on their smartphone, which prompted them to perform weekly 10-minute recordings of spontaneous swallowing using a lavalier microphone (VT506Mobile Omni, Voice Technologies, Switzerland) adhered to the skin just below the lateral cricoid cartilage. Recordings were in 64kbps *mp4* format.

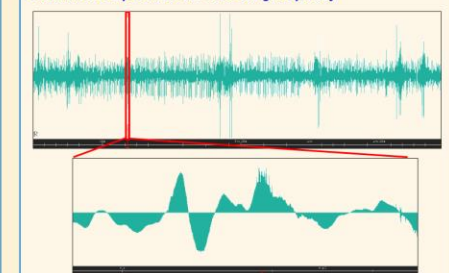
All recordings were analyzed off-line using stereo headphones (Qc35, Bose, USA) and an acoustic software program (WavePad, NCH Software, USA). Spontaneous swallowing frequency was calculated as swallows per minute across each 10-minute recording.

### Data Collection

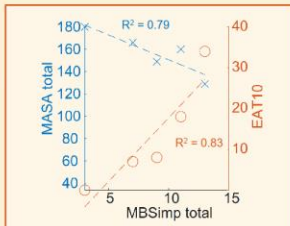


The equipment, microphone placement instructions, and directions given to subjects to perform the spontaneous swallowing recording at home.

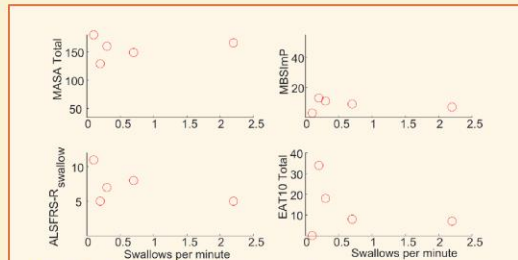
### Calculation of spontaneous swallowing frequency



Trained listeners reviewed recordings in 1-minute segments to identify swallow activity (example shown). While the visual waveform is also referenced during measurement, the acoustic signal is the primary source of analysis.



Initial MASA scores ranged from 129-180; EAT10 scores ranged from 0-34. Both had a significant relationship ( $p < 0.05$ ) with MBSImp, which ranged from 3-13.



No relationships were found between spontaneous swallowing frequency and clinical assessments of swallow function.

### Conclusions

- This technique appears to be feasible for home measurement of spontaneous swallow in persons with ALS.
- Initial analyses indicate that the MASA, adapted for use in an ALS setting, appears to correlate with the results of the radiographic swallowing study.
- Future work will follow up to 20 subjects for 6 months. Analysis will be repeated with consideration of the use of oral or injectable medications for secretion management.

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