VELOPHARYNGEAL FUNCTION DURING SPEECH PRODUCTION IN AMYOTROPHIC LATERAL SCLEROSIS

By

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Abstract

Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease that leads to decreased muscle function resulting in problems with movement, breathing, swallowing, and speech. In the United States, approximately 5,600 people are diagnosed with ALS annually (ALS Association [ALSA], 2010). ALS can attack muscles all over the body, including those in the velopharynx, a muscular valve-like structure located at the back of the oral cavity. In a healthy adult, the velopharynx closes off the passageway to the nasal cavity during speech production to direct air through the mouth rather than through the nose (except during productions of /m/, /n/, and /ng/). Speech that is produced with an open velopharynx sounds indistinct and has a nasal quality. Many people with ALS experience difficulty producing clear, articulate speech because their velopharynx remains open for the majority of speech sounds. As a result, their speech eventually becomes unintelligible.

Currently, there is little information available about the function of the velopharynx in people with ALS. The purpose of this study is to describe velopharyngeal function during speech in people with ALS. This information will be compared with their speech rate and intelligibility scores, both common measures used to document speech decline.

INTRODUCTION

Amyotrophic lateral sclerosis (ALS) is a degenerative neurological disease that progressively affects muscle function resulting in trouble with movement, breathing, swallowing, and speech. In America, approximately 5,600 individuals are diagnosed with ALS each year (ALS Association [ALSA], 2010). Men are more likely than women to develop the disease and the average age of diagnosis is 55 years old. Once diagnosed with ALS, the average life expectancy is 2 to 5 years (ALSA, 2010). Genetics is not a common factor for determining if someone is likely to be diagnosed with ALS; most cases are random without any familial link (Wijesekera & Leigh, 2009). At the present time there is no known cure for this disease. The primary goal of treatment for ALS is symptom management to enhance quality of life while living with the disease. As part of enhancing quality of life, it is pertinent to maintain communication and to provide alternative options to those whose speech becomes unintelligible or who cannot speak at all. This paper begins with a general overview of ALS, describes issues related to respiration, swallowing, and speech, and then introduces the concept of using forms of communication other than speech. Next, this paper describes a method that may assist speech-language pathologists in measuring the function of one part of the speech mechanism, the velopharynx, in individuals with ALS. The degree to which velopharyngeal function is impaired may help indicate when alternative communication should be introduced.

General Overview of ALS

ALS is a motor neuron disease characterized by muscle paresis and paralysis which may lead to difficulties with communication by the weakening muscles of the respiratory, laryngeal, velopharyngeal, and oral subsystems. It is a progressive neurological disease that results in the deterioration and death of upper and lower neurons (Wijesekera & Leigh, 2009). Upper motor neurons are responsible for transmitting motor (movement) information from the primary motor cortex to the lower motor neurons in the brainstem and spinal cord which, in turn, activate muscles. People with ALS may be diagnosed with one of three forms of the disease; spinal, bulbar, or mixed (Richter, Ball, Beukelman, Lasker, & Ullman, 2003). Spinal onset is the most common form of ALS, affecting approximately 66% of people with the disease (Wijesekera & Leigh, 2009). Those with the spinal form of ALS initially show signs of muscle weakness in their arms and legs, and later show signs of weakness in other muscles needed for speech and swallowing. The bulbar form of ALS is more aggressive and initially affects the speech and swallowing muscles. People who present with signs and symptoms of both the spinal and bulbar forms of ALS are diagnosed with a mixed form of the disease (Richter et al., 2003). It is typical for everyone diagnosed with the disease to eventually experience signs and symptoms associated with the bulbar form of the disease, even if they are initially diagnosed with the spinal form. Each type of ALS results in progressive neuron degeneration that impairs the transmission of messages from the cerebral motor cortices to the muscle fibers (Wijesekera & Leigh, 2009). This disease becomes fatal when the respiratory muscles become paralyzed resulting in respiratory failure, or when dysphagia (swallowing impairment) results in aspiration pneumonia.

Respiratory Impairment and Dysphagia

Management strategies for people with ALS include treatment of problems acquired from the disease such as respiratory weakness and swallowing impairments. It is especially imperative to monitor the decline of muscle strength of the respiratory system as respiratory failure is the most common cause of death in people with ALS (Wijesekera & Leigh, 2003). Respiratory care practitioners monitor vital capacity (the maximum amount of air a person can inhale and exhale from their lungs) and the strength of the diaphragm muscle in order to determine when a person should be offered assisted ventilation. Research has found that the respiratory measure of vital capacity declines at a relatively consistent rate over time in people with ALS (Kent et al., 1991). Other pulmonary measures such as maximum ventilatory volume and peak expiratory flow have not been found to consistently decline throughout the progression of the disease. The weakening of the respiratory system affects speech in people with ALS (Kühnlein et al., 2008). The auditory-perceptual signs of respiratory impairment include short phrases, low loudness, and audible inspirations in inappropriate junctures.

People who present with bulbar signs of ALS may experience dysphagia (difficulty swallowing). Dysphagia can be caused by spastic or weak orofacial structures such as the tongue, lips, palate, and larynx (Kühnlein et al., 2008). Swallowing becomes more difficult as the strength and coordination of these structures deteriorate, affecting each of the four stages of swallowing; oral preparatory, oral transport, pharyngeal, and esophageal. People with ALS who also have dysphagia are at an increased risk for dehydration, malnutrition, and aspiration of food and liquid leading to possible pneumonia (Higo, Tayama, & Nito, 2004). The tongue muscles are often one of the first groups of bulbar muscles to exhibit signs of weakness. Impaired muscle activation in the tongue results in reduced ability to move the bolus (the mass of food or liquid) from the oral cavity into the pharynx and esophagus. The oral stage of swallowing may be prolonged, thereby causing food to remain in the oral cavity for longer than normal periods. In addition to the deterioration of the tongue muscles, lip muscles also weaken which make lip closure during chewing a challenge (Kühnlein et al., 2008). The inability to seal the lips increases the occurrence of mouth breathing and causes problems with the oral preparation of the bolus when attempting to swallow. Reduced or absent neural innervation of the larynx impairs the swallowing process by not moving the larynx upwards to initiate the swallowing reflex and closing of the larynx to protect the lower airways. Due to the progressive nature of ALS, problems caused by neural deterioration will increase throughout the course of the disease even with therapy. There are some strategies that people with ALS may use in order to be able to eat orally for as long as possible and to prevent aspiration. Strategies include changing posture while eating, tucking the chin down, or using thickening agents in order to make swallowing liquids more manageable. In the event a person is no longer able to volitionally swallow and displays effects of malnutrition, invasive feeding alternatives, such as feeding tubes, may need to be considered.

Dysarthria associated with ALS

People with ALS develop a speech disorder called dysarthria that is often characterized by problems with their voice, articulatory precision, rate of speech, as well as a decline in the ability to control the loudness and prosody (rhythm, stress, and intonation) of speech. The dysarthria most commonly associated with ALS is a mixed flaccid-spastic dysarthria. It is estimated that over 80% of people diagnosed with ALS will develop dysarthria; therefore, it is imperative to recognize the signs and be able to predict the course of speech deterioration, as well as how to prolong natural communication through the use of compensatory techniques (Richter et al., 2003).

Flaccid dysarthria is caused by damage to lower motor neurons which causes atrophy of the tongue muscles, impairs palatal movement, as well as weakens the jaw and gag reflexes (Tomik & Guiloff, 2010). Persons with flaccid dysarthria may sound breathy, hypernasal, and monotone. These speech characteristics are due to weakness in the larynx, velopharynx, respiratory system, as well as weakness in the tongue and lips resulting in articulatory imprecision. Spastic dysarthria is caused by damage to the upper motor neurons which results in spasticity and reduced range and speed of movement of the speech structures. Perceptual speech characteristics of persons with spastic dysarthria are harsh or strained sounding voice, slow speech rate, imprecise articulation, as well as little variation in pitch or loudness. The mixed flaccid-spastic dysarthria of ALS combines features of flaccid and spastic types including slow, effortful phrases, inappropriate pauses, articulatory imprecision and hypernasality (Watts & Vancryckeghem, 2001). Any type of dysarthria will contribute to the decline in speech intelligibility as the disease progresses.

Declining speech rates, often measured in words per minute, have been shown to be helpful in predicting the degeneration of speech intelligibility. Research has shown that the speaking rate in individuals with ALS decreases before speech intelligibility is severely affected (Ball et al., 2001). When the speech rate falls below 100 words per minutes (wpm), people with ALS are only about 80% intelligible, and as the rate continues to decrease intelligibility also decreases. Therefore, when a person’s speech rate falls between 100-120 wpm it is suggested that assistive communicative technology should be introduced to help aid lucid communication between a speaker and listener (Yunusova et al., 2010).

Alternative forms of communication may be helpful to individuals living with ALS. Approximately 80% of people with ALS will be unable to speak at the time of their death, which makes it imperative to introduce alternative forms of communication early in the disease process (Richter et al., 2003). The timing of when to introduce an augmentative and alternative communication (AAC) approach should be based on the progressive degeneration of muscles needed for speech, as well as indicators such as declining speech rate. It is also important when choosing an AAC device that physical capabilities, such as use of fine and gross motor skills, are taken into consideration (Yorkston et al., 1993). The importance of acquiring a device and learning how to use it before it becomes necessary is a vital consideration for someone living with ALS. Depending on the abilities of the person, there are several types of AAC techniques or devices to choose from.

A combination of diagnostic factors should be used to determine when to introduce alternative forms of communication so that a person may become familiar with it before they are completely reliant on it. In a typical clinical setting, the primary determining factor for referring a client for communication assistance is when their speaking rate is 125 wpm or slower. The kind of alternative communication selected for a person depends, in part, on the type of ALS (spinal, bulbar, or mixed) and how the speech systems are functioning. For example, a person with a spinal form of ALS may not have decreased muscle function in their articulators, but may have reduced respiratory function. In this case, amplification might aid communication ability. Although speaking rate is the central measure to determine when alternative communication should be introduced, measuring velopharyngeal function could also become vital in helping to determine when a person should be introduced to an alternative mode of communication.

Velopharyngeal Function

The velopharynx is composed of the soft palate and the pharynx, and together these structures are imperative for clear speech production. During speech production, the velopharynx remains closed most of the time. Closure of the velopharynx allows sufficient oral air pressure to build to produce clear consonants. The velopharynx should only open during the production of the nasal consonants /m/, /n/, and /ŋ/. In some instances, it may open for vowels due to the effects of

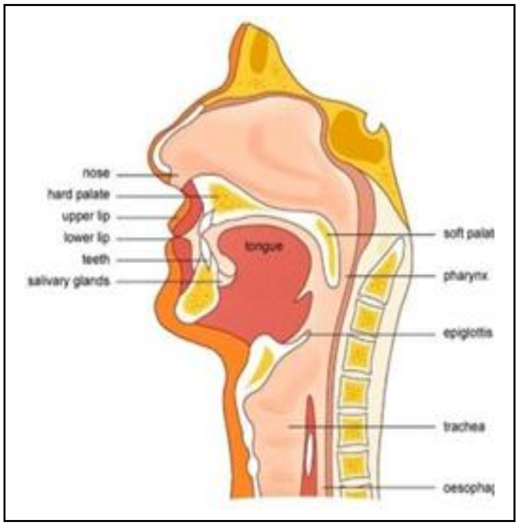

Figure 1 A drawing of the soft palate and the pharynx which comprise the velopharynx.
Figure taken from: http://everythingspeech.com/evaluation/dyphagia/dysphagia-evaluation/

coarticulation (the affect of one sound on another) such as in the word "pan" or "sing." As velopharyngeal function becomes increasingly impaired in ALS, more air will escape through the nasal cavity. When the velopharynx cannot close for speech production, the voice sounds hypernasal and certain consonants are indistinct. Indistinct consonants are a major contributor to decreased intelligibility.

The function of the velopharynx contributes to the distinction between stop and nasal contrasts for consonants (Kent et al., 1992). Stop consonants, (i.e. /p/, /b/, /t/) and fricatives (i.e. /s/, /f, /v/), require the velopharyngeal port to close in order for oral pressure to build to create speech sounds precisely. A study done by Ball et al. (2001) found that speech is most unintelligible when a person is unable to maintain sufficient velopharyngeal closure throughout the production of a pressure consonant (i.e. /p/, /b/, /t/) (Ball, Willis, Beukelman, & Pattee, 2001). A decline in velopharyngeal function can result in imprecise articulation and a decrease in intelligibility.

Currently, there is little information available about the function of the velopharynx in people with ALS. The purpose of this study is to describe velopharyngeal function during speech in people with ALS, and to compare that function with their speech rate and intelligibility scores. It is hypothesized that the velopharynx will remain open more often than it would in normal speakers for oral consonants and that the frequency of velopharyngeal opening will be greater in people with lower speech rate and intelligibility scores.

METHOD

Participants

The participants in the study were a group of three individuals diagnosed with ALS who visited the Speech-Language Clinic at the University of Arizona. Velopharyngeal testing, speech rate, and intelligibility testing were included as part of a full speech and AAC evaluation.

Procedure

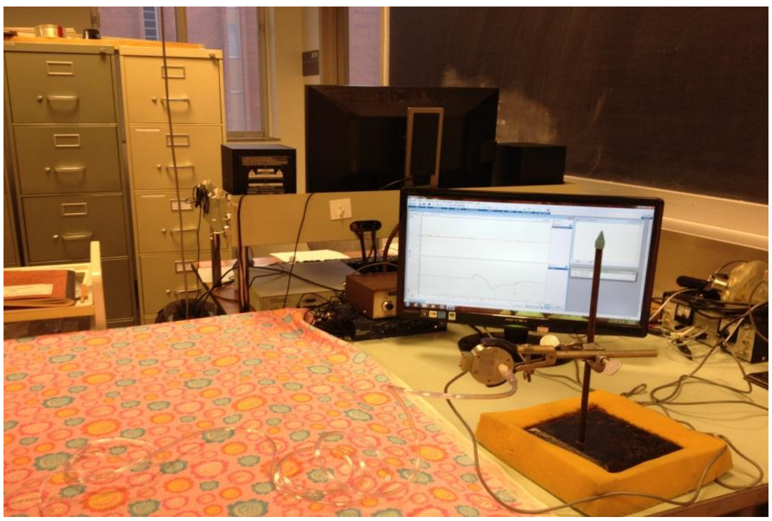

Figure 2 The equipment set-up used for each evaluation.

Velopharyngeal function was measured by monitoring nasal ram pressure (NRamP). The N-RamP technique for measuring velopharyngeal function involved placing a nasal cannula into the anterior nares of the participant while the other end of the cannula was connected to a pressure transducer, as shown in Figure 2. A small microphone was taped to each participant's shirt to record their speech. The signals were recorded on a computer using LabChart software.

After the cannula and microphone were placed on the person, they were asked to perform several tasks. Throughout the tasks, each participant was free to take breaks in between tasks as needed.

1. Inspire, expire, and hold their breath in order to achieve a baseline pressure signal before they began to speak.

2. Sustain the vowel and were told to stop when they seemed to run out of air.

    Take a breath and say "aaaaah" until directed to stop.

    Take a breath and say "eeeeee" until directed to stop.

3. Repeat the syllables and were told to stop when they seemed to run out of air.

    Say "papapapapa" until directed to stop.

    Say "tatatatata" until directed to stop.

    Say "kakakakaka" until directed to stop.

    Say "sasasasasa" until directed to stop.

4. Read a list of sentences (Appendix A) using their normal speaking voice. Each sentence contained a different target consonant. Each sentence was produced twice with a breath in between.

5. Read a triad of identical words with breath in between each triad.

    1. Pamper-pamper-pamper (*take a breath)* Pamper-pamper-pamper

    2. Tinted-tinted-tinted (*take a breath)* Tinted-tinted-tinted

3. Thinker-thinker-thinker (*take a breath)* Thinker-thinker-thinker

5. Read the "Zoo Passage" (Fletcher, 1972) with no instructions about when to take a breath (Appendix B).

The Zoo Passage was chosen for this study because there are no nasal sounds in the paragraph. If there was positive pressure detected during the reading of this passage, then it can be concluded that the velopharynx is open without the need to determine if nasalization was caused by a coarticulation effect.

RESULTS

The results are organized as a series of case reports. The first describes the data from a healthy speaker. The next three cases contain data from individuals diagnosed with ALS.

HEALTHY PARTICIPANT: 22-YEAR OLD FEMALE

Data were obtained from a healthy 22 year old female speaker to provide a baseline for what normal velopharyngeal function should look like in order to compare it to the impaired functioning in persons with ALS. This speaker produced all oral speech sounds during sustained vowels, sentences, and paragraph reading with a closed velopharynx. An example is shown in Figure 3 of data generated during the production of "Vickie drove to Vegas." The flat line shows that the velopharynx was closed for the entire production.

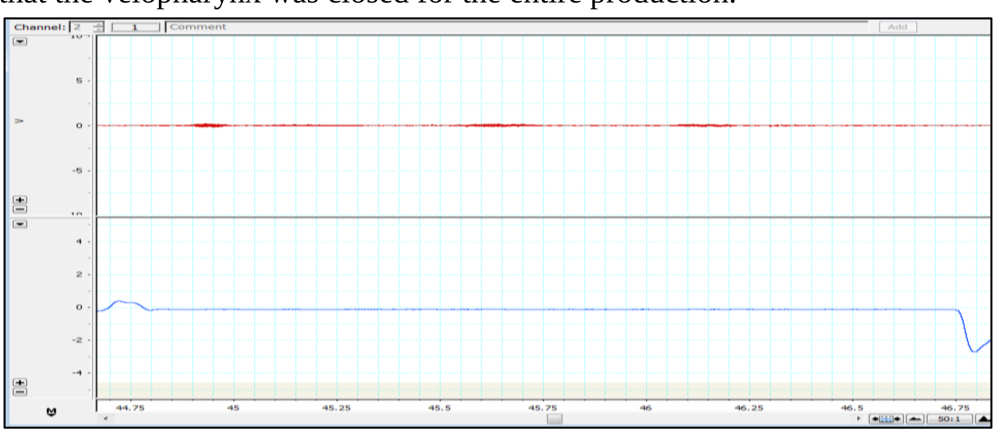

Figure 3 Healthy Participant's production of "Vickie drove to Vegas."

As expected, the velopharynx was open during the production of nasal consonants /m/ and /n/. Figure 4 shows the production of "Mama makes lemon jam." The parts of the pressure tracing that are above zero show when the velopharynx was open.

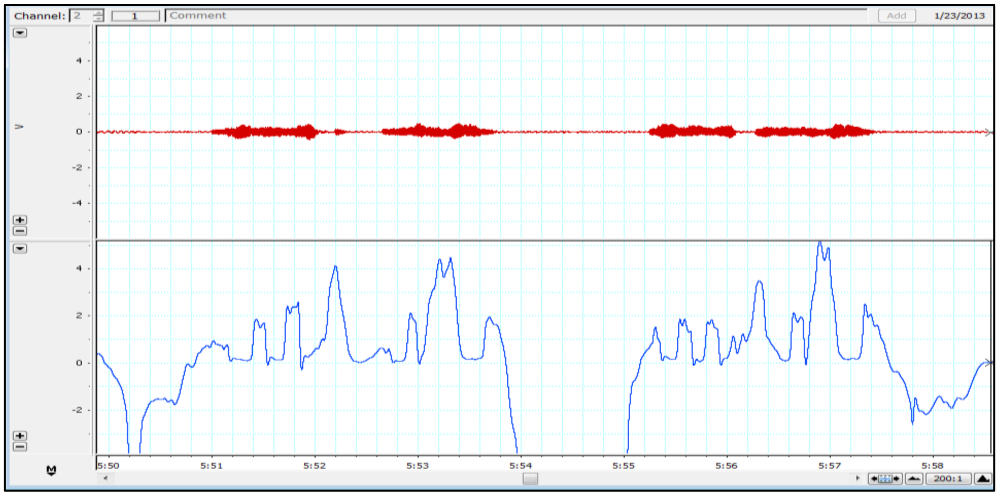

Figure 4 Healthy Participant's production of "Mama makes lemon jam."

In healthy speakers, it is not uncommon for the velopharynx to open for oral consonants when it is next to a nasal consonant. In Figure 5, the velopharynx is open for the /p/ that comes before the /m/. This is a result of coarticulation and is a normal occurrence.

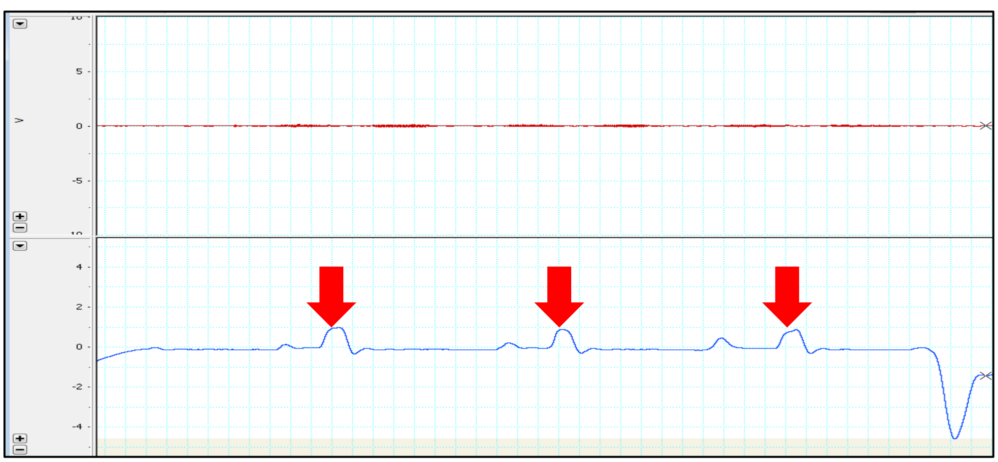

Figure 5 The production of "pamper, pamper, pamper" by the Healthy Participant. Arrows indicate an open velopharynx.

The speech rate for this healthy speaker was 3.68 syllables/second (or 234 wpm) while reading the Zoo Passage. Her intelligibility was 100%.

ALS PARTICIPANT 1: 28-YEAR OLD MALE WITH ALS

This 28-year old male was diagnosed with ALS 6 months prior to his evaluation at the University of Arizona Speech –Language clinic. His velopharyngeal function was found to differ across speaking tasks.

During the sustained vowel task for both "aaaah" and "eeeee" the velopharynx was closed 100% of the time. This is shown in Figure 6.

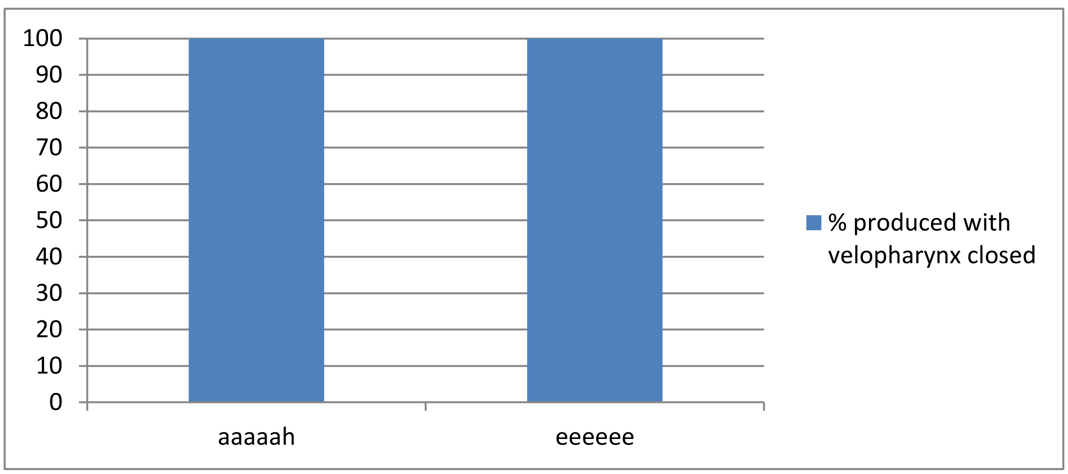

Figure 6 Data from ALS Participant 1 for the sustained vowel task shown as percentage produced with a closed velopharynx.

Results for the repeated syllables are shown in Figure 7. The velopharynx was closed 50% of the time during the production of "papapapa," 7% of the time during the production of "tatatata," 0% of the time during the production of "kakakaka" and 81.82% of the time during the production of "sasasasa."

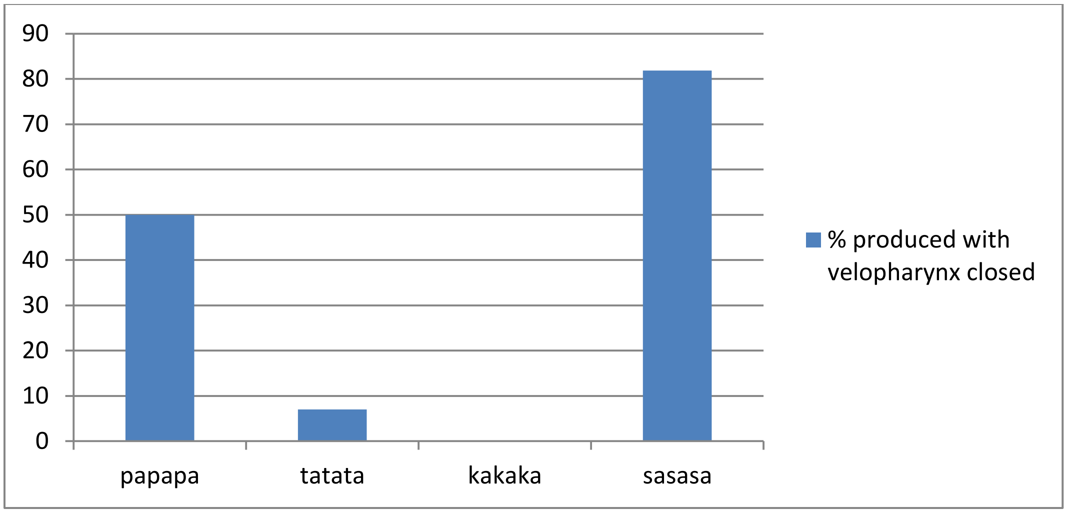

Figure 7 Data from ALS Participant 1 for the syllable repetition task shown as percentage produced with a closed velopharynx.

Figure 8 displays the percentage of target consonants produced with a closed velopharynx during the sentence task. The oral consonants that were produced with a closed velopharynx at least 50% of the time included some stops (/p/, /b/, /k/, /g/) and fricatives (/f/, /v/). The remaining oral consonants were produced with a closed velopharynx less than half the time and included stops (/t/, /d/), fricatives (/s/, /z/, /ð/, / θ/, /ʃ/), and affricates (/tʃ/, /dʒ/).

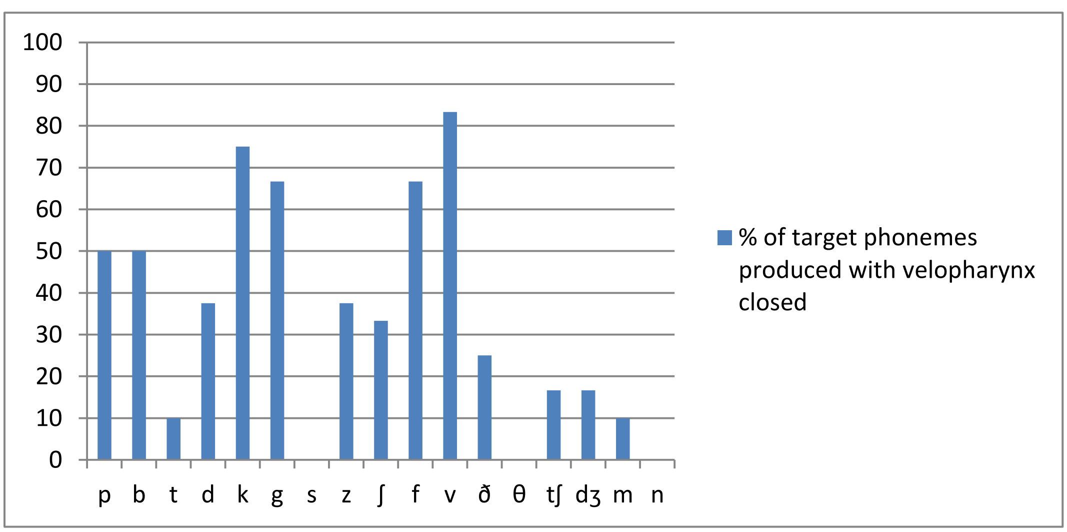

Figure 8 Data from ALS Participant 1 for the sentence reading task shown as a percentage produced with a closed velopharynx for each target consonant.

Figure 9 shows an example of the utterance "Phil fried the fish." The /f/ in "Phil" was produced with an open velopharynx (note that pressure is above zero). In contrast, the /f/ in "fried" and "fish" were produced with a closed velopharynx as indicated by the fact that pressure was at zero during production of those consonants.

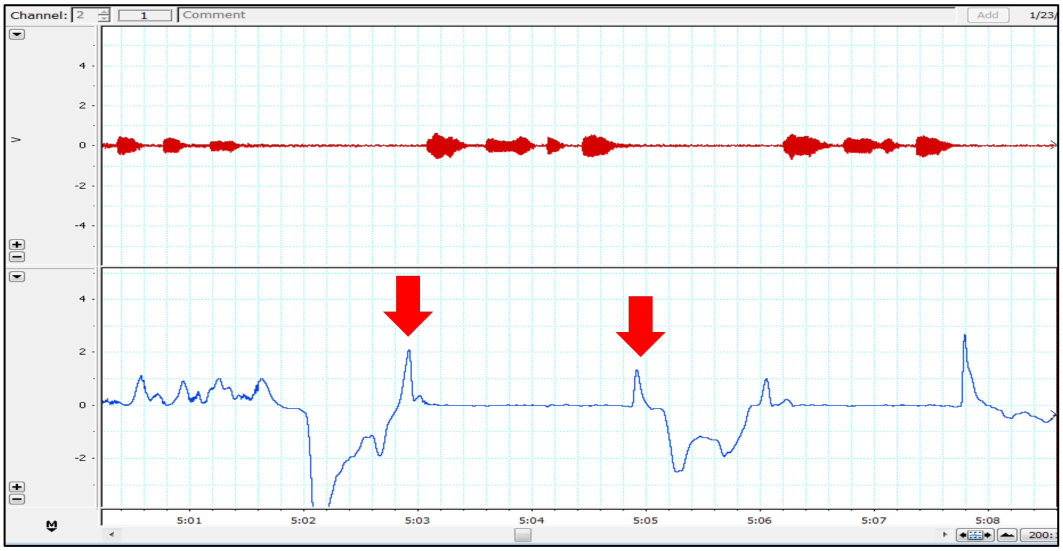

Figure 9 Tracings of acoustic signal (upper tracing) and nasal air pressure (lower tracing) of "Phil fried the fish" produced by ALS Participant 1. The arrows indicate an open velopharynx.

Another example shown in Figure 10 illustrates the opening of the velopharynx during the two productions of "Charlie chopped the cheese." The velopharynx was open for /tʃ/ for each word in the phrase, except for the first production of "chopped" during which it was closed.

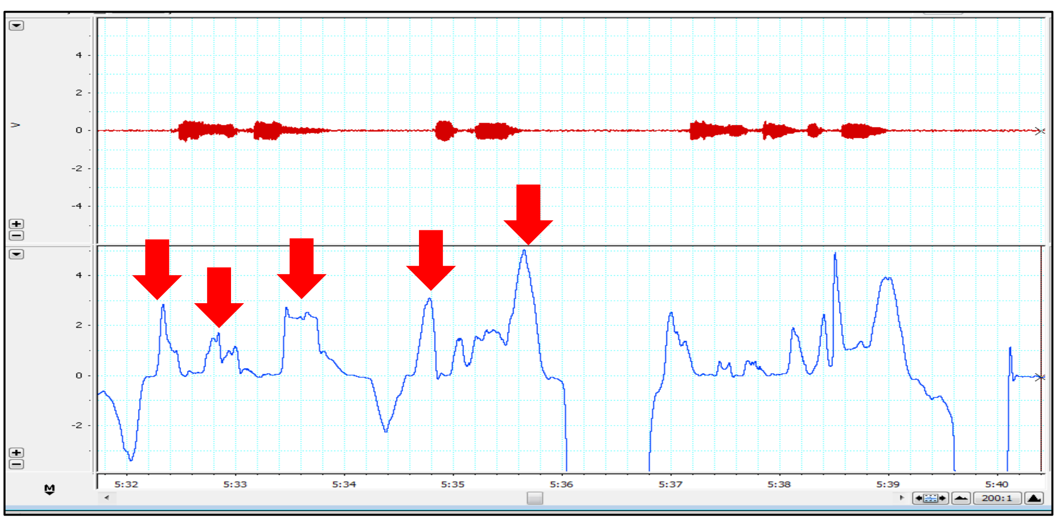

Figure 10 Data tracings of "Charlie chopped the cheese" produced by ALS Participant 1. The arrows indicate an open velopharynx.

The Zoo Passage consists of 71 words. ALS Participant 1 produced 31 words with a closed velopharynx (56.33%). Recall that the healthy speaker read aloud 100% of this passage with a closed velopharynx.

The speech rate was 1.36 syllables/second (or 76 wpm) while reading the Zoo Passage. Intelligibility was 83%, as determined using the AIDS.

ALS PARTICIPANT 2: 69-YEAR OLD FEMALE WITH ALS

This 69-year old female was diagnosed with ALS prior to her evaluation at the University of Arizona Speech –Language clinic. Her velopharyngeal function differed across speaking tasks.

During the sustained vowel task for both "aaaah" and "eeeee" the velopharynx was closed 100% of the time. This is shown in Figure 11.

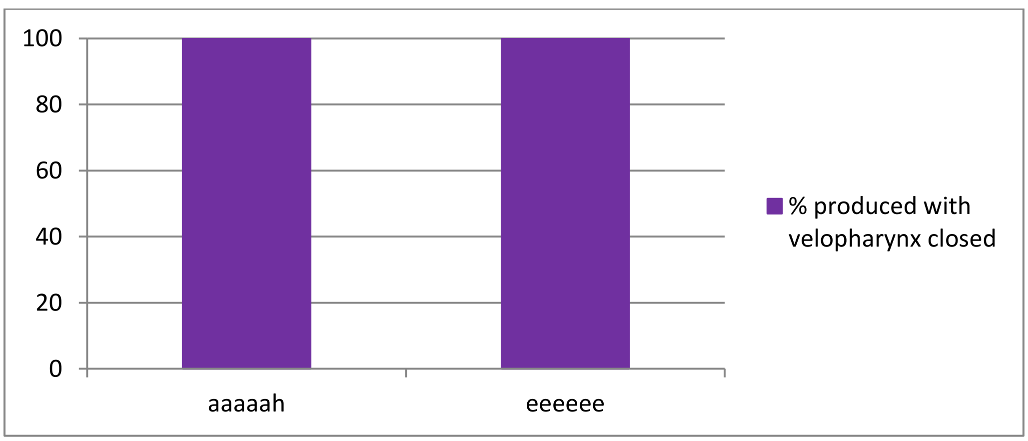

Figure 11 Data from ALS Participant 2 for the sustained vowel task shown as percentage produced with a closed velopharynx.

Results for the repeated syllables are shown in Figure 12. The velopharynx was closed 0% of the time during the production of "papapapa," 78% of the time during the production of "tatatata," 100% of the time during the production of "kakakaka" and 60% of the time during the production of "sasasasa."

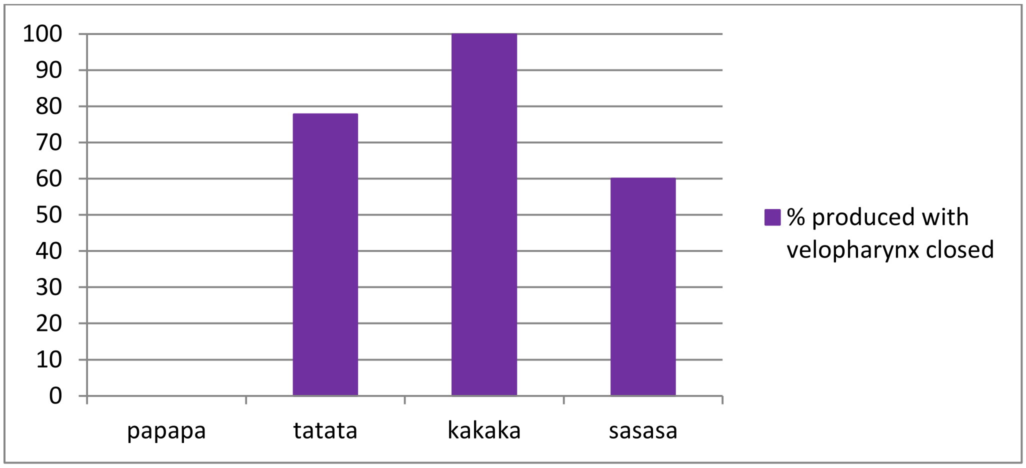

Figure 12 Data from ALS Participant 2 for the syllable repetition task shown as percentage produced with a closed velopharynx.

Figure 13 displays the percentage of target consonants produced with a closed velopharynx during the sentence task. The oral consonants that were produced with a closed velopharynx at least 50% of the time included some stops (/b/, /t/, /d/, /k/, /g/), fricatives (/s/, /z/, / ʃ /, /f/, /v/, /ð/, /θ/), and one affricate (/dʒ/). The remaining oral consonants were produced with a closed velopharynx less than half the time and included one stop (/p/) and one affricate (/tʃ/).

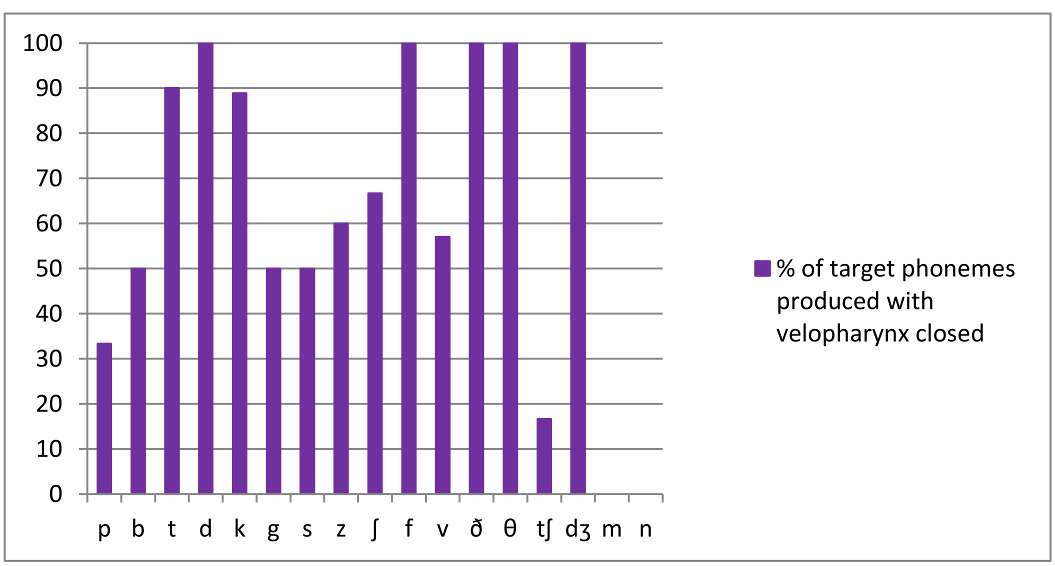

Figure 13 Data from ALS Participant 2 for the sentence reading task shown as percentage produced with a closed velopharynx for each target consonant.

Figure 14 shows the production of the utterance “Vickie drove to Vegas.” The /v/’s in “Vickie,” “drove,” and “Vegas” were produced with an open velopharynx (note that the pressure is above 0). During this production, she produced “drove” twice. The velopharynx was closed for the remainder of the utterance as indicated that the pressure was at zero for the other consonants.

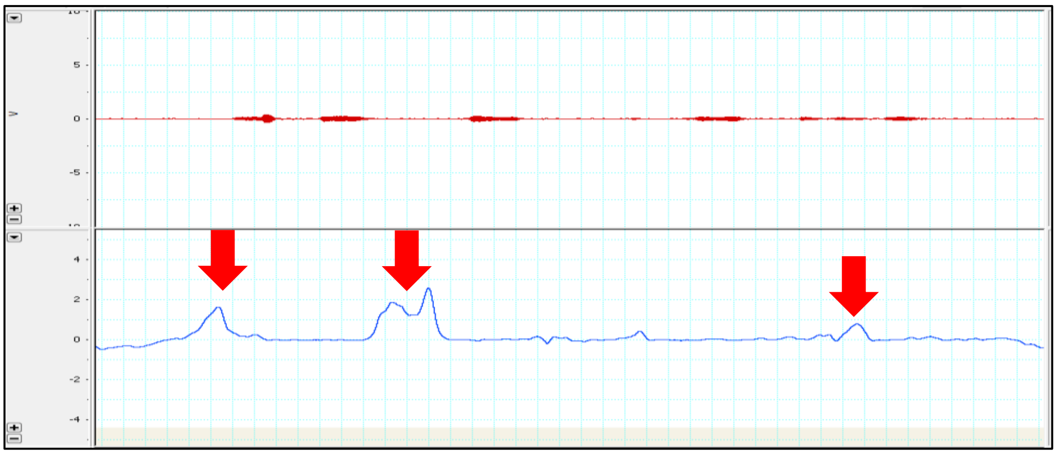

Figure 14 Two productions of “Vickie drove to Vegas” by ALS Participant 2. The arrows point to an open velopharynx.

An additional example shown in Figure 15 illustrates the opening of the velopharynx during the production of the phrase “Charlie chopped the cheese.” The velopharynx was open during the /tʃ/ in “Charlie,” “chopped,” and “cheese.”

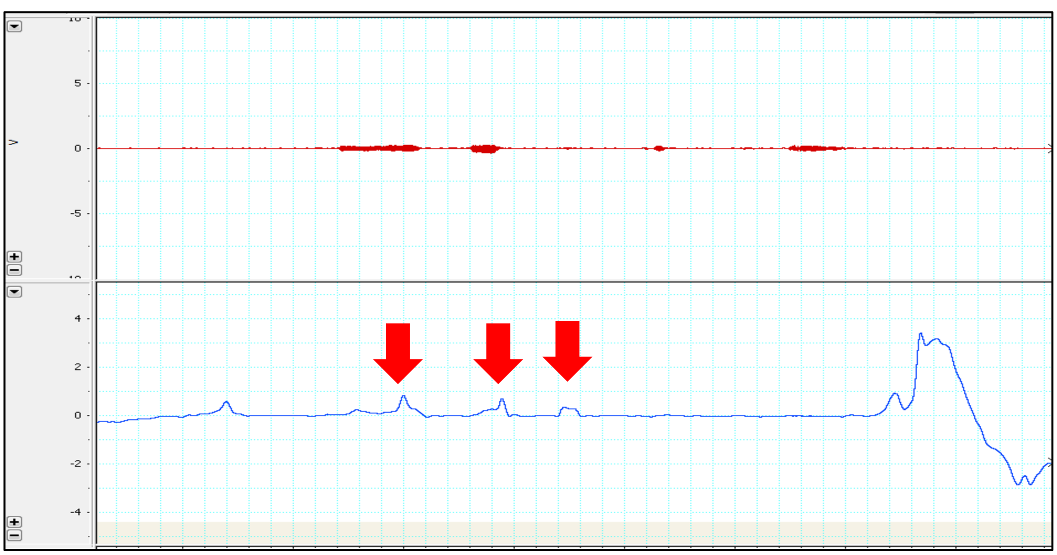

Figure 15 A production of “Charlie chopped the cheese” by ALS Participant 2. The arrows point to an open velopharynx.

The Zoo Passage consists of 71 words. ALS Participant 2 produced 57 words with a closed velopharynx (79.16%).

The speech rate was 2.86 syllables/second (or 144 wpm) while reading the Zoo Passage. Intelligibility was 74%, as determined using the AIDS.

ALS PARTICIPANT 3: 59-YEAR OLD MALE WITH ALS

This 59-year old male diagnosed with ALS 2 months prior to his evaluation at the University of Arizona Speech –Language clinic. The sustained vowel and repeated syllable tasks were not done during this evaluation.

Figure 16 displays the percentage of target consonants he produced with a closed velopharynx during the sentence task. All of the oral consonants were produced with a closed velopharynx at least 50% of the time.

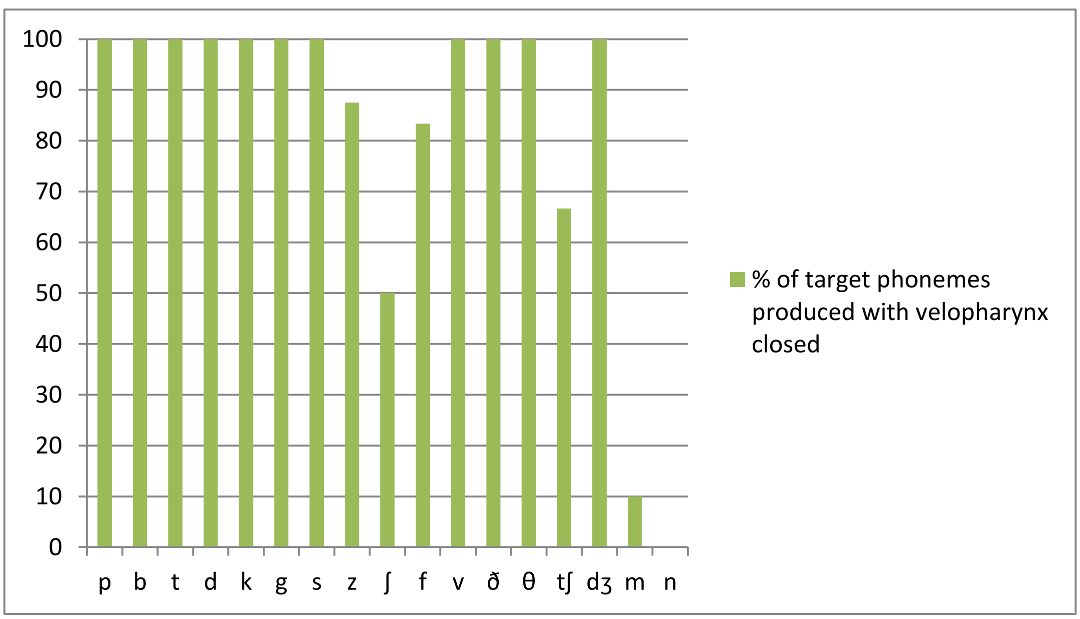

Figure 16 Data from ALS Participant 3 for the sentence reading task shown as percentage produced with a closed velopharynx for each target consonant.

Figure 17 shows an example of the utterance “Sheryl shook the sheets.” The /ʃ/ in “Sheryl” and “sheets” were produced with an open velopharynx as pressure peaked above zero. For the remainder of the utterance, the velopharynx was closed as shown by the pressure remaining at zero.

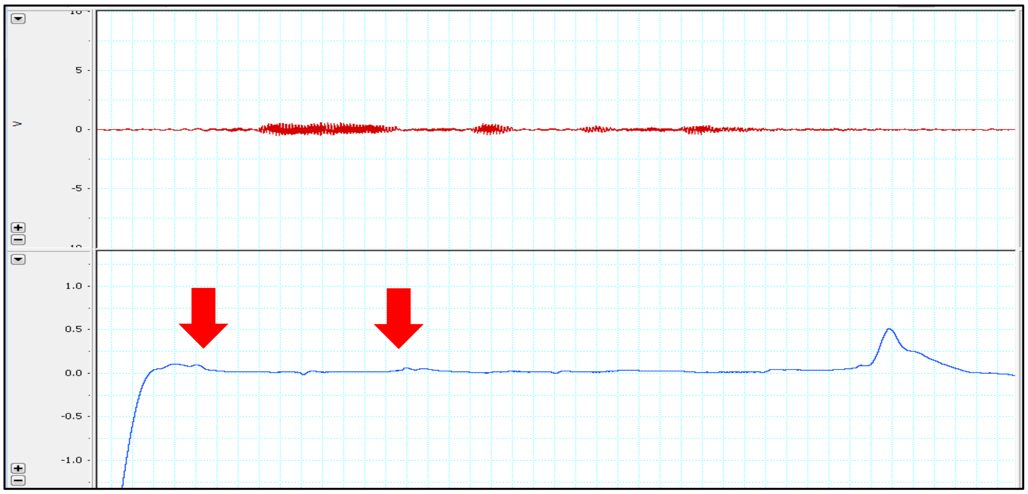

Figure 17 A production of “Sheryl shook the sheets” by ALS Participant 3. The arrows point to an open velopharynx during the production of “Sheryl” and “sheets.”

The Zoo Passage was produced with a closed velopharynx on 67 of the 71 words. Thus, ALS Participant 3 produced 94.34% of the words with a closed velopharynx.

The speech rate was 3.22 syllables/second (or 163 wpm) while reading the Zoo Passage. Intelligibility was 95%, as determined using the AIDS.

PARTICIPANT SUMMARY

Table 1 summarizes the results for the healthy participant and the three participants with ALS. In the table are shown the percentage of high pressure consonants produced with a closed velopharynx during vowel production, sentence and paragraph reading. This table also reports each participant’s speech rate (in wpm) and intelligibility scores (in %).

Participant	Vowels (% closed)	Sentences (% closed)	Paragraph (% closed)	Speech Rate (wpm)	Intelligibility (%)
Healthy	100	100	100	234	100
ALS 1	100	37	56.33	76	83
ALS 2	100	71	79.16	144	74
ALS 3	N/A	93	94.34	163	95

Table 1 Summary of results.

DISCUSSION

The purpose of this study was to investigate how the velopharynx functions during speech production in people with ALS. Toward this end, nasal pressure data were obtained. By using a nasal cannula to detect air pressure changes from the anterior nares, decisions about the status of the velopharynx (whether it was open or closed during speech production) could be made. Collectively, the data obtained from each person varied, which reflects the fact that ALS is not an entirely predictable disease and affects each person differently. It can be noted that each person with ALS exhibited an open velopharynx for many oral speech productions and had lower than average speech rate and intelligibility scores.

Sustained vowels (“aaaah” and “eeeee,”) were produced with a closed velopharynx 100% of the time by both ALS participants who performed this task. This could be a result of better velopharyngeal control when producing a single sound compared to uttering sentences with a variety of phonemic contrasts that require rapid movement of articulators. Results from this task were not predictive of the performance on the subsequent speech tasks. This is probably because the repeated syllable, sentence reading, and Zoo Passage reading tasks reflected velopharyngeal function during the production of more complex speech movements.

A general pattern gleaned from all speech tasks was that the participants' relative performance was generally consistent across the tasks, with the exclusion of the sustained vowel. For ALS Participant 1, his velopharynx was closed for only about 37% of the high pressure consonants targeted in the syllable repetition and sentence reading tasks and about 56% of the words in the paragraph reading. ALS Participant 2 exhibited less impaired velopharyngeal function as indicated by the fact that her velopharynx was closed for about 59% of the targeted high pressure consonants in the syllable repetition task, 71% during the sentence reading task, and about 79% in the paragraph reading. ALS Participant 3 displayed the best velopharyngeal function as he produced 93% of the intended high pressure consonants in the sentence and paragraph reading tasks with a closed velopharynx.

Velopharyngeal function seems to relate to speech rate and intelligibility scores. As shown in Table 1, ALS Participant 3 produced the most high pressure consonants with a closed velopharynx and subsequently had the highest speech rate and intelligibility scores. ALS Participant 2 produced the second most targeted consonants with a closed velopharynx and had the next highest speech rate score. ALS Participant 1 produced the least amount of speech with a closed velopharynx and had the lowest speech rate score of the three participants. Performance in the sentence task and the Zoo Passage support this finding as well, as ALS Participant 3 read the most with a closed velopharynx, followed by the ALS Participant 2, and finally ALS Participant 1. Based on these results, there appears to be a relationship between the amount of speech produced with a closed velopharynx, speech rate, and intelligibility. The one exception was that

ALS Participant 1 had a higher intelligibility score but a lower speech rate and velopharyngeal closure percentage than ALS Participant 2.

Among all three participants, there were few similarities in regards to producing oral consonants with a closed velopharynx at least 50% of the time during sentence reading. Variability in these data supports the notion that ALS is an unpredictable disease that affects individuals differently. However, there was one trend noted that suggests that certain sounds may be more difficult for people with ALS to produce with velopharyngeal closure. As can be seen in Table 2, the cumulative percentage of targeted oral consonants produced with closed velopharynx during sentence reading among the three cases indicates that the consonants /s/, /ʃ/, and /tʃ/ could be the most difficult to produce with a closed velopharynx. Each of those target sounds were produced with a closed velopharynx 50% or less of the time taking all cases into consideration. Appendix C displays individual data for each case. The separable data supports the cumulative data, as the production of /s/, /ʃ/, and /tʃ/ were among the lowest percentage of consonants produced with a closed velopharynx in each case.

Targeted oral consonant	Sentences (% closed)
p	61.11
b	66.67
t	66.67
d	79.17
k	87.96
g	72.22
s	50.00
z	61.67
ʃ	50.00
f	83.33
v	80.11
ð	75.00
θ	66.67
tʃ	33.33
dʒ	72.22

Table 2 Cumulative data summary for target consonants produced with a closed velopharynx during sentence reading.

Speech rate scores obtained for all three participants were below average ranging from 76-163 wpm. Research indicates that the average speech rate for a healthy speaker ranges from 190-220 wpm. In individuals with ALS, speech rate is reduced as a result of weakening articulators. Due to this weakness, persons have a reduced ability to control the speed of their articulators (jaw, lips, and tongue) which results in difficulty with volitionally controlling speech rate (Mefferd, Green, & Pattee, 2012). As the disease progresses, speech rate will continue to decline due to increased muscle weakness.

The evaluations also indicated that each participant had a lower than average intelligibility score ranging from 74-95% (a healthy speaker should be 100% intelligible). These intelligibility scores were assessed by using the Assessment of Intelligibility of Dysarthric Speech (AIDS). Research has shown that listeners have a difficult time understanding speech when intelligibility is below 81% (Ball, Beukelman, & Pattee, 2004). Comprehending dysarthric speech (resulting from ALS) becomes more difficult for unfamiliar listeners as intelligibility decreases. Context is crucial for assisting listeners with understanding speech and may increase intelligibility, however, without context, listener comprehension deteriorates. When the velopharynx does not function properly, speech becomes more difficult to understand as a result of air leaking through the nose when it should be coming out of the oral cavity. A consequence of this phenomenon is speech having a perceptible nasal quality. Additionally, as the velopharynx declines, high pressure consonants can become less distinguishable and can sound slurred. The decline in muscle function will affect articulators and the velopharynx which combined will certainly affect intelligibility, and an individual's ability to effectively communicate.

CONCLUSION

In individuals with ALS, it is practical to measure the function of the velopharynx to determine if it is opening during the production of oral consonants. This information, combined with speech rate and intelligibility scores, can be valuable in helping a clinician decide when to recommend alternative communication possibilities. Additional research is suggested in order to provide more specific information about the decline of intelligibility in relation to the decline of the velopharynx.

SUGGESTIONS FOR FUTUTRE RESEARCH

An idea to improve upon this current research would be to add a perceptual component in order to gather information about perceived voice quality, as well as perceived phonemes to unfamiliar listeners. It would be particularly interesting to measure perception over time in regards to velopharyngeal function to determine how much the structure influences how listeners hear the dysarthric speech. This could provide additional insight into how critical the velopharynx is for intelligible speech, as well as evaluate how listener's perceptions of disordered speech change over time as the disease progresses. It would also be interesting to investigate how much intelligibility scores decline as a lower percentage of oral consonants are produced with a closed velopharynx

It would also be important to consider the date of diagnosis, as well as account for the type of diagnosis (spinal or bulbar) for each participant. This would also be valuable in measuring speech decline as a bulbar diagnosis would affect speech sooner than a spinal diagnosis. A longitudinal study taking into account the aforementioned variables could prove to be beneficial in determining if certain phonemes decline faster than others as a result of a weakening velopharynx.

References

ALS Association (2010). Facts you should know. Retrieved from: http://www.alsa.org/about-als/facts-you-should-know.html

Ball, L.J., Beukelman, D. R., & Pattee, G.L. (2004). Acceptance of augmentative and alternative communication technology by persons with amyotrophic lateral sclerosis. *AAC: Augmentative & Alternative Communication, 20*(2), 113-122. doi:10.1080/0743461042000216596

Ball, L.J., Willis, A., Beukelman, D.R., & Pattee, G.L. (2001). A protocol for identification of early bulbar signs in amyotrophic lateral sclerosis. *Journal of the Neurological Sciences 191*, 43-53.

Ball, L.J., Beukelman, D.R., & Pattee, G.L. (2004). Communication effectiveness of individuals with amyotrophic lateral sclerosis. *Journal of Communication Disorders 37*, 197-215.

Bunton, K., Hoit, J., & Gallagher, K. (2011). A simple technique for determining velopharyngeal status during speech production. *Seminars in Speech & Language*, *32*(1), 69-79. doi:10.1055/s-0031-1271976

Fletcher, S.G. (1972). Contingencies for bioelectric modification of nasality. Journal of Speech and Hearing Disorders, 37, 329-346.

Higo, R., Tayama, N., & Nito, T. (2004). Longitudinal analysis of progression of dysphagia in amyotrophic lateral sclerosis. *Auris Nasus Larynx*, *31*(3), 247-254. doi:10.1016/j.anl.2004.05.009

Kent, R.D., Kent J.F., Weismer, G., Sufit, R.L., Martin, R.E., Rosenbeck, J.C., & Brooks, B.R. (1990). Impairment of speech intelligibility in men with amyotrophic lateral sclerosis. *Journal of Speech and Hearing Disorders 55*, 721-728.

Kent, J.F., Kent R.D., Rosenbek, J.C., Weismer, G., Martin, R., Sufit, R., & Brooks, B.R.. (1992). Quantitative description of the dysarthria in women with amyotrophic lateral sclerosis. *Journal of Speech and Hearing Research, 35*, 723-733.

Kent, R.D., Sufit, R., Rosenbeck, J.C., Kent, J.F., Weismer, G., Martin, R.E., & Brooks, B.E.. (1991). Speech deterioration in Amyotrophic Lateral Sclerosis: a case study. *Journal of Speech and Hearing Research, 34*, 1269-1275.

Kühnlein, P., Gdynia, H., Sperfeld, A., Lindner-Pfleghar, B., Ludolph, A., Prosiegel, M., & Riecker, A. (2008). Diagnosis and treatment of bulbar symptoms in amyotrophic lateral sclerosis. *Nature Clinical Practice Neurology, 4*(7), 366-375. doi:10.1038/ncpneuro0853

Mefferd, A.S., Green, J.R., & Pattee, G. (2012). A novel fixed-target task to determine articulatory speed constraints in persons with amyotrophic lateral sclerosis. *Journal of Communication Disorders, 45*, 35-45.

Murhpy, J. (2004). Communication strategies of people with ALS and their partners. *Amyotrophis Lateral Sclerosis & Other Motor Neuron Disorders, 5*(2), 121-126.

Richter, M., Ball, L., Beukleman, D., Lasker, J., & Ullman, C. (2003). Attitudes toward communication modes and message formulation techniques used for storytelling by people with amyotrophic lateral sclerosis. *AAC: Augmentative & Alternative Communication, 19*(3), 170-186.

Tomik, B., & Guiloff, R. J. (2010). Dysarthria in amyotrophic lateral sclerosis: A review. *Amyotrophic Lateral Sclerosis*, *11*(1/2), 4-15. doi:10.3109/17482960802379004

Watts, C.R., & Vancryckeghem M. (2001). Laryngeal dysfunction in Amyotrophic Lateral Sclerosis: a review and case report (2001). *BMC Ear, Nose and Throat Disorders 1(*1),

Wijesekera, L. C., & Leigh, P. (2009). Amyotrophic lateral sclerosis. *Orphanet Journal of Rare Diseases*, *41*-22. doi:10.1186/1750-1172-4-3

Yorkston, K.M., Strand, E., Miller, R., Hillel, A., & Smith, K.. (1993). Speech deterioration in Amyotrophic Later Sclerosis: implications for the timing of intervention. *Journal of Medical Speech-Language Pathology 1*(1), 35-46.

Yorkston, K.M.. (2007). The degenerative dysarthrias: a window into critical clinical and research issues. *Folia Phoniatrica et Logopaedica 59*, 107-117. doi:10.1159/000101769

Yunusova, Y., Green, J., Lindstrom, M., Ball, L., Pattee, G., Zinman, L.. (2010). Kinematics of disease progression in bulbar ALS. *Journal of Communication Disorders*, *43*(1). doi: 10.1016/j.jcomdis.2009.07.003

APPENDIX A

Paul picked up the pipe. (*take a breath*) Paul picked up the pipe.

Bobby bought a bat. (*take a breath*) Bobby bought a bat.

Toby talked to Taylor. (*take a breath*) Toby talked to Taylor.

Daddy dug a ditch. (*take a breath*) Daddy dug a ditch.

Katie cooked the crab. (*take a breath*) Katie cooked the crab.

Gabby gave her a goat. (*take a breath*) Gabby gave her a goat.

Susie sailed with Sylvia. (*take a breath*) Susie sailed with Sylvia.

Zack zipped up his zipper. (*take a breath*) Zack zipped up his zipper.

Sheryl shook the sheets. (*take a breath*) Sheryl shook the sheets.

Phil fried the fish. (*take a breath*) Phil fried the fish.

Vickie drove to Vegas. (*take a breath*) Vickie drove to Vegas.

The toothbrush is theirs. (*take a breath*) The toothbrush is theirs.

Charlie chopped the cheese. (*take a breath*) Charlie chopped the cheese.

Jill jogged to Jasper. (*take a breath*) Jill jogged to Jasper.

Mama makes lemon jam. (*take a breath*) Mama makes lemon jam.

Nathan needs one banana. (*take a breath*) Nathan needs one banana.

(Hoit, 2012)

APPENDIX B

Look at this book with us. It's a story about a zoo. That is where bears go. Today it's very cold out of doors, but we see a cloud overhead that's a pretty, white fluffy shape. We hear that straw covers the floor of cages to keep the chill away; yet a deer walks through the trees with her head high. They feed seeds to birds so they're able to fly.

(Zoo Passage, Fletcher, 1972)

APPENDIX C

ALS PARTICPANT 1

Targeted oral consonant	Sentences (% closed)
p	50
b	50
t	10
d	37.5
k	75
g	66.67
s	0
z	37.5
ʃ	33.33
f	66.67
v	83.33
ð	25
θ	0
tʃ	16.67
dʒ	16.67

ALS PARTICIPANT 2

Targeted oral consonant	Sentences (% closed)
p	33.33
b	50
t	90
d	100
k	88.89
g	50
s	50
z	60
ʃ	66.67
f	100
v	57
ð	100
θ	100
tʃ	16.67
dʒ	100

ALS PARTICIPANT 3

Targeted oral consonant	Sentences (% closed)
p	100
b	100
t	100
d	100
k	100
g	100
s	100
z	87.5
ʃ	50
f	83.33
v	100
ð	100
θ	100
tʃ	66.67
dʒ	100