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AERODYNAMICS AND DYSPHAGIA

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Bachelor of Science in Biology  
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Submitted in partial fulfillment of requirements for the degree

MASTER OF ARTS IN SPEECH-LANGUAGE PATHOLOGY AND AUDIOLOGY

at the

CLEVELAND STATE UNIVERSITY

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This thesis has been approved  
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# AERODYNAMICS AND DSYPHAGIA

MARIAM BAIG

## ABSTRACT

This study investigated the influence of aerodynamic measures of Maximum Phonation Time (MPT) and the S/Z ratio on swallowing. Twelve individuals were examined, six with a diagnosis of dysphagia, and six as a control group. The study hypothesized that (1) there would be a reduced MPT in the dysphagic group compared to the control (2) there would be an S/Z ratio greater than 1.0 in the dysphagic group. The rationale for this study was that since MPT and S/Z measures are easily administered, they may prove to be useful, non-invasive, inexpensive tools to predict a patient's potential risk for aspiration. The results showed (1) a reduction of MPT values in the dysphagic group compared to the control (2) no significant difference in S/Z ratios between groups (3) a significant decrease in duration of individual /s/ /z/ productions in the dysphagic group and (4) a significant difference in /z/ duration compared to /s/ duration was found in both the dysphagic and control groups. The results suggest that only the MPT may be a useful indicator in detecting patients who may be at risk for aspiration. Contrary to the hypothesis, the S/Z ratio is not a predictor for detecting patients who may be at risk for aspiration.

## TABLE OF CONTENTS

	PAGE
ABSTRACT.....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
CHAPTER	
I. INTRODUCTION.....	1
The Maximum Phonation Time (MPT).....	2
The S/Z Ratio.....	2
Anatomy and Physiology of Phonation.....	4
Glottic Efficiency and Relevance to Dysphagia.....	5
Previous Research.....	5
Rationale and Research Questions.....	6
II. METHODS.....	7
Participants.....	7
Procedures.....	8
III. RESULTS.....	9
IV. DISCUSSION.....	18
Clinical Implications.....	21
Limitations.....	21
Future Studies.....	22
REFERENCES.....	23

	PAGE
APPENDICES.....	24
A. Cleveland State University Informed Consent Form.....	25
B. Study Procedure Directions.....	26

## LIST OF TABLES

TABLE	PAGE
Table 1.....	8
Table 2.....	9
Table 3.....	11
Table 4.....	12
Table 5.....	13
Table 6.....	13
Table 7.....	15
Table 8.....	15
Table 9.....	16

## LIST OF FIGURES

FIGURE	PAGE
Figure 1.....	10
Figure 2.....	11
Figure 3.....	12
Figure 4.....	14
Figure 5.....	16



## CHAPTER I

### INTRODUCTION

Aerodynamic analysis of voice production is the measurement of airflow, air pressure, and their relationship during phonation. This information provides insight regarding vocal efficiency and functioning and may serve as a clinical measure during diagnosis and assessment (Dejonkere H., 2010). The ability of the vocal folds to adduct efficiently and consistently vibrate through cycles of phonation is defined as glottic efficiency (Williamson, 2008). A person who is unable to adequately adduct the vocal folds may experience poor voice quality, difficulty projecting the voice, and vocal fatigue. In severe cases, the person may be at risk for aspiration of food and liquid into the lungs, secondary to poor airway protection.

## **Maximum Phonation Time (MPT)**

There are many non-invasive perceptual measures that can be used to test for glottic efficiency. One of these is a basic estimate of the efficiency of phonation called the Maximum Phonation Time (MPT), measured in seconds. It is an aerodynamic parameter of voicing defined by Hirano, Koike, & von Leden (1968), as a measure of respiratory and sound control. The individual is asked to sustain a vowel sound /ah/ on one deep breath while the duration is measured in seconds. The best of three attempts at sustaining the vowel is used as the individual's MPT (Dejonkere H., 2010). In the absence of laryngeal pathology, it is expected that adult males will be able to sustain vowel sounds for durations between 25 and 35 seconds, and adult females between 15 and 25 seconds (Hirano et al., 1968). However, MPT can differ among healthy individuals as a function of age, gender, anatomical differences in vital lung capacities, and posturing; yet the duration of MPT remains relatively the same, within the average range (Williamson, 2008). In cases of vocal dysfunction or laryngeal pathology, the MPT may be considerably reduced. According to Hirano et al. (1968), an MPT of 7 seconds or less is an indicator of poor glottic efficiency.

## **S/Z Ratio**

A second perceptual measure of aerodynamics in phonation is the S/Z ratio. The use of the S/Z Ratio as an indicator of laryngeal pathology was first proposed by Eckel and Boone (1981). It is a fairly simple procedure which measures the length of time a person can sustain the individual sound /s/ and /z/, both after maximum inhalation across three trials. In each case the two values are then calculated to obtain a numerical ratio. The principle underlying this measure is the assumption that maximum glottal efficiency

will result in equal, or near equal duration for both /s/ and /z/ fricatives, yielding a ratio of approximately 1.0. However, in the production of voiced /z/ there is additional glottal and lingual airflow impedance, whereas the production of /s/ the voiceless correlate, has only lingual impedance. An individual with glottal inefficiency would most likely encounter difficulty producing the /z/ sound as it requires a narrower and more focused constriction of air. A reduction in glottal efficiency would most likely result in decreased /z/ duration relative to /s/ resulting in a ratio greater than 1.0 (Sorenson & Parker, 1992). It stands to reason that a person with impaired vocal folds will experience difficulty in maintaining the same control of airflow and subglottic pressure as a person with healthy vocal folds. The higher the value of the S/Z ratio, the greater the possibility that the person is experiencing difficulty with phonation. According to Eckel and Boone (1981), 95% of individuals with laryngeal pathologies have an S/Z ratio of greater than 1.4

Several studies have been performed in an effort to establish maximum durations for /s/ and /z/ prolongation, and S/Z ratio normative data. These studies have been inconsistent in both procedures and results. Procedurally, studies have differed in aspects of type of instructions, number of trials, variables controlled (e.g. loudness, pitch, motivation, training, respiratory effort), and age of the participants (Gelfer & Pazera, 2006). Differences in results include disagreements over basic issues as the original premise of the S/Z ratio: that both phonemes should be produced for approximately the same duration in vocally healthy individuals, resulting in an S/Z ratio of 1.0 (Gelfer & Pazera, 2006).

The S/Z ratio discrepancies are explained by the fact that the production of /z/ may involve lower glottal airflow rates and increased glottal efficiency because of the increased glottal resistance associated with vocal fold vibration. The production of /s/, on

the other hand, may yield substantially greater airflow and reduced efficiency because of an open glottal configuration (Gelfer & Pazera, 2006). Presumably, higher airflow would reduce duration for /s/ compared with /z/. This justification for longer /z/ prolongations was suggested by Tait, Michel, & Carpenter (1980), who stated that if /z/ typically exceeds /s/ in duration, it may reflect conservation in airflow due to laryngeal valving, rather than a pathology.

### **Anatomy and Physiology of Phonation**

In order to fully appreciate glottal efficiency, it is important to understand the structure and functioning of the larynx and vocal folds during phonation as well. The vibratory movement of the vocal folds is described by the classical myoelastic aerodynamic theory of phonation (van den Berg, 1958). In this theory the adducted vocal folds can no longer resist the high subglottic pressure and they become separated. The pressure at the level of the glottis becomes negative causing the folds to be drawn back together again. This cycle is repeated continuously during phonation (Titze, 2006).

Individuals who are unable to produce adequate levels of phonation may be displaying inefficiency at the laryngeal or respiratory level. This inadequate function of phonation is expressed by a deterioration of vocal performance due to incorrect respiratory, laryngeal, or articulatory movement patterns (Schultz-Coulon, 1980). Dysfunction of the vocal folds can be recognized by a pathological alteration of aerodynamic parameters, and by a change of the vibratory pattern with correspondingly less effective conversion of air volume into sound energy.

## **Glottic Efficiency and Relevance to Dysphagia**

While glottic efficiency as described above is crucial to sustaining phonation, it is also a critical component in swallowing. During the swallowing process, the larynx is responsible for protecting the opening to the trachea by being pulled upward and allowing the epiglottis to fold over it. The epiglottis covers the airway, thus preventing food from entering the lungs, a medical concern known as aspiration. Three actions occur simultaneously to protect the airway: firstly, the larynx and the hyoid bone are both pulled upward and forward; this movement enlarges the laryngopharynx and peristaltic contractions of the pharyngeal walls pull the bolus downward (Logemann, 1998). Secondly, the true and false vocal folds adduct. Closure begins at the level of the true vocal folds, progresses up to the false vocal folds, and then to the aryepiglottic folds. Lastly, the epiglottis retroflexes to cover the larynx, protecting the airway and diverting the bolus into the pyriform sinuses. Complete glottal adduction is the primary laryngopharyngeal protective mechanism to prevent aspiration during the swallow. Since the true vocal folds adduct during the moment of a swallow, a finite period of apnea occurs ranging from 0.3- 2.5 sec (Aviv, 2012). If an individual exhibits an inability to achieve efficient glottic closure during a swallow, then aspiration will most likely occur (Wilson, Pryde, White, Maher, & Maran, 1995).

## **Previous Research**

A study conducted by Valim, Santos, Filho, Abdulmassih, & Serrato (2007), examined the relationship between MPT and fundamental frequency as they relate to protection of the lower airways in patients with neurological dysphagia. Thirty-one adult patients between 26 and 91 years of age were investigated. This study revealed those with

the shortest MPT were associated with aspiration. This was directly related to their inability to sustain complete vocal fold adduction during a swallow.

As the physiological mechanisms of deglutition, phonation, and respiration utilize the same structures to perform their specific tasks, it is critical that the structures involved are functioning to prevent aspiration of the bolus. Difficulty with swallowing is frequently observed in neurological patients and aspiration pneumonia is associated with dysphagia. The study of swallowing and phonation structures is necessary for the diagnosis and treatment of dysphagia and other breathing difficulties (Valim et al., 2007). The understanding of the relationship among the integrated mechanisms of breathing, deglutition, phonation, and their effects in dysphagia is highly essential in order to provide maximal treatment to patients. The MPT and S/Z ratio both may serve as quick measures for perceptually assessing the potential for a swallowing problem, specifically in patients with neurological deficits.

### **Rationale and Research Questions**

The purpose of this present study is to investigate the influence of aerodynamic measures of MPT and the S/Z ratio in individuals with a swallowing problem. It is hypothesized that individuals with a compromised swallowing system will exhibit abnormal MPT and S/Z measures. The rationale for this study is that since MPT and S/Z measures are easily administered, then these may prove to be useful, non-invasive, inexpensive tools to predict a patient's potential risk for aspiration.

## CHAPTER II

### METHODS

#### **Participants**

Two groups of six participants each (n=12), between the ages of 40-95 were included in this study. The control group was composed of six non-impaired adults that were recruited from the Cleveland State University (CSU) community using informational flyers. The experimental group was composed of six individuals previously diagnosed with dysphagia, recruited from local hospitals. The non-impaired group reported they had no previous history of stroke, dysphagia, chronic obstructive pulmonary disease (COPD), pneumonia, emphysema, or any other medical condition involving the respiratory process.

All testing for the control group was completed in the Voice Clinic of the Speech and Hearing Department at Cleveland State University. Experimental procedures performed and data collected from the dysphagic participants took place at the local hospital site. This study was approved by both the Institutional Review Board (IRB) at the local hospital and Cleveland State University. All participants read and signed the

Informed Consent Form (ICF) (see Appendix A). Table 1 provides a description of the dysphagic participants' diagnoses.

**Table 1.** *Medical diagnoses of experimental group both genders*

<b>PARTICIPANT</b>	<b>DIAGNOSIS</b>
DM1	Right cortical CVA
DM2	Left lower lobe beginning stages of pneumonia
DM3	Silent aspiration, history of recurrent pneumonia, reduced pharyngeal sensation, coronary artery disease
DF4	Right CVA, coronary artery disease w/ stent
DF5	Persistent left lower lobe pneumonia
DF6	Right CVA

DM= dysphagic male DF= dysphagic female

## **Procedures**

Following instruction and a practice trial, the participants completed two tasks: sustaining a vowel /ah/ to obtain a MPT, and sustaining the sounds /s/ and /z/ to obtain the S/Z ratio. The participants were asked to complete three trials for each sound; the longest production time was used, and the remaining trials were discarded. The length of production (in seconds) was timed with a stopwatch and audio recorded as a voice sample on an Apple I-PAD. See Appendix B for specific instructions.

The data were entered into an Excel 2010 spreadsheet at the time of the participants' production. Intra-rater reliability was tested using a coefficient of reliability. Results of this analysis showed an intra-rater agreement of  $r^2 = 0.99$ .



## CHAPTER III

### RESULTS

The data were first analyzed with respect to whether there was a difference between MPT in the dysphagic group versus the control group. The mean scores and Standard Deviations are contained in Table 2.

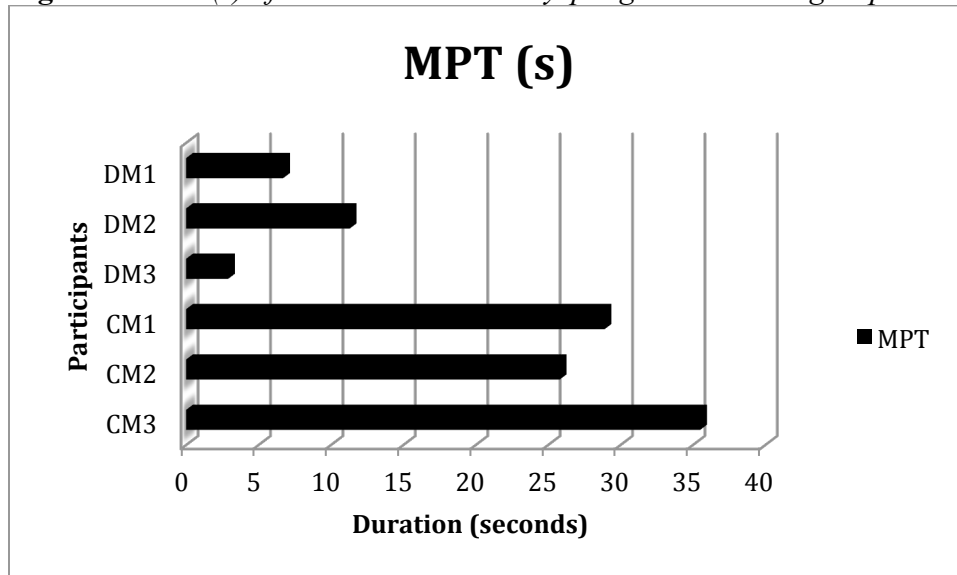
**Table 2.** *Mean and Standard Deviation for MPT of all subjects both genders*

	MALE	FEMALE
Dysphagic	Mean= 6.9 SD= 4.2	Mean= 7.2 SD=3.3
Control group	Mean= 30.1 SD=4.9	Mean= 27.8 SD= 10.7

SD= Standard Deviation

Upon visual inspection it is apparent that the average MPT for males and females of the dysphagic group was less than the values obtained from the control group. Figure 1 shows the MPT values for the male dysphagic participants and the male control group.

**Figure 1.** *MPT (s) of vowel /ah/ in male dysphagic vs. control group*



DM= dysphagic male CM= control group male

The dysphagic males collectively produced lower maximum phonation times compared to the male control group. A 2-way Analysis of Variance (ANOVA) revealed a significant difference in the MPT of the dysphagic versus the control group,  $F(1, 8) = 34.09, p < .001$ . However, there was no significant difference between male and female dysphagic and control group participants for MPT (see Table 2).

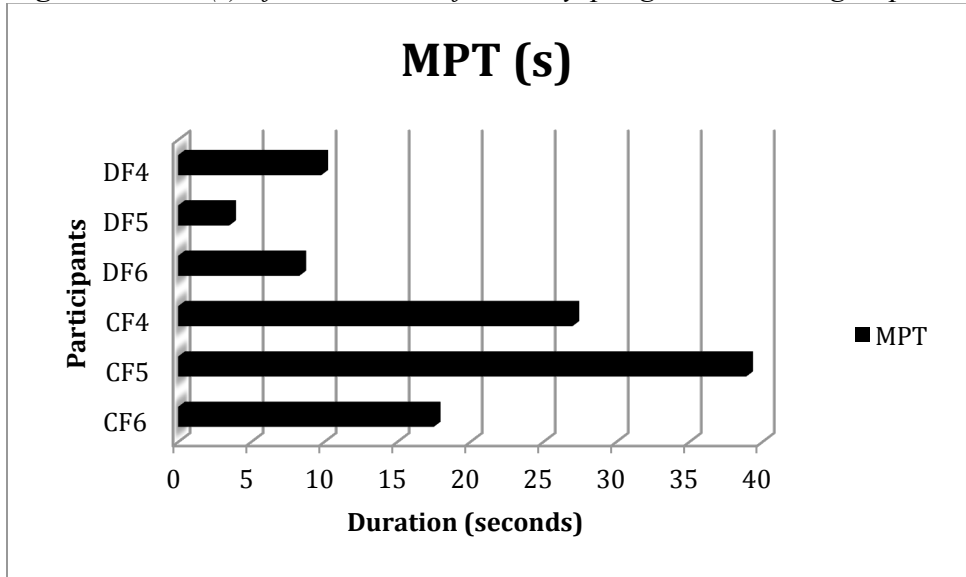
**Table 3.** *MPT (s) of vowel /ah/ in male dysphagic vs. control group*

<b>PARTICIPANTS</b>	<b>MPT (seconds)</b>
DM1	6.7
DM2	11.3
DM3	2.9
CM1	28.9
CM2	25.8
CM3	35.5

DM= dysphagic male CM= control group male

The raw data in Table 3 depicts the MPT values for both dysphagic and control group males. While none of the dysphagic participants were able to produce MPTs that fall within the average phonation range of 25-35 seconds, all of the control group males were able to do so (see Table 3).

**Figure 2.** *MPT (s) of vowel /ah/ in female dysphagic vs. control group*



DF= dysphagic female CF= control group female

In the MPTs for the female dysphagic and control group depicted in Figure 2, it can be seen that the dysphagic females produced significantly lower MPT values than the control group females.

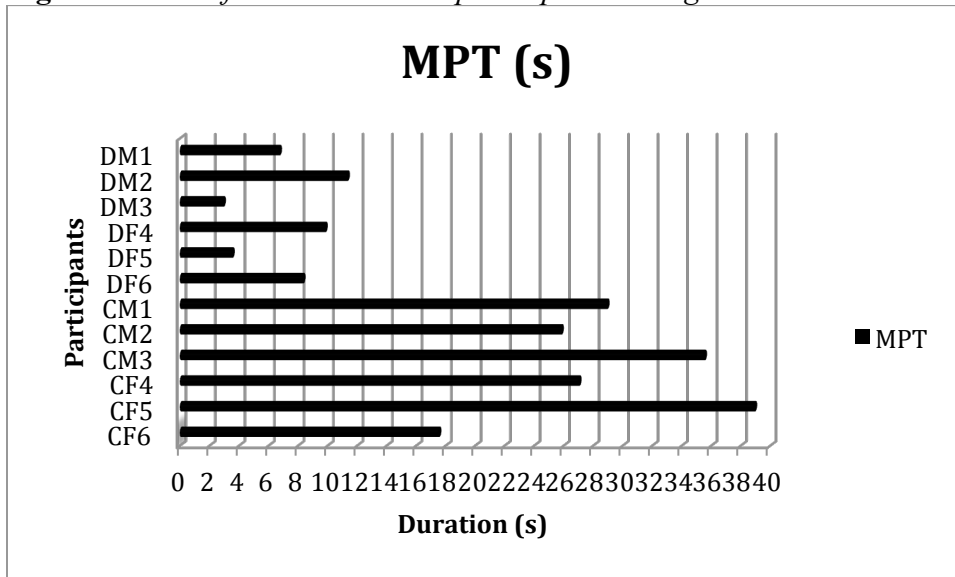
**Table 4.** *MPT (s) of vowel /ah/ in female dysphagic vs. control group*

<b>PARTICIPANTS</b>	<b>MPT (seconds)</b>
DF4	9.8
DF5	3.5
DF6	8.3
CF4	27
CF5	38.9
CF6	17.5

DF= dysphagic female CF= control group female

Table 4 provides the values for the MPTs of the female dysphagic and control groups. The dysphagic females were unable to produce an MPT within the average range of 15-25 seconds, while the females in the control group produced MPT's that were within the average range.

**Figure 3.** *MPT of vowel /ah/ in all participants both genders*



DM= dysphagic male    CM= control group male  
 DF= dysphagic female    CF= control group female  
 $F(1, 8) = 34.09, p < .001$

Figure 3 shows the difference in values of MPTs overall between the dysphagic group and control group. The dysphagic group collectively presented with lower MPT values ranging from 2.9-11.3 seconds, while the control group presented with consistently higher values ranging from 25.8- 38.9 seconds.

**Table 5.** *MPT (s) of vowel /ah/ in all participants both genders*

<b>PARTICIPANTS</b>	<b>MPT (seconds)</b>
DM1	6.7
DM2	11.3
DM3	2.9
DF4	9.8
DF5	3.5
DF6	8.3
CM1	28.9
CM2	25.8
CM3	35.5
CF4	27
CF5	38.9
CF6	17.5

DM= dysphagic male CM= control group male  
DF= dysphagic female CF= control group female

The raw values in Table 5 reflect the differences in MPTs between the control group and dysphagic group. Upon visual inspection, the dysphagic group collectively showed MPT values lower than the average range of 15-35 seconds, while the control group MPT values were within the average range of phonation. This again corroborates the finding of the 2-way ANOVA  $F(1, 8) = 34.09, p < .001$  which reveals significantly lower MPT's for the dysphagic group versus the control group. Gender was not a significant factor in MPT's across both groups.

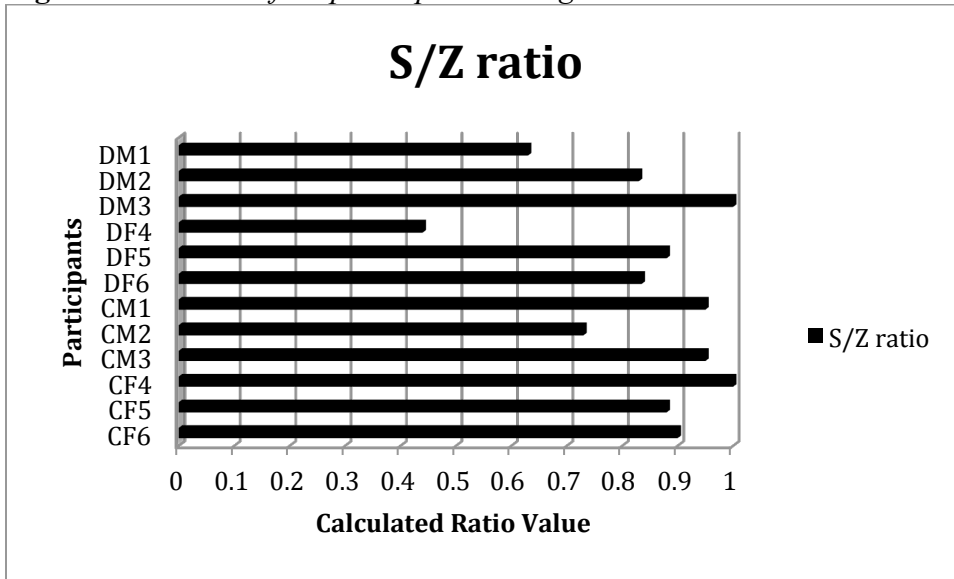
The data for the S/Z ratio were analyzed using a 2-way ANOVA and there was no significant difference found between the S/Z ratio of the dysphagic group when compared with the control. Table 6 depicts the mean and standard deviations for both groups.

**Table 6.** *Mean and Standard Deviation for S/Z ratios of all participants both genders*

	<b>MALE</b>	<b>FEMALE</b>
Dysphagic	Mean= .820 SD= .185	Mean= .712 SD= .253
Control group	Mean= .876 SD= .127	Mean= .927 SD= .064

SD= Standard Deviation

**Figure 4.** *S/Z ratio of all participants both genders*



DM= dysphagic male    CM= control group male  
 DF= dysphagic female    CF= control group female

There was not a significant difference in the S/Z ratio across genders and both groups as a whole. However, there was a significant difference in the length of the individual /s/ and /z/ durations. A 2-way ANOVA revealed a significant difference for the production of /s/  $F(1,8) = 17.18; p=.003$ , and /z/  $F(1,8)= 14.66; p=.005$  between groups. Table 7 depicts the means and standard deviations for the production of /s/ and /z/ for the dysphagic and control groups.

**Table 7.** /s/ duration mean and standard deviation of all participants both genders

	MALE	FEMALE
Dysphagic	Mean= 5.26 SD= 3.88	Mean= 3.73 SD=1.63
Control group	Mean= 25.3 SD=4.81	Mean= 31.03 SD= 18.7

SD= Standard Deviation

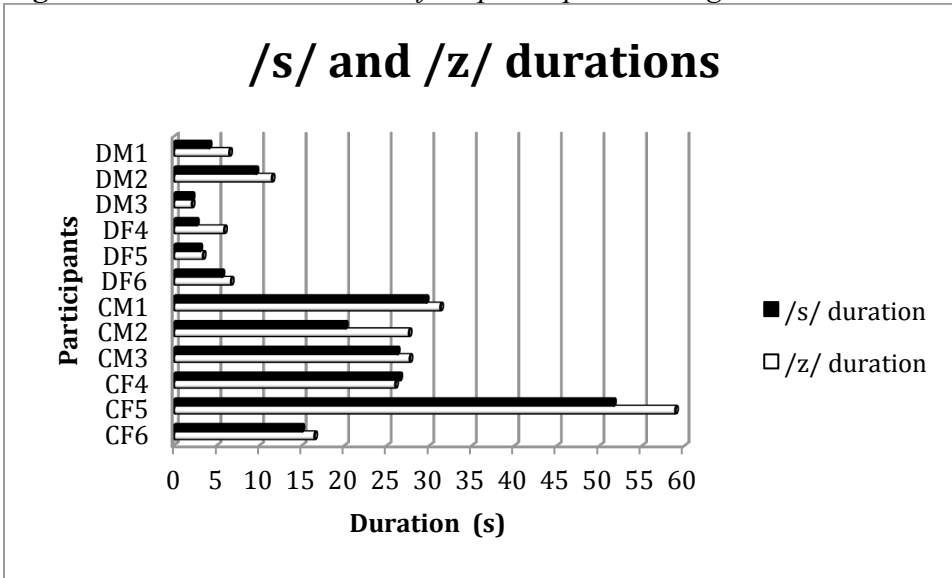
**Table 8.** /z/ duration mean and standard deviation of all participants both genders

	MALE	FEMALE
Dysphagic	Mean= 6.70 SD= 4.70	Mean= 5.33 SD=1.72
Control group	Mean= 28.8 SD=2.10	Mean= 33.8 SD= 22.2

SD= Standard Deviation

As shown in Tables 7 and 8, the average duration of /s/ and /z/ was lower in the dysphagic group compared to the control group across genders. Using a paired samples T-test it was found that the duration of /z/ was significantly longer across genders and test groups compared to /s/,  $t(11)= 3.15$ ;  $p=.009$ . The duration of /z/ was longer than /s/ with a mean difference of 2.34 seconds. A paired samples T-test also revealed a significant difference within the dysphagic group for a longer duration of /z/ compared to /s/,  $t(5)=2.97$ ;  $p=.031$ .

**Figure 5.** /s/ and /z/ durations of all participants both genders



CM= control male    DM= dysphagic male  
 CF= control female    DF= dysphagic female  
 /s/  $F(1,8) = 17.18$ ;  $p=.003$ , and /z/  $F(1,8)= 14.66$ ;  $p=.005$

Figure 5 displays the overall /s/ /z/ durations, and S/Z ratio for the dysphagic and control groups. There is an insignificant difference between test groups for S/Z ratio, and the consistently longer production of /z/ compared to /s/. It also shows the lower duration of /s/ and /z/ exhibited by the dysphagic participants when compared to the control.

**Table 9.** S/Z ratio and /s/ /z/ duration of all participants both genders

<b>PARTICIPANTS</b>	<b>S/Z RATIO</b>	<b>/s/ duration</b>	<b>/z/ duration</b>
DM1	0.63	4.1	6.5
DM2	0.83	9.6	11.5
DM3	1.0	2.1	2.1
DF4	0.42	2.6	5.9
DF5	0.88	3	3.4
DF6	0.835	5.6	6.7
CM1	0.95	29.6	31.3
CM2	0.73	20.1	27.6
CM3	0.95	26.2	27.7
CF4	1.0	26.5	26.0
CF5	0.88	51.6	58.9
CF6	0.90	15	16.5

DM= dysphagic male    CM= control group male  
 DF= dysphagic female    CF= control group female



The raw values of /s/ /z/ duration, and the S/Z ratio across both groups are depicted in Table 9. It is evident that the dysphagic group of males and females produced consistently lower than average productions of /s/. However, the difference in S/Z ratio remains negligible between both groups. Both groups collectively produced /z/ for an average of 2.34 seconds longer than /s/  $t(11) = 3.15$ ;  $p = .009$ . The dysphagic group produced /z/ significantly longer than /s/  $t(5) = 2.97$ ;  $p = .008$ ; however, both /s/ and /z/ duration for the dysphagic group remained significantly lower than that of the control group.

## CHAPTER IV

### DISCUSSION

This current study investigated aerodynamic measures of MPT and S/Z ratio as possible indicators of a swallowing disorder. The study hypothesized that (1) there would be a reduced MPT in the dysphagic group compared to the control and (2) there would be an S/Z ratio greater than 1.0 in the dysphagic group. The results of this study indeed showed that the MPT may be a useful indicator of glottic inefficiency in individuals with a swallowing problem. The low MPT values in the dysphagic group strongly indicated a glottic compromise. These findings appear to be in agreement with the earlier claims of Valim et al., (2007) whose study revealed that patients with the shortest MPT were associated with aspiration.

This discussion will examine the following findings: (1) a reduction of MPT values in the dysphagic group compared to the control (2) the lack of significance between the S/Z ratios of the dysphagic group compared to the control (3) a significant decrease of duration of individual /s/ /z/ production in the dysphagic group (4) and a significant difference in /z/ duration compared to /s/ duration in both dysphagic and control groups.

In this study, the average MPT for the dysphagic group was 6.9 and 7.2 seconds for male and females, respectively (see Table 2). These findings appear to corroborate that of Hirano et al. (1968) who state that an MPT of 7 seconds or less is indicative of poor glottic efficiency. MPT is a good measure of glottic efficiency and glottic compromise is a hallmark of dysphagia, therefore, a test such as the MPT can readily provide an assessment of a person's possible risk for aspiration.

While the MPT was found to be reduced in the dysphagic participants, there was no significant difference between the S/Z ratio of the dysphagic group compared to the control. These findings are indicated in Table 6 and Figure 5, and substantiated by the ANOVA. The S/Z ratio is used to give specific information of vocal fold efficiency as it compares the voiceless /s/ with the voiced /z/ correlate. It was hypothesized that people who are aspirating because of impaired vocal fold function would produce a lower voiced /z/ duration compared to /s/. This was not the case in the dysphagic and control group participants, and the overall S/Z ratio remained insignificant between the groups.

However, there was a significant decrease in duration of /s/ and /z/ in the dysphagic group compared to the control. As seen in Table 7, the dysphagic group produced /s/ for an average of 5.26 and 3.73 seconds for males and females respectively. According to Eckel and Boone (1981), persons over the age of 16, should be able to sustain /s/ for 15 and 20 seconds for males and females respectively. The dysphagic participants did not meet this value. Table 8 shows that the average productions of /z/, 6.70 and 5.33 seconds, for males and females respectively, were also low. While the dysphagic group was able to give a complete S/Z ratio value that was considered average, the actual durations of the /s/ and /z/ components were below average.

Surprisingly, Paired Samples T-test findings indicated a significant difference in duration of /s/ and /z/ across both groups, and within the dysphagic group. The duration of /z/ was longer in both groups by a mean of 2.34 seconds, and longer in the dysphagic participants by a mean of 2.97 seconds. This difference in duration is represented visually in Figure 5 and Table 9. Tait et al., (1980) suggest that if /z/ typically exceeds /s/ in duration, it may reflect conservation in airflow due to laryngeal valving, rather than a pathology. For the production of /s/, which was lower in duration across participants, the airway is open, and there may be a lack of airflow control, as well as an increase in rate of air loss. However, for the production of /z/ there is more reservation of air due to laryngeal impedance and constriction, consequently it takes more time for the air to flow through the vocal tract, resulting in a longer duration of the sound. While literature indicates that an individual with healthy functioning vocal folds should achieve an S/Z ratio of 1.0, this was not found to be the case. The majority of the control group were unable to achieve a ratio of 1.0, and collectively produced S/Z ratio values in the range of 0.73-1.0. This finding was similar to Gelfer & Pazera (2006) who also found inconsistencies in the S/Z ratio produced by a normal group studied. The results of this current study do not support the S/Z ratio as a reliable measure in terms of identifying potential risk for aspiration, as there is inconsistency in the established values. Whereas the MPT appears to be a more efficient measure of predicting glottic inefficiency.

## **Clinical Implications**

The findings of this study suggest that MPT may be a useful indicator in detecting patients who may be at risk for aspiration. These results are corroborated with previous findings from Valim et al., (2007), and Hirano et al., (1968) that a low value of MPT (7 seconds or less) is an indicator of glottic inefficiency. The S/Z ratio may not be as useful an indicator of vocal fold efficiency as there was not a significant difference between dysphagic participants and control group ratios. While the duration of /s/ and /z/ was significantly decreased in the dysphagic group, the /z/ duration was still significantly longer than /s/; this may not clearly indicate difficulty in phonation due to the affect of laryngeal valving on the duration of the sound. These findings suggest that the MPT should be strongly considered as a part of the assessment protocol for patients who may be at risk for aspiration.

## **Limitations**

This study was limited in the number of participants. A larger sample of participants may have yielded more significant results to strengthen the clinical indications of MPT when assessing for dysphagia. It would also have been beneficial to exclude patients with respiratory complications. This would help to focus on the correlation between swallowing and phonation, with respiration being held as a control. Vital lung capacities could also be used as a measure of control so that emphasis would be on phonation. This study did not indicate onset time of the swallowing disorder. Different results may have been obtained if a distinction were made between newly onset dysphagia and chronic dysphagia.

## **Future Studies**

Future studies should consider using objective measurements for glottal efficiency and dysphagia. For example, the Fiberoptic Endoscopic Examination of Swallowing (FEES) could be used to measure vocal fold functioning during phonation as well as swallowing. Future studies should also strive to utilize a larger sample.

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## APPENDICES



APPENDIX A

INFORMED CONSENT FORM

My name is Mariam Baig; I am a graduate student working with Dr. Violet Cox at **Cleveland State University** in the Speech and Hearing Department. I am studying the relationship between aerodynamic measures and how they relate to swallowing disorders. This study will help to establish if aerodynamic measures can be used as diagnostic tools when assessing for swallowing disorders.

I would like to record your Maximum Phonation Time (MPT) and S/Z ratio. You will be asked to produce the vowel sound /ah/, and the sounds /s/ and /z/, for as long as possible. There will be three separate trials completed for each sound. The study tasks will take place in the Voice lab of the Cleveland State University Speech and Hearing Clinic MC 429. This will be a one time, 15-20 minute session. You may not have any medical history of Chronic Obstructive Pulmonary Disease (COPD), Emphysema, or a medical diagnosis involving respiratory disorders. Your participation is entirely voluntary and you may withdraw at any time without penalty. No identifying information will be asked of you other than your name. Your participation in this research and all data collected will be kept confidential.

If you want to know more about this project, please contact Mariam Baig at (440) 465-9370 or Dr. Violet Cox at (216) 687-6909.

This project has been approved by the Institutional Review Board of Cleveland State University. If you have further questions you may contact the Institutional Review Board. "I understand that if I have any questions about my rights as a research subject I can contact the CSU Institutional Review Board at (216) 687-3630."

By checking the box below and signing your name, you are stating that you are 18 years of age or older, understand the above information, and agree to participate in this research.

I understand the above information and consent to participate in this study [ ]

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## APPENDIX B

### Study Procedure Directions

“I would like to record the length of time you can produce the vowel sound /ah/, and the sounds /s/ and /z/. When I say ‘go’ take a full, deep breath and begin holding out the sound for as long as you can. We will repeat each sound production three times.”