ACOUSTIC AND RESPIRATORY MEASURES AS A FUNCTION OF AGE IN THE MALE VOICE

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We hereby approve this thesis for

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"It is not incumbent upon us to complete the work; however, we are not free to desist from it."
ACOUSTIC AND RESPIRATORY MEASURES AS A FUNCTION OF AGE IN THE MALE VOICE

MARK SELENT

ABSTRACT

The purpose of this study was to extend understanding of the effects of aging on the male voice by obtaining and analyzing both acoustic and respiratory measures across the aging continuum. Aerodynamic measurements such as vital capacity (VC), maximum phonation time (MPT) and the acoustic measurement Speaking Fundamental Frequency (SFF) are used commonly in Speech-language Pathology to aid in the assessment and treatment outcomes of vocal dysfunction. However, current research lacks analysis of the interaction across these parameters within males and younger ages. This information may be important in understanding the normal changes in the speech mechanism with age and provide important direction for voice assessment and therapy outcomes. This study examined the changes of these parameters and interactions in males across various age groups. Acoustic measures of SFF, MPT, and VC were obtained in age groups of 20-29, 30-39, 40-49, 50-59, and 60-69, N=35. A statistically significant decrease in SFF with age was observed. No statistically significant interaction was observed between MPT and VC. Additionally, no statistically significant interaction was observed between MPT and age, or between VC and age.
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NOMENCLATURE

$F_0$: Fundamental Frequency

MPT: Maximum Phonation Time

SD: Standard Deviation

SFF: Speaking Fundamental Frequency

VC: Vital Capacity
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</tbody>
</table>
CHAPTER I
INTRODUCTION

Based on gerontological literature, the term ‘aging’ is often associated with individuals who are 65 and over. Furthermore, aging is defined not only in chronological changes, but in terms of changes in societal roles and capabilities (Glascock & Feinman, 1980). One of the major hallmarks of aging is changes in capabilities as evidenced by change in physical characteristics. Physical changes are the most predominant measure of aging. An outstanding physical characteristic of aging is in the area of vocal change.

After decades of relative vocal stability, noticeable changes in the voice occur as a function of the aging process. For example, as the body ages, there is loss in muscle mass, thinning of mucosal membranes, as well as in coordination. These changes not surprisingly, are reflected in laryngeal function that leads to changes in the voice.

Common age attributed characteristics of the elderly voice are hoarseness, breathiness, roughness, instability, reduced acoustic volume, changes in pitch and vocal tremor (Gorham-Rowan & Laures-Gore, 2006; Hartman, 1979; Verdonck-de Leeuw & Mahieu, 2004). The quality of voice resulting from air loss, laryngeal tension, tremor, and
altered fundamental frequency associated with age may allow listeners to easily distinguish elderly voices from younger voices (Lundy, Silva, Casiano, Lu, & Xue, 1998). Elderly individuals experience voice disorders and dysphonia at a higher rate than younger individuals. The prevalence of voice disorders in the elderly has been estimated to be between 12% to 47% (Golub, Chen, Otto, Hapner, & Johns, 2006; Roy, Stemple, Merrill, & Thomas, 2007; Turley & Cohen, 2009). The most commonly reported age related voice complaint is reduction in vocal quality (Verdonck-de Leeuw & Mahieu, 2004).

Decreased voice quality secondary to aging has been shown to negatively impact quality of life. Many elderly individuals report an inability to speak in a noisy situation, insufficient air, reduced ability to practice one’s profession, and social isolation (Murry, Medrado, Hogikyan, & Aviv, 2004; Schneider, Plank, Eysholdt, Schützenberger, & Rosanowski, 2011). Turley & Cohen (2009) surveyed 605 elderly individuals in a retirement community in the areas of swallowing and voice issues on two measures, the Voice-Related Quality of Life (VRQOL) and the Center for Epidemiology Studies Depression Scale (CES-D). Those with voice problems reported higher level of impairment on the VRQOL and the CES-D, indicating that voice issues negatively affected their quality of life. They found that 22.4% of those suffering from dysphonia sought treatment and 72% reported that the treatment helped. The high prevalence of voice problems in elderly individuals is mostly attributable to the anatomical and physiologic changes of the elderly voice.
Anatomical and physiological changes in the speech mechanism due to the aging process have been reported by several researchers. Some established age related changes in the speech mechanism are due to structural changes in the thoracic skeleton and chest cavity, decreased lung capacity, poor laryngeal valving, ossification and calcification of laryngeal cartilages, atrophy of laryngeal muscles, changes in blood supply, and significant changes in the vocal folds (Kahane, 1990; S. Xue & Hao, 2003). These collective changes are often referred to as presbylaryngis. Age related changes in both the structure and physiology of the speech mechanism are believed to impact voice production and acoustic qualities. These changes are not uniform in men and women. Some degenerative changes occur earlier in the life and to a greater extent in men than in women (Kahane, 1990). Therefore, one would expect greater changes in acoustic and respiratory measures to begin earlier and occur faster in the lifespan of males. Additionally, there are different structural and physiological changes in the speech mechanism in men and women (Kahane, 1981). However, structural changes in the speech mechanism may not clearly produce functional changes in speech production. It has been suggested that men and women may differentially adjust their speech to accommodate these changes (Linville & Rens, 2002). The nature and extent of these anatomical, physical, and acoustic changes are still being investigated.
1.1 Maximum Phonation Time

There are many acoustic and respiratory measures available to researchers to ascertain information about the speech and respiratory mechanisms. Some of these measures are MPT, VC, and SFF. MPT is an accepted standard clinical task in speech-language pathology for the assessment of respiratory and phonatory function. (Kent, Kent, & Rosenbek, 1987; Pearl Solomon, Garlitz, & Milbrath, 2000).

Maximum phonation time is defined as the longest period during which an individual can sustain phonation of a vowel sound, typically /a/. Usually a timer and audio recorder, with or without audio analysis, are the only instruments needed to measure MPT. MPT is used as a quick, noninvasive, low-cost diagnostic tool to assess vocal function. It measures laryngeal function in different pathological circumstances such as dysphonia and Parkinson’s disease. It is also used to measure improvement after voice therapy (Maslan, Leng, Rees, Blalock, & Butler, 2011; Speyer, 2008).

Several researchers have reported norms for MPT, however, there have been inconstancies among these findings Maslan et al. (2011) MPTs seem to be longer in males than females presumably due to an average larger VC (Kent et al., 1987; Maslan et al., 2011). Maslan et al. (2011) found that MPTs were longer for individuals over 65 than previously reported; however, times were shorter among younger individuals. Still, it is not clear to what extent MPT is influenced by age. Kent, Kent, & Rosenbek (1987) sought to gain data concerning several common clinical tests, one of which was such as
maximum phonation time. Kent, Kent, & Rosenbek (1987) noted that a reduced MPT may be attributable to an inadequate volume of air used during phonation or to excessive wasting of air during phonation as a result of poor laryngeal valving. Kent et al. (1987) concluded that MPT alone is not a useful determinate of respiratory inefficiency.

Pearl Solomon, Garlitz, & Milbrath (2000) reported a correlation between MPT duration and the presence of organic and functional voice disorders. They also found an inverse relationship between MPT and the severity of a voice disorder. MPT durations have been used in pre-post therapeutic measurements to assess treatment outcomes (Stemple, Weinrich, & Brehm, 2008). Selected studies reporting MPT for typical males are presented in Table I.

<table>
<thead>
<tr>
<th>Study</th>
<th>Age Group</th>
<th>Age/Gender</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent (1987)</td>
<td>Older adults (1)</td>
<td>65-75</td>
<td>14.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Ptacek &amp; Sanders (1966)</td>
<td>Older adults (2)</td>
<td>68-89</td>
<td>18.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Mueller (1982)</td>
<td>Older adults (3)</td>
<td>85-92</td>
<td>13.0</td>
<td>-</td>
</tr>
<tr>
<td>Ptacek &amp; Sanders (1963)</td>
<td>Young adults (4)</td>
<td>17-41</td>
<td>24.6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Older adults (5)</td>
<td>71-80</td>
<td>23.12</td>
<td>1.71</td>
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<tr>
<td></td>
<td>Older adults (5)</td>
<td>81-90</td>
<td>21.72</td>
<td>1.53</td>
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<tr>
<td></td>
<td>Adults (6)</td>
<td>40-59</td>
<td>22.96</td>
<td>8.40</td>
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<tr>
<td></td>
<td>Older adults (6)</td>
<td>60-89</td>
<td>19.94</td>
<td>6.79</td>
</tr>
</tbody>
</table>

SD = Standard Deviation
1.2 Vital Capacity

In order to produce sound, air must be expelled from the lungs into the vocal tract. Vital capacity (VC) is defined as the greatest volume of air that can be expelled from the lungs after taking the deepest possible breath. VC is related to the quantity of air available for phonation. Age related reduction in the vital capacity directly reduces the amount of air available to be expelled for phonation. This reduction in air available for phonation contributes to various age related changes in speech production (Kahane, 1990).

Total lung Capacity (TLC) is the total volume of air in the lungs after a maximal inhalation. Tidal Volume (TV) is the amount of air that is inspired and expired from the lungs during a cycle of quiet respiration. Inspiratory reserve volume (IRV) is the volume that can be inhaled after a tidal inspiration, while, Expiratory Reserve Volume (ERV) is the amount of air that can be expired following a tidal expiration. Even after a maximal exhalation there is air left within the lungs, this volume is referred to as Residual Volume (RV).
Total lung capacity (TLC) and residual volume remain relatively the same across the adult lifespan, while vital capacity (VC), inspiratory capacity (IC), and expiratory reserve volume (ERV) diminish with age (Hoit & Hixon, 1987). Rochet (1991) reported that changes in pulmonary function due to aging become measurable at around age 40. While there are declines in the respiratory system of both men and women, these changes are greater in women than men (Gorham-Rowan & Laures-Gore, 2006).

VC is known to be influenced by an individual’s age, sex, and height (Kent, Kent, & Rosenbek, 1987). There are numerous studies which provide normative data for both men and women (Kent, Kent, & Rosenbek, 1987; Yiu, Yuen, Whitehill, & Winkworth, 2004; Zraick, Smith-Olinde, & Shotts, 2012). One recent study utilizing the Phonatory Aerodynamic System (PAS) found that the mean expiratory volume for males was 4.14
for ages 18-38; 4.19 for ages 40-59, and 3.09 for ages 60-89 (Zraick, Smith-Olinde, Shotts, 2012). The results of this study are presented in Table II.

### TABLE II: VC NORMS PRESENTED BY ZRAICK, 2012

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-39</td>
<td>4.14 liters</td>
<td>1.14</td>
</tr>
<tr>
<td>40-59</td>
<td>4.19 liters</td>
<td>1.1</td>
</tr>
<tr>
<td>60-89</td>
<td>3.09 liters</td>
<td>1.00</td>
</tr>
</tbody>
</table>

SD = Standard Deviation

1.3 **Speaking Fundamental Frequency**

Frequency is the acoustic correlate of pitch. In relation to speaking, frequency is determined by the rate at which the vocal folds open and close. The rate of vocal fold opening and closing does not remain constant while speaking; therefore, acoustic frequency does not remain the same throughout speech. Fundamental frequency ($F_0$) is the lowest frequency in a sound sample (Reetz & Jongman, 2011, p. 119). Fundamental frequency can be derived from isolated vowels, reading, or connected speech. When fundamental frequency is derived from connected speech it is often referred to as speaking fundamental frequency and describes the average frequency across an utterance (Boone, McFarlane, Von Berg, & Zraick, 2013, p. 154; Kay Elemetrics Corp., 2004; S. A. Xue & Deliyski, 2001). A measurement of speaking fundamental frequency can be obtained from any speech sample. In a clinical or research setting there are multiple ways to elicit a speech sample to determine the SFF. Zraick, Skaggs, & Montague (2000) examined four different elicitation tasks for SFF: automatic speech, elicited speech, spontaneous, and reading aloud. They reported no significant differences in SFF between
different elicitation tasks. Siupsinskiene & Lycke (2011) investigated average speaking fundamental frequency for adult males and females. They reported that the range of SFF for men was 89.0-175.0 Hz with a mean of 112.4 Hz and that the range for females was 164.5-260.0 Hz with a mean of 212.4 Hz. Fundamental frequency is a commonly assessed measure by speech-language pathologists when evaluating voice disorders (Roy Barkmeier-Kraemer, Eadie, Preeti , Mehta,Paul, & Hillman, 2013).

A speaker’s fundamental frequency is not constant; rather, there is variability of the frequencies produced. This variability of frequency is measured in one of two ways, standard deviation of \( F_0 \) or in semitones called pitch sigma. (Baken & Orlikoff, 2000) define pitch sigma is a “measure of the average distance of values from the mean.” This measure is the standard deviation (SD) of the frequencies included in a speech sample, which is the “square root of the sum of the squares of the deviations from the mean” (Baken & Orlikoff, 2000). The average standard deviation of fundamental frequency (\( F_0 \)SD) for both men and women is 25 to 30 Hz (Boone, McFarlane, Von Berg, & Zraick, 2013, p. 156). Using pitch sigma, Siupsinskiene & Lycke (2011) reported that men have a range of 7.5 to 21.0 with a mean of 14.5 while females have a range of 5.2 to 16.1 with a mean of 10.7. The lower pitch sigma in the female voice is representative of less variation in \( F_0 \). Age related changes in SFF indicate that, for men, \( F_0 \) drops approximately 10 Hz until around age 50 and then begins to gradually increase by up 35 Hz afterwards. For women, \( F_0 \) continues to decrease with age, or it stays constant until menopause after which time it decreases anywhere from 10 to 35 Hz (Hollien & Shipp, 1972; McGlone & Hollienn, 1963; Sataloff, Rosen, Hawkshaw, & Spiegel, 1997).
Researchers have attributed changes in speaking fundamental frequency to differences in anatomical and physiological changes in men and women (Awan, 2006; Awan & Mueller, 1992; Gilbert & Weismer, 1974; Russell, Penny, & Pemberton, 1995). Men tend to exhibit an increase in F₀ due to vocal fold atrophy, in contrast, females tend to exhibit a decrease in F₀ post-menopause as a result of reductions in vocal fold mass. There have been several investigations into changes of fundamental frequency across age groups that show this trend (Awan, 2006; Linville, 1987; Ramig & Ringel, 1983; Stathopoulos, Huber, & Sussman, 2011; Torre & Barlow, 2009; S. A. Xue & Deliyski, 2001). The impact of hormonal changes prior, during and post menopause to the voice are extensive in the literature (D’haeseleer, Depypere, Claeys, Van Borsel, & Van Lierde, 2009). These hormonal changes during the menopause can cause additional vocal alterations (D’haeseleer et al., 2009). While males do experience hormonal changes throughout their life, they are drastically different from the changes experienced by females (Tenover, 1997). The menopausal voice has been associated with a decreased vocal frequency range and decreased fundamental frequency (Mendes-Laureano Mendes-Laureano, Sá, Ferriani, Reis, Aguiar-Ricz, Valera, Küpper, & Romão, 2006).

### 1.4 Research Questions and Hypothesis

The purpose of this investigation is to provide preliminary data that would address the following questions:
1) Are MPT and VC related in males?

2) Does MPT decline across age groups in males?

3) Does SFF change across age groups in males?

It is hypothesized that:

1) MPT and VC will be related in males

2) MPT and VC will decline across age groups in males

3) SFF will increase across age groups of males

Concerning the first question, it was hypothesized that MPT and VC will be related. Kent, Kent, & Rosenbek (1987) concluded that since MPT requires the voluntary expulsion of air, a reduction in available air from a reduced VC would naturally reduce the duration of MPT. Conversely, an increase in VC would provide more air for phonation and lengthen the duration of MPT. To the author’s knowledge, Awan’s 2006 study was the only study that directly compared VC and MPT; however, Awan (2006) only used female participants. Since there are established differences in vital capacities and respiratory aging patterns in females, it is necessary to test this correlation in males.

Addressing the second question, it is hypothesized that both MPT and VC will reduce as a function of age. VC is known to decrease with age in both males and females (Spector, 1956, p. 267). However, there is less agreement about the nature of changes in
MPT with age. Kent, Kent, & Rosenbek (1987) and Maslan, Leng, Rees, Blalock, & Butler, (2011) both reported a reduction in MPT in individuals over age 65 but Maslan’s 2011 data showed less of a decline in MPT in elderly individuals than previously reported in both males and females. Maslan, Leng, Rees, Blalock, & Butler (2011) investigated norms for MPT and reported that, on average, males had longer MPTs than females and presumed that this was due to the fact that, on average males, have a higher VC. However, Maslan et al. (2011) did not incorporate VC into their investigation. Awan (2006) established a correlational reduction of MPT and VC with age. The fact that not much is known about the nature of decline in MPT across the lifespan in males prompts the need for further investigation.

The third hypothesis is that SFF will increase with age in males. This is consistent with previous reports (Higgins & Saxman, 1991; Hollien & Shipp, 1972; McGlone & Hollien, 1963; Mysak, 1959; Sataloff, Rosen, Hawkshaw, & Spiege, 1997).
CHAPTER II

METHODOLOGY

The investigation, materials, and procedures were approved by the Institutional Review Board (IRB) of Cleveland State University. Participants were recruited on the campus of Cleveland State University using flyers placed on approved campus bulletin boards. Additionally, the investigator contacted individuals within Cleveland State University and members from the greater community. A total of thirty five individuals participated in this study. There were no financial incentives provided for participation.

2.1 Consent Form

The investigator recruited, screened and collected data for all participants. All data were collected in the voice laboratory of the Speech and Hearing Clinic at Cleveland State University. All participants agreed and signed the consent form after discussing with the examiner. The participants were also offered a reference copy.
2.2 Screening

Based on self-report, prospective participants were screened for laryngeal pathologies and other health conditions that could affect the voice. Exclusionary conditions that participants were asked to self-report were asthma, sinus problems, acid reflux, use antihistamines, vocal fold pathology, emphysema or neuromotor impairment that may impact the voice. Prospective participants were also asked to self-report if they currently had a respiratory infection. They were also asked if they have used tobacco consistently in the past five years. The questionnaire used to screen participants can be found in Appendix B.

2.3 Data Collection

Two instruments were used to record the acoustic and respiratory measures. The Visi-Pitch IV (Model 3950)/Sona-Speech II (Model 3650) with a Shure hand-held microphone was used to record and analyze all speech samples at a sampling rate of 50 kHz. Acoustic data were collected and analyzed using the Real-Time Pitch module, a component of Visi-Pitch, which allows the user to capture a speech signal and perform a variety of acoustic analyses. The Real-Time Pitch module was also used to determine MPT. The spirometer used was a Buhl type hand-held spirometer produced by Baseline. Each participant received a disposable plastic mouthpiece which was discarded after use. Each data elicitation task was preceded by the investigator reading an explanatory script explaining what the participant needed to do in order to perform a task.
2.4 Vital Capacity

To obtain vital capacity measures participants were asked to breathe in as deeply as possible and exhale maximally into a handheld spirometer in order to measure vital capacity. The investigator offered an example of a maximal inhalation and exhalation. The highest of two trials was taken as a measure of vital capacity. A copy of this script can be found in Appendix C.

2.5 Maximum Phonation Time Procedure

Participants were asked to take the largest breath possible and sustain the vowel /a/ for the longest possible time. The experimenter provided a verbal description of the maximum phonation time task using a script, then offered a demonstration. A copy of this script can be found in Appendix C. The longest of two trials was used. This measure was calculated using the Visi-Pitch-IV Maximum Phonation Time protocol.

2.6 Average Fundamental Frequency

Participants spoke into a hand-held microphone placed four to six inches away from their mouths. Participants were asked to read an excerpt from the “Rainbow Passage” at a comfortable volume (Fairbanks, 1969) available in appendix C. The Visi-Pitch Real-Time Pitch module was used to calculate the average fundamental frequency
across the reading sample. Average Fundamental Frequency in Hz was defined as the average value of all extracted period-to-period fundamental frequency values, excluding voice break areas (Kay Elemetrics Corp., 2004). This measure was calculated using the Visi-Pitch-IV Speaking Fundamental Frequency protocol.
CHAPTER III

RESULTS

3.1 Participant Data

Descriptive statistics for the participants and all measures were calculated. Raw data for all participants can be found in Appendix F. The number of participants in each age group, mean age within group, and standard deviation are presented in Table III.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Number of Participants</th>
<th>Mean Age within Group</th>
<th>SD of Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-29</td>
<td>10</td>
<td>22.7</td>
<td>2.541</td>
</tr>
<tr>
<td>30-39</td>
<td>5</td>
<td>34.6</td>
<td>3.050</td>
</tr>
<tr>
<td>40-49</td>
<td>6</td>
<td>42.5</td>
<td>2.074</td>
</tr>
<tr>
<td>50-59</td>
<td>9</td>
<td>55.11</td>
<td>2.619</td>
</tr>
<tr>
<td>60-69</td>
<td>5</td>
<td>62.6</td>
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<tr>
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<td>15.2</td>
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SD = Standard Deviation
Group means and standard deviations for SFF, VC, and MPT are presented in Table IV of SFF, VC, and MPT. The highest SFF was within the 30-39 year old group. The highest mean MPT and VC were in the 40-49 year old group.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mean SFF</th>
<th>SD of SFF</th>
<th>Mean MPT</th>
<th>SD of MPT</th>
<th>Mean VC</th>
<th>SD of VC</th>
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SFF=Speaking Fundamental Frequency; MPT=Maximum Phonation Time; VC=Vital Capacity; SD=Standard Deviation

3.2 Analysis of Acoustic and Respiratory Measures

A series of Pearson product-moment correlations between all variables: age, MPT, VC, and SFF were calculated. Additionally, scatter plot diagrams are provided with the measures that were compared using the Pearson product-moment with the line of best fit. SigmaPlot 11.0 was used to calculate the results and scatter plot figures.
The data from all age groups were analyzed with respect to whether there was a correlation between age and MPT. A Pearson product-moment correlation was calculated to determine the relationship between age and MPT. There was no significant correlation between age and MPT ($r=-1.46$, $p>0.05$). A scatterplot representing the relationship between age and MPT is presented in Figure 2.

Figure 2: Age and Maximum Phonation Time

![Figure 2: Age and Maximum Phonation Time](image-url)
The data from all age groups were analyzed with respect to whether there was a correlation between age and VC. A Pearson product-moment correlation was calculated to determine the relationship between age and Vital Capacity. There was no significant correlation between age and MPT ($r=-3.08$, $p>0.05$). A scatterplot representing the relationship between age and Vital Capacity is presented in Figure 3.

Figure 3: Age and Vital Capacity
The data from all age groups were analyzed with respect to whether there was a correlation between age and SFF. A Pearson product-moment correlation was calculated to determine the relationship between age and Speaking Fundamental Frequency. There was a significant correlation between age and SFF (r=-3.06, p<0.05). A scatterplot representing the relationship between age and SFF is presented in Figure 4.

Figure 4: Age and Speaking Fundamental Frequency
The data from all age groups were analyzed with respect to whether there was a correlation between VC and MPT. A Pearson product-moment correlation was calculated to determine the relationship between VC and MPT. There was no significant correlation between VC and MPT ($r=.323$, $p>0.05$). A scatterplot representing the relationship between VC and MPT is presented in Figure 5.

Figure 5: Vital Capacity and Maximum Phonation Time
The data from all age groups were analyzed with respect to whether there was a correlation between MPT and SFF. A Pearson product-moment correlation was calculated to determine the relationship between MPT and SFF. There was no significant correlation between MPT and SFF ($r=0.089$, $p>0.05$). A scatterplot representing the relationship between MPT and SFF is presented in Figure 6.
The data from all age groups were analyzed with respect to whether there was a correlation between VC and SFF. A Pearson product-moment correlation was calculated to determine the relationship between VC and SFF. There was no significant correlation between VC and SFF (r=0.185, p>0.05). A scatterplot representing the relationship between VC and SFF is presented in Figure 7.

Figure 7: Vital Capacity and Speaking Fundamental Frequency
A one-way ANOVA was calculated between MPT and VC was calculated. The ANOVA revealed no statistical significance between MPT and VC (F=1.202, df=27, p=.43, p<0.05). The results of the ANOVA are presented in table VI.

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<th>MPT</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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<td>7</td>
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</tbody>
</table>

TABLE V: ANOVA OF MPT AND VC
CHAPTER IV

DISCUSSION

4.1 Research Questions

The research questions proposed in this study are as follows:

1) MPT and VC will be related in males

2) MPT and VC will decline across age groups in males

3) SFF will increase across age groups of males

Regarding the first question, visual inspection of the scatterplot in Figure 5 shows that an increased VC is consistent with an increased MPT. However, the Pearson product-moment found no statistical correlation between MPT and VC, \( r=.323, p>.05 \). Additionally the ANOVA that was calculated comparing MPT and VC showed no correlation, \( F=1.202, \text{df}=27, p=.43, p<.05 \). The lack of correlation could be attributable to several factors. Firstly, this study was comprised of only thirty five participants. The
scatterplot shown in Figure 5 visually suggests a correlation but statistical tests failed to show a correlation. Perhaps with more participants a statistical significance would have been reached. Alternatively, participants with lower vital capacities may be able to effectively compensate while producing MPTs.

Regarding the second hypothesis, MPT and age were not found to be statistically significant, \((r=-1.46, p>.05)\). VC and age were also not found to be statistically significant \((r=-3.08, p>.05)\). However, a visual inspection of Figure 2 comparing MPT with age and Figure 3 comparing VC with age visually show a negative correlation of both measures with age. The failure to reach statistical significance could be attributable to a small number of participants. Additionally, chronological age may not be a strong predictor of these measures; rather, other factors including physiological age, height, weight, and activity levels may be better predictive factors.

Regarding the third hypothesis, SFF will increase with age; the results of this study revealed a statistically significant negative correlation of age and SFF in males by calculating a Pearson product-moment \((r=-3.06, p<.05)\). Figure 4 shows a decrease in SFF with age. These results were inconsistent with previous reports of fundamental frequency increasing with age in males. It has been suggested that the possibility for elderly men to attempt to compensate for high-pitched unstable voice and for elderly woman to attempt to avoid a deep voice (Pontes, Brasolotto, & Behlau, 2005). Perhaps, men compensated for a natural increase in fundamental frequency while reading the passage.
4.2 Limitations of the Study

There were several limitations to this study and the results represent preliminary data of a pilot study. The most significant limitation was the number of participants, N=35. The number of participants in groups

This study was also limited by type of instrumentation used. Despite being a medical grade hand-held spirometer it was only accurate to .05 liters. Additionally, spirometer was analog, therefore requiring the experimenter to read the volume.

There were several known influencers of VC, MPT, and SFF that were not included in the study. There were no controls for the height or weight of participants which are both known influencers of both VC and F₀ (Boone, McFarlane, Von Berg, & Zraick, 2013). Additionally, the study did not control for the activity levels of participants. The activity level of a participant would be assumed to directly affect VC. Race and ethnic background were not considered in the participation criteria or organization of the data and groups. Race and voice interactions have been suggested by Boone et al. (2011) and Richard (2013).
CHAPTER V

CONCLUSION

5.1 Overview

The purpose of this study was to examine the effects of age on acoustic and respiratory measures and the interaction between VC and MPT. Data analysis demonstrated that there was no statistically significant interaction between MPT and VC, and similarly no interaction between MPT and VC with age. There was however, a statistically significant interaction between age and speaking fundamental frequency. There was a decrease in SFF as a function of age. The knowledge gained from this study is relevant for diagnosis and assessing treatment outcomes using acoustic and aerodynamic measurements.
5.2 Clinical Implications

VC and MPT are measured routinely used by speech-language pathologists during informal assessments and are incorporated within assessment protocols such as the Dysphonia Severity Index (Wuyts, Bodt, Molenberghs, Remacle, Heylen, Millet, Lierde, Raes, & Heyning, 2000). These measures are used by clinicians to make judgments about breath support for speech production. Breathe support has been defined as the reservoir of available air for speech production along with the efficiency of valving and air control at the level of the vocal folds. VC is a measure of the total amount of air available for phonation, while MPT provides a measure regarding an individual’s functional ability to use available air. A large VC paired with a low MPT could indicate that an individual is unable to functionally use all of the air available during a sustained vowel task. Conversely, a low VC paired with a high MPT could indicate a high level of efficiency at the glottal level. This study did not yield a statistical correlation between these two measures, nevertheless, a reduced VC or MPT both reflect an underlying deficit of the speech and respiratory system. Given the results of this study, a clinician cannot measure either variable and reliably assume about the other. It must be noted that any correlations or lack of correlation between MPT and VC in healthy speakers may not be true of those with vocal disorders or other disease processes. When analyzing functional use of voice, MPT is a test of maximum performance; therefore, it might not accurately reflect an individual’s ability to use their voice during everyday speech tasks.
Interest in VC and MPT extends beyond the identification and treatment of vocal pathologies. VC and MPT are of clinical interest for individuals experiencing difficulty with adequate respiratory volume or ability to produce speech for sustained durations during activities such as lecturing, singing, and continued talking. Improvement of VC may result in an individual possessing a larger volume of air to use for phonation. An increase in VC could result in an increased ability to functionally use one’s voice for longer durations and at increased volume. This study’s findings that VC and MPT are not statistically correlated suggest that an individual interested in improving the length of ability to speak should not be primarily concerned with increasing VC.

The lack of correlation between both MPT and VC with age is important for clinicians making judgments about an individual’s speech and respiratory system. The clinician should consider factors such as physiological age, height, weight, and activity levels in addition to chronological age.

Previous research has shown an increase in fundamental frequency with age in males; however this study showed a decrease in speaking fundamental frequency with age. Fundamental frequency is often obtained using a single vowel sound while SFF is obtaining using connected speech. Co-articulatory factors across a speech sample could influence the average fundamental frequency resulting in a lower frequency than when measured in isolated vowel sounds. The result of this study show an age related reduction in SFF similar to that which was displayed in females in Awan (2006). This demonstrates that a reduction in SFF within males is typical with age.
It has also been suggested that perhaps elderly men to attempt to compensate for high-pitched unstable voice (Pontes, Brasolotto, & Behlau, 2005). If indeed men’s fundamental frequency increases with age and the results of this study reflect a compensatory behavior in men. If this is so, clinicians need to consider the results of data collected on measures like SFF considering the possibility of compensatory behaviors, not just physiologic changes.
Despite the clinical reliance on MPT, VC, and SFF during voice evaluations these measures have not been used extensively in the same research design and directly compared to each other. A future study could examine the interaction of these measures in both males and females in the same research design. A future study could group participants based on height, weight, physiologic age, and activity levels. Other parameters of respiratory function could also be included such as phonation quotient and peak expiratory flow. Future studies could incorporate newer digital instruments such as the Phonatory Aerodynamic System and the different respiratory parameters it provides.
REFERENCES


Siupsinskiene, N., & Lycke, H. (2011). Effects of vocal training on singing and speaking voice characteristics in vocally healthy adults and children based on choral and


APPENDICES
Voice Health Questionnaire

Date of Screening ____________  (Filled out by Researcher) Participant ID ____________

Please provide your age ____________

Please circle your level of education:

Below 7th grade education  above 8th grade

1. Are you currently experiencing problems with your voice?
   ☐ Yes ☐ No

2. Do you currently have respiratory problems like the cold, flu, or other upper-respiratory infection?
   ☐ Yes ☐ No

3. Do you currently use any medications shown to have a negative effect on voice?
   ☐ Yes ☐ No

4. Do you have a history of asthma, sinus problems, acid reflux, use antihistamines, vocal fold pathology, emphysema or neuromotor impairment that may impact the voice?
   ☐ Yes ☐ No

5. Have you ever sought treatment for a voice problem or voice disorder?
   ☐ Yes ☐ No

6. Have you had any previous voice surgery?
   ☐ Yes ☐ No

7. Have you used tobacco consistently in the past 5 years?
   ☐ Yes ☐ No

8. Are you a professional or trained singer?
   ☐ Yes ☐ No
8. Do you consider yourself physically active?

☐ Yes ☐ No

If so, how many hours a week do you spend exercising (walking, jogging, lifting weights, sports etc.) ________________
APPENDIX B

Consent Form

Dear Participant:

My name is Mark Selen and I am a student in the master’s program in speech language pathology at Cleveland State University working with Dr. Violet Cox. I am studying voice and breathing measures in typical males in order to provide me with information about changes in the male voice. The purpose of this investigation is for others to learn how the male voice changes with age in order to contribute to the body of knowledge about the aging voice, as well as, to provide information for the diagnosis of voice disorders and make treatment recommendations. In addition to signing this form you will also be asked to fill out a consent form to determine if you meet the participant guidelines.

There are no known risks for participating in this research project beyond those associated with daily risks of living.

Participating in this project will take approximately 30 minutes once in the Voice Lab of the Cleveland State University Speech and Hearing Clinic in MC 429 where the data is collected.

Data collected will be confidential. Your name will not be collected or appear anywhere on the survey and complete privacy will be guaranteed. Participation is completely voluntary and you may withdraw at any time. There is no reward for participating or consequence for not participating.

For further information regarding this research please contact Dr. Violet Cox CCC-SLP at (216) 687-6909, email: v.cox@csuohio.edu, or the student researcher, Mark Selen at (440) 242-5152, email: m.selen@csuohio.edu

There are two copies of this letter. After signing them, keep one copy for your records and return the other one. Thank you in advance for your cooperation and support.

If you have any questions about your rights as a research subject you can contact the CSU Institutional Review Board at (216) 687-3630.

There are two copies of this letter. After signing them, keep one copy for your records and return the other one. Thank you in advance for your cooperation and support.

Please indicate your agreement to participate by signing below.

I am 18 years or older and have read and understood this consent form and agree to participate.

Signature: ___________________________ Date: ______________
APPENDIX C

Scripts

INSTRUCTIONS PROVIDED TO PARTICIPANTS
FOR MAXIMUM PHONATION TIME (MPT)

“Please take in the largest breathe you can and say ‘ah’ using a natural pitch and voice. Hold this sound for as long as possible. You will repeat this for a total of three trials. You may rest as long as you need to between trials.”

INSTRUCTIONS PROVIDED TO PARTICIPANTS
FOR READING THE RAINBOW PASSAGE

“I’m going to give you a short passage to read. Please read the passage at a comfortable pitch, volume, and rate.”

INSTRUCTIONS PROVIDED TO PARTICIPANTS
FOR VITAL CAPACITY

“Please hold the spirometer in your preferred hand. Do not place the mouthpiece between your lips while inhaling. Take in the largest breathe you can and exhale into the spirometer for as long as you can. You will repeat this for a total of two trials. You may rest as long as you need to between trials.”
Rainbow Passage

"When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow."

APPENDIX E

IRB Approval

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Memorandum
Institutional Review Board

To: Violet Cox
Speech and Hearing

From: Bernie Strong (b.r.strong@cuohio.edu, X3624)
IRB Coordinator
Office of Sponsored Programs & Research

Date: December 3, 2013

Re: Results of IRB Review of your project number: #29968-COX-HS
Co-Investigator: Mark Selent, Student
Title: Acoustic and Respiratory Measures as a Function of Age in the Male Voice

The IRB has reviewed and approved your application for the above named project, under the category noted below. Approval for use of human subjects in this research is for a one-year period as noted below. If your study extends beyond this approval period, you must contact this office to initiate an annual review of this research.

By accepting this decision, you agree to notify the IRB of: (1) any additions to or changes in procedures for your study that modify the subjects' risk in any way; and (2) any events that affect that safety or well-being of subjects. Notify the IRB of any revisions to the protocol, including the addition of researchers, prior to implementation.

Thank you for your efforts to maintain compliance with the federal regulations for the protection of human subjects.

---

Approval Category: Expedited (6)
Approval Date: December 1, 2013
Expiration Date: November 30, 2014

cc: Project file
### APPENDIX F

Raw Data for all Participants

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<th>MPT</th>
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<th>SFF</th>
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