ACOUSTIC INDICES OF VOCAL FOLD AGING IN LATE MIDDLE-AGE AND OLD ADULT MALES

by

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INTRODUCTION

The Vocal Folds

The vocal folds are involved in a variety of biological functions including respiration, swallowing, and phonation. They lie within the larynx, a constricted tube with a smooth surface situated above the trachea.[1] The laryngeal framework, which includes cartilage and other connective tissues, provides the vocal folds with structure and connects them to the muscles that facilitate movement.[1] Through muscle movement the vocal folds can be adducted, abducted, elongated, and shortened. These actions by muscles act to open, close, tense or relax the tissue of the vocal folds during voice production, and contribute to the perceptual voice quality of a speaker.

The vocal folds are comprised of five layers of tissue categorized into three functional sections: the cover, transition, and body.[2] The cover includes the superficial epithelium and the superficial layer of the lamina propria. The epithelial layer is only 0.1 mm thick and is made up of squamous epithelial cells which gives the vocal folds a glistening white quality due to the low density of blood vessels within the tissue.[2] The superficial layer of the lamina propria is filled with a viscous, gel-like ground substance which oscillates very easily during vocal fold vibration. Both the intermediate and deep layers of the lamina propria make up the vocal fold transition layer and are composed of elastic and collagen fibers. The intermediate layer consists of many elastic fibers, which allow the vocal folds to stretch and rebound to their original position. The deepest layer of lamina propria is composed of collagen fibers which somewhat resist extension so that the vocal folds are not ripped from their cartilaginous attachments.[2] The body of the vocal folds, or thyrovocalis muscle, serves as the main bulk of the folds, and is able to actively tense or relax the vocal fold cover.[2] These layers are essential in vocal fold function. Anything that changes the microstructure of these layers will also have an effect on voice quality.

Anatomical Effects of Aging

As the vocal folds age, along with the rest of the human body, change is inevitable. Though there is much variation from individual to individual with regards to how aging is manifested in the larynx, vocal fold aging can be so severe that it creates a clinical condition known as presbylaryngis or presbyphonia. Physiological processes which facilitate vocal aging include muscular atrophy, ossification of laryngeal cartilage, and tissue changes.[3] Atrophy results in a thinning of the vocal fold muscle (thyrovocalis), which can cause structural change in the form of bowed vocal folds. This type of change also causes the vocal folds to become stiff and less pliable.[3] When adducted, a gap is left between the folds resulting in a soft, breathy phonation. Muscular changes that result from aging may also reduce pitch range.[4]

Ossification, or hardening of the laryngeal cartilages, also occurs secondary to vocal aging.[5] According to a recent study, the process of ossification can result in the cricoid and arytenoid cartilages becoming hard as an individual ages.[6] Adolescent and young adult laryngeal cartilages are characterized by a white, pearlescent, smooth and shiny appearance. However, in the elderly the laryngeal cartilages can take on a yellow, wrinkled, hard, and dull appearance due to the effects of laryngeal aging.[6]

As the body ages, respiratory function decreases as well. Studies have shown that elderly adults use a larger lung volume to increase subglottal pressure when speaking.[7] This requires more effort from the respiratory muscles. Decreases in an elderly person's functional reserve can make communication difficult. When they are forced to hold out long utterances in conversation, the respiratory system is taxed and vocal performance can be poor.[7]

Perceptual Effects of Aging

The anatomical changes which occur secondary to vocal aging can also result in perceptual changes noted by listeners. Symptoms are characterized by poor vocal projection, roughness of voice, and the inability to hold out sounds for long periods of time.[8] Patients also report that their vocal quality deteriorates throughout the day.[8] Interestingly, these changes are even more prominent in males. While the speaking fundamental frequency (SFF – the physical equivalent of perceived pitch) in women remains constant into middle age and then drops slightly into old age, men's SFF lowers into middle age and then rises again into old age. While aging does not have an influence on the fundamental frequency (F_0) of male adults up to age 50, research has shown that speaking F_o increases in those over 50 years old.[9] As a result, older males are perceived as having a higher pitch than their female counterparts. The elderly male voice is characterized by increased tension and breathiness.[10] Breathiness results from incomplete closure of the glottis. In an attempt to compensate for the gap between the folds, laryngeal tension is increased, adding to breathy phonation.[4] The aging voice is also characterized by excessive airflow and friction at the level of the vocal folds, which creates more noise in the signal.[9, 10]

Perceived vocal symptoms due to aging can be heightened because there is a reduced hearing ability among the aging population as well.[11] Unable to hear their voice loud enough to self-monitor, and because their peers cannot hear them as clearly as they once could, communication can become much more difficult for an individual with presbylaryngis. Research has shown that when there is no auditory feedback, or it has been changed or masked, F_o control is greatly lost.[12] While these changes are normal in the elderly population, specific characteristics such as hoarseness can be due to organic diseases instead of natural aging alone.[8] Voice changes may be a result of benign vocal lesions or polyps, malignant lesions, functional dysphonia, vocal-fold paralysis, or a neurologic disorder.[8] Degenerative disorders such as dementia also decrease communication ability causing impairment of memory, making the person more dependent upon others.[13] A study by Ling et al indicates that smoking results in decreased fundamental frequency, higher jitter and shimmer, and leads to a rough, breathy voice.[14] It has been proven that better overall health has a positive impact on vocal quality in elderly people.[8] Changes effect the elderly population on a personal level as well. Individuals with presbylaryngis often avoid social situations and may have a lower perception of life quality.[8]

Acoustic Analyses

Changes in the voice due to vocal aging can also be measured using acoustic analyses. Increasing instability of vocal fold vibration is a physiological characteristic of the aging voice. Acoustic measures have shown that frequency and intensity perturbation increase in both aging males and females.[8] Additive noise in the acoustic signal produced by aging vocal folds can result in the acoustic measure of harmonics-to-noise ratio (HNR) to decrease. Most acoustic measures used in basic and clinical voice research have relied on computer software which detects vocal fold behavior over time, and these measures are often referred to as "time-based" acoustic measures. Measures such as jitter (frequency perturbation) and shimmer (amplitude perturbation), as well as many types of harmonics-to-noise ratio measures, are time-based measures. Time-based measures have typically been limited to analyses of sustained vowels due to the natural variation of connected speech, which results in irregular voice peaks over time. This causes the computer software to have difficulty accurately detecting where vocal fold vibratory cycles begin and end, which can invalidate the acoustic time-based measurements when applied to connected speech. The same is also true of time-based measures being applied to moderate and severely dysphonic voices, which are also characterized by irregularity in the vibratory cycles over time.

Acoustic measures which rely on elements of the spectrum, rather than time, allow for valid measures even in the presence of an acoustic signal that is highly variable. Through mathematical analysis of the acoustic waveform using Fourier Transforms, measures of spectral tilt and cepstral peak can be calculated in connected speech and moderate-to-severe dysphonic voices.[15, 16, 17] These spectral and cepstral measures rely on calculations of the harmonic and noise energy in the acoustic signal at any point in time, rather than being time dependent. Newer clinical software has allowed for automatic calculations of spectral and cepstral acoustic measures. Although some normative data for these measures is available, no study to date has specifically applied spectral and cepstral measures to study vocal aging in a cross-section of male or female speakers between the ages of 50 to 80 years. This normative data is clinically important if clinicians are going to determine if a patient in their clinic could be considered deviant from what would normally be expected of an individual their age.

Review

In summary, as the vocal folds age they begin to atrophy, or lose mass. They become stiff and bowed in appearance. Unable to close like they once could, a gap is left between the folds resulting in a soft and breathy phonation. The laryngeal cartilages harden and respiration function decreases. Instability of frequency and intensity increases while the ability to hold out sound is diminished. New software, utilizing spectral and cepstral measures, has allowed clinicians to obtain valid acoustic measurements from connected speech and moderate-to-severely dysphonic voices. Normative data for these measurements are lacking, so that direct comparisons of treatment seeking males who are early to late middle age (between 50 and 80) to equivalent age groups is not available.

Purpose

The purpose of this study is to measure the acoustic features of connected speech in male speakers that are between 50 to 59, 60 to 69, and 70 to 79 years of age using these new acoustic measurements. Specific research questions to be asked are: (1) Do spectral/cepstral measurements differ between the three age groups when producing different vowels?; (2) Do spectral/cepstral measurements differ between the three age groups when producing a commonly used clinical sentence?; and (3) Do spectral/cepstral measurements differ between the three age groups when reading a phonetically balanced reading passage?

METHODOLOGY

Participants

Participants in this study were adult males who were recruited into three different age groups between the ages 50-79. There were ten participants from three age groups: 50-59 (mean =54.4, 3.06), 60-69 (mean = 63.6, 2.8), and 70-79 (mean =74.6, 2.8). Inclusion criteria for the participants included (a) no history of diagnosed voice disorders, (b) no history of neurological diseases, (c) no reports of current voice complaints or problems within the last 2 months other than symptoms which might be age related (breathiness or subtle pitch changes), and (d) participants were non-smokers within the last ten years. They were recruited from the local community by passing out flyers around TCU's campus, at churches, and through snowball sampling methods.

Instrumentation

Equipment for this study consisted of the KayPentax (Montvale, NJ) Computerized Speech Lab (CSL) and an affiliated software program. The CSL digitized and recorded analog signals produced by speakers, with input to the CSL from an AKG Acoustics (Northridge, CA) head-mounted microphone. All recorded signals were sampled at 44.1 KHz and saved to a desktop computer. The software program Analysis of Dysphonia in Speech & Voice (ADSV – KayPentax) was used to analyze the recorded signals and collect the dependent variable measurements. Measurements of cepstral peak prominence, fundamental frequency, and the multiparametric measure Cepstral/Spectral Index of Dysphonia (CSID) were acquired from the ADSV software.

Cepstral Peak Prominence (CPP)

According to Heman-Ackah et al, CPP is a measure of periodicity, or variability of vibration in the voice by analyzing amplitude of the cepstral peak.[18] The cepstral peak is the dominant harmonic (a harmonic is called a “rhamonic” in the context of the cepstrum, which is an anagram of “harmonic”), or the harmonic with the greatest amplitude in the cepstrum. The cepstrum is obtained and measured by applying a Fourier Transform to the acoustic waveform, which results in a spectrum, and then applying a 2^{nd} Fourier Transform to the spectrum, which results in the sound energy being displayed in the cepstrum. CPP correlates with perception of breathiness and roughness. A high CPP indicates a more periodic voice.[18] A lack of periodicity results in a rough, breathy voice, contributing to overall dysphonia and a lower CPP.

Fundamental Frequency (F_o)

Fundamental frequency (F_o) represents the average rate of vocal fold vibration. Typical F_o averages for young healthy males and females are 125Hz and 225Hz, respectively. Cepstral/Spectral measures using the ADSV program calculate F_o from the cepstrum. The location of the dominant rhamonics along the X-axis of the cepstrum represents the F_o.

Cepstral/Spectral Index of Dysphonia (CSID)

CSID is a measure of overall dysphonic severity, which incorporates spectral and cepstral measures of the voice, produced by the ADSV program.[19] A mathematical formula is used to combine measures of CPP, the standard deviation of CPP, the ratio of harmonic energy below 400Hz to that above 4000Hz, and the standard deviation of that harmonic energy ratio. Perceptual studies have confirmed that the larger the CSID, the more dysphonic the voice is.

Procedures

All participants were recorded in the Laryngeal Function Laboratory in the Miller Speech and Hearing Clinic. They were informed as to what they would be doing, read and then voluntarily signed a consent form. Once consent was obtained, a head-mounted microphone was placed on the participants. They were recorded saying four different utterances using the Core CSL program (two vowels, one sentence from the Consensus Auditory Perceptual Evaluation of voice [CAPE-V], and the Rainbow Passage). The four recorded stimuli and instructions used to obtain them included the following:

a) Participants produced the vowels /i/ and /u/, with the following instructions:

"*Take an easy breath in, and say the vowel /i/ (or /u/) at a comfortable pitch and loudness, as steady as you can, until I say stop. I will ask you to stop after 5 or 6 seconds*."

b) After being asked to silently read the six sentences of the Consensus Auditory Perception Evaluation of Voice (CAPE-V), participants were asked to produce them with the following instructions:

"*Please read each of these sentences at a comfortable pitch and loudness, just as if you were talking to me in a conversation. Make sure you take an easy breath in before reading each sentence*."

Only the third sentence, "We were away a year ago", was applied to acoustic analysis.

c) After being asked to read the Rainbow Passage silently, they were asked to produce the passage with the following instructions:

"*Please read this paragraph at a comfortable pitch and loudness, just as if you were talking to me in a conversation*."

Analyses

The ADSV program was used to calculate three different measurements from each recorded stimulus: (1) Fundamental frequency (F_0), (2) cepstral peak prominence (CPP), and (3) cepstral/spectral index of dysphonia (CSID). Dependent variables were defined as follows:

Fundamental frequency: The average rate of vocal fold vibration as measured from the location of the dominant rhamonic in the cepstrum.

Cepstral Peak Prominence: The amplitude of the dominant rhamonic in the cepstrum.

Cepstral/Spectral Index of Dysphonia: A multiparametric measure which combines spectral harmonic amplitude data with cepstral peak data to produce a single statistic representing the periodicity of vocal fold vibration.

This resulted in three different ADSV measurements (F_0, cepstral peak, CSID) for four different stimuli (vowels /i/ and /u/, sentence, and paragraph). Table 1 illustrates the stimuli acquired and the measurements derived from them.

Table 1. Dependent Variables

Stimulus (Condition)	Measurements (dependent variables)		
Vowels (/i/ & /u/)	F_o (Hz)	Cepstral Peak (dB)	CSID
CAPE-V sentence	F_o (Hz)	Cepstral Peak (dB)	CSID
Rainbow Passage	F_o (Hz)	Cepstral Peak (dB)	CSID

Inter-measurer reliability was assessed by randomly selecting 80% of the recorded files and re-measuring dependent variables. A Pearson-product moment correlation was applied to the reliability data to assess the degree of relationship between the first and second measurements. To answer the main research questions, four separate one-way between-group analyses of variance (ANOVA's) were applied to the three dependent variables across the four speaking conditions, with Group (50 year-olds vs. 60 year-olds vs. 70 year-olds) as the between subject factor.

RESULTS

Inter-measurer reliability was calculated by re-measuring 80% of the data and comparing it to the initial measures using a Pearson-product moment correlation. Results revealed a very strong correlation at $r=0.987$.

The following describe analytical findings after CPP, F_0, and CSID measures were applied to vowels /i/ and /u/, the CAPE-V Sentence, and The Rainbow Passage in 50, 60, and 70 year-old speakers' voices. Table 2 displays means and standard deviations for all dependent variables across the three age groups.

Table 2. Means & standard deviations for dependent variables

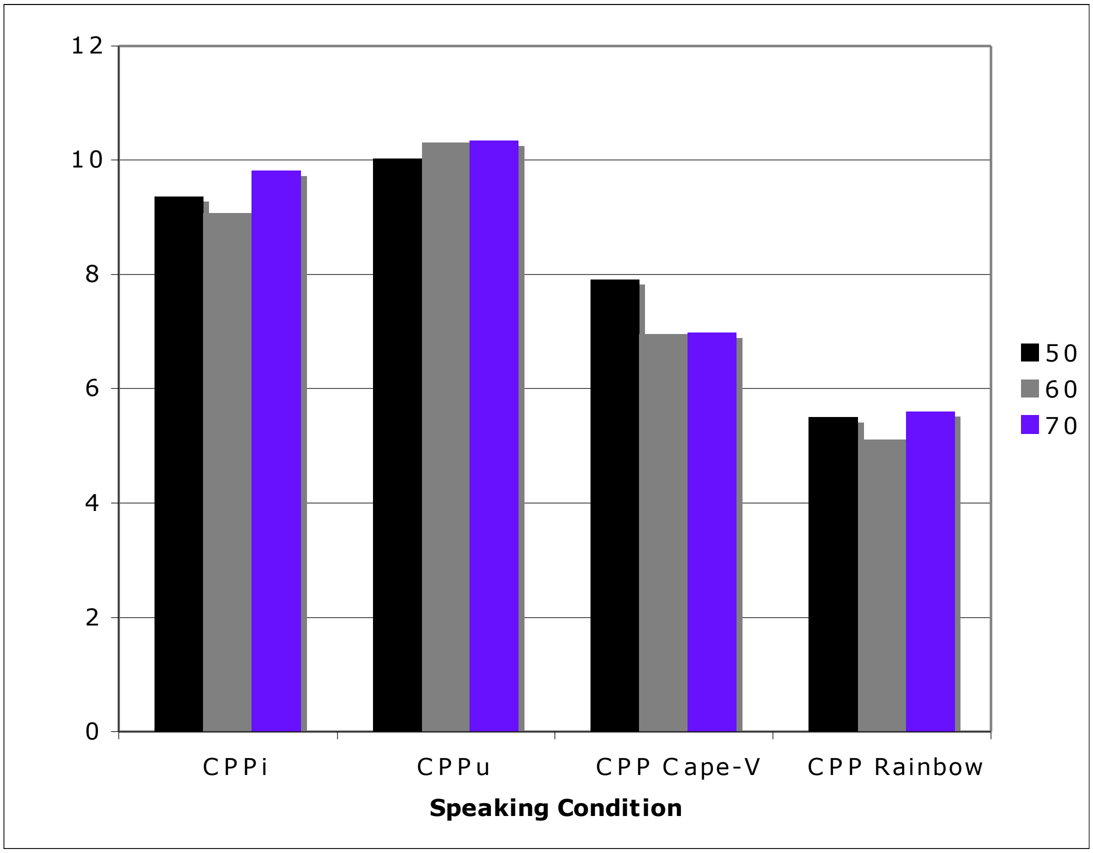
Group	CPPi		CPPu		CPP Sentence		CPP Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
50	9.36	2.0	10.03	1.65	7.91	1.31	5.49	1.14
60	9.07	2.65	10.31	1.92	6.95	1.38	5.11	0.7
70	9.81	1.79	10.34	1.91	6.98	2.32	5.6	1.61
	F_oi		F_ou		F_o Sentence		F_o Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
50	120Hz	16	122Hz	16	127Hz	17	146Hz	18
60	125Hz	14	130Hz	18	132Hz	17	147Hz	9
70	128Hz	27	133Hz	29	146Hz	33	153Hz	29
	CSIDi		CSIDu		CSID Sentence		CSID Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
50	20.96	11.93	12.4	9.67	-8.69	9.77	-6.62	13.78
60	23.04	17.41	9.14	9.81	-2.63	9.62	-6.04	7.14
70	25.66	9.67	10.48	7.92	-4.38	11.28	-3.44	16.13

CPP Analysis

CPP is a measure of periodicity in the vibratory cycles of the vocal folds during phonation. The larger the CPP, the less dysphonic the voice sounds.[18] It was predicted that 70 year-olds would have the lowest CPP, followed by 60 year-olds and 50 year-olds. Figure 1 illustrates the mean CPP scores for each age group in each speaking condition. For vowels /i/ and /u/, and the Rainbow Passage, 70 year-olds had the highest CPP, which did not meet expectations. The 60 year-olds always had lower CPP measures than the 70 year-olds, which also did not meet predictions. The 50 year-olds did have the highest CPP measure in the CAPE-V sentence, and had greater CPP measures than the 60 year olds in each condition except for the vowel /u/. Overall these results indicated no trend in CPP between 50 to 70 year-olds. Figure 1 visually illustrates the relationship between groups on the CPP measure.

Results from the one-way ANOVAs applied to the CPP data in each speaking condition revealed no significant group differences in either /i/ ($F[2, 27]=0.299$, $P=0.74$), /u/ ($F[2, 27]=0.087$, $P=0.92$), the CAPE-V Sentence ($F[2, 27]=0.991$, $P=0.384$), or the Rainbow Passage ($F[2, 27]=0.454$, $P=0.64$).

Figure 1. Means and standard deviations for cepstral peak prominence (CPP) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).

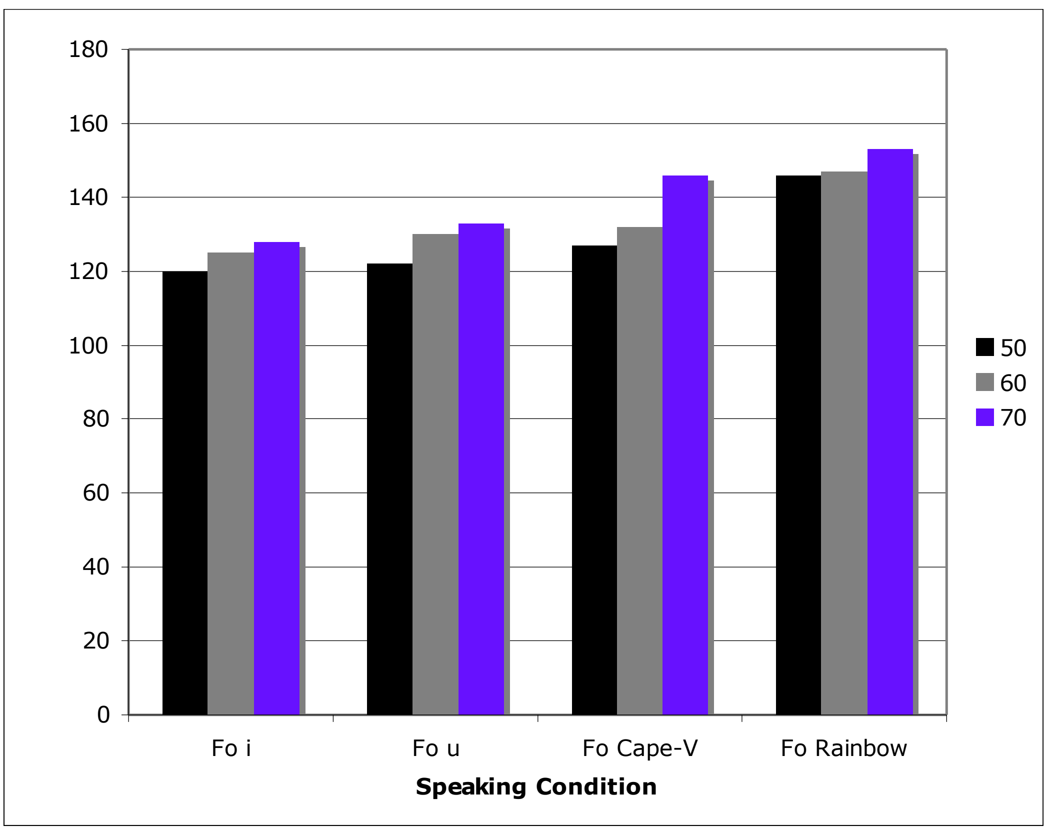


F_0 Analysis

Since speaking F_0 increases in males over 50 years old, it was expected that the F_0 of the participants would rise over the age groups.[9] Figure 2 illustrates the mean F_0 scores for each age group in each speaking condition. The results of the study showed that F_0 increased with age for vowels /i/ and /u/, the CAPE-V sentence, and The Rainbow Passage. The greatest change in F_0 between 50 and 70 year old speakers was only 19Hz for the Cape-V sentence. The smallest change in F_0 for these two groups was 7Hz for The Rainbow passage.

Results from the one-way ANOVAs applied to the F_0 data in each speaking condition revealed no significant group differences in either /i/ ($F[2, 27]=0.428$, $P=0.656$), /u/ ($F[2, 27]=0.59$, $P=0.562$), the CAPE-V Sentence ($F[2, 27]=1.684$, $P=0.205$), or the Rainbow Passage ($F[2, 27]=0.341$, $P=0.714$).

Figure 2. Means and standard deviations for fundamental frequency (F_0) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).

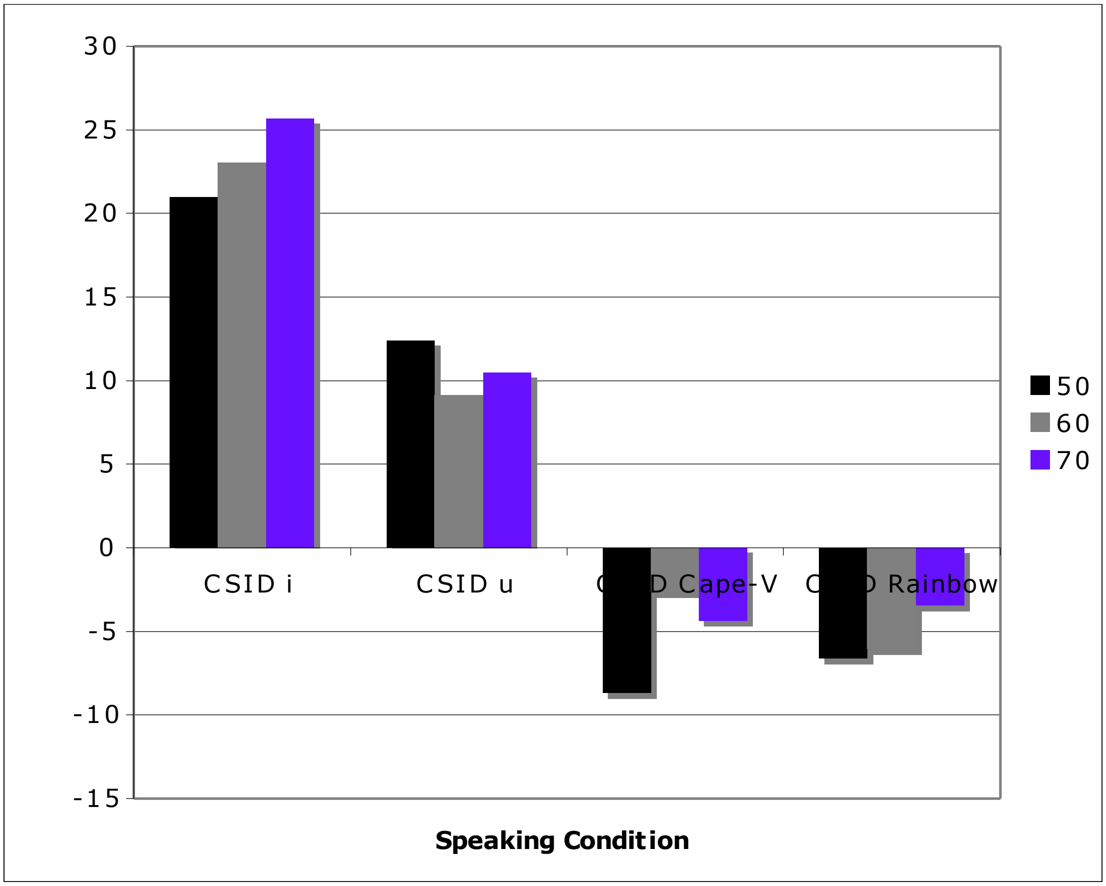


CSID Analysis

A larger CSID, a measure of overall dysphonia severity, indicates a more dysphonic voice. This would indicate less periodicity in vocal fold vibration. It was expected that the 70 year-old age group would have the largest CSID results compared to the 50 and 60 year-old groups. Figure 3 illustrates the mean CSID scores for each age group in each speaking condition. For vowels /i/ and /u/ there was no identifiable pattern across the groups. For the vowel /i/, the 50 year-olds had the lowest CSID results. For the vowel /u/, the 50 year-olds had the highest CSID results. CSID was the lowest in 50 year olds in the CAPE-V Sentence and The Rainbow Passage.

Results from the one-way ANOVAs applied to the CSID data in each speaking condition revealed no significant group differences in either /i/ ($F[2, 27]=0.309$, $P=0.737$), /u/ ($F[2, 27]=0.319$, $P=0.729$), the CAPE-V Sentence ($F[2, 27]=0.925$, $P=0.409$), or the Rainbow Passage ($F[2, 27]=0.172$, $P=0.843$).

Figure 3. Means and standard deviations for Cepstral/Spectral Index of Dysphonia (CSID) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).



DISCUSSION

Summary of Findings

The purpose of this study was to measure the acoustic features, CPP, F_0, and CSID, in vowels (/i/ and /u/) and connected speech (The CAPE-V Sentence and The Rainbow Passage) in male speakers ages 50 to 79 utilizing spectral and cepstral measures.

While F_0 findings followed expected results, CPP and CSID measures resulted in no identifiable pattern. Additionally, none of the data collected resulted in statistically significant information. These findings were surprising, as multiple studies have proven acoustic changes in the aging male voice using time-based measures. Additionally, other studies have validated the use of spectral and cepstral measures in analyzing connected speech and dysphonic voice. There are several hypothesized reasons as to why these results did not meet expectations relating to sample representation, sample size, and attributes of the participants included in the study.

Sample Representation

One factor that may have impacted results is that the sample may have been too representative across the age ranges. How different, for instance, is the voice of a 59 year-old, included in the 50 year-old group, compared with a 60 year-old, included in the 60 year-old group?

To test this phenomenon, data for the five youngest 50 year-olds was compared to data from the five oldest 60 year-olds and five oldest 70 year-olds. The mean age for the modified 50 year-old group was 52, the mean for the modified 60 year-old group was 66, and the mean for the modified 70 year-old group was 77. These ages were statistically different ($F[2, 12]=387$, $P<0.001$).

When statistics were applied to these modified age group samples, CPP for vowels /i/ and /u/, the CAPE-V Sentence, and The Rainbow Passage, was the highest in the modified 50-year-old group and lowest in the modified 70 year-old group. These results met expectations, however, none of the data was considered statistically significant.

F_0 measures also indicated stronger trends in vocal aging. For the vowel /i/, F_0 varied by 19Hz between 50 and 70 year-old modified groups. Vowel /u/ varied by 25Hz between the ages. Likewise, connected speech varied by 36Hz and 29Hz for the CAPE-V Sentence and The Rainbow Passage, respectively. F_0 increased more significantly between the modified 50 year-old and 70 year-old groups, yet remained statistically insignificant.

For CSID measures, data followed expected trends in that modified 70 year-olds had the highest CSID compared with modified 50 year-olds who had the lowest CSID for the vowel /i/, the CAPE-V Sentence, and The Rainbow Passage. The vowel /u/, however, indicated that the modified 60 year-old group had the lowest CSID. Still, in this particular set of data, the modified 70 year-old group had the highest CSID as predicted.

While the results of the modified age groups indicated stronger expected trends, none of the data was considered statistically significant, indicating that not only did representation of the sample impact results, but also the number of participants included in the study.

Sample Size

In this study, thirty participants was not a large enough sample to yield statistically significant results. Power is the ability to determine a statistical difference, if in fact a difference does exist. Calculations of statistical power revealed that the greatest power was in the comparisons of F_0 during the CAPE-V Sentence. Power in this condition was calculated at 0.323, which was very small. Most other calculations of power were below 0.1. A much larger sample size may have more closely reflected the expected trends in data. While some of the expected aging trends were clearly present, especially in the modified age group data, results were not strong enough to indicate a reliable pattern. A sample of 75 participants split into three groups, for example, may have provided stronger trends in data. A group of 300 participants split into three groups, may have provided even stronger trends still, and so on.

Because of high variability between voices within each age group, the thirty selected subjects may not have been representative of the adult male population as a whole.

Individual Voice Differences

Another factor that may have impacted results was the variability of the participants. While there were specific criteria that each participant had to meet to be included in the study, there were limits as far as what could be controlled.

Several of the participants in this study were professors recruited from a university campus. A few other participants were, or had been, singers who received vocal training. One participant had been on the radio for several years prior to this study. These men may have used or trained their voices more than the average adult male in their age range. Results may have been a reflection of these differences.

A study by Wingate et al indicated that professional voice users make up 25 to 35% of the working population in the US.[20] They are also more likely to seek and receive treatment for their voices.[20] However, participants in this study had no history of current or past voice complaints.

While the majority of participants spoke English as their first language, one participant's first language was Farsi, and another's was Spanish. Even though both men spoke fluent English, their voices may not accurately reflect the average adult male's voice.

Conclusions

This study did not find significant differences in measurements of CPP, F_0, and CSID in different speaking conditions among 50, 60, and 70 year-old speakers. There is no debate about whether the male voice changes physically and perceptually with aging. In this study we used cepstral/spectral analyses to obtain the acoustic measurements in male speakers between 50 to 79 years of age. The results of this study somewhat differ from previous research. The use of cepstral/spectral measures may explain this discrepancy, although sample representation within each age group, sample size, and professional voice use in the current sample may also explain the discrepancy. Alternatively, there may not be that much of a difference and the results of this study may accurately reflect reality. Future research will be needed to clarify these issues. A study that monitors the same participants over several years would be the most accurate approach to study the aging male voice.

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ABSTRACT

Objective: To measure the acoustic features of connected speech in male speakers between the ages of 50-79 using new cepstral/spectral measures (F_0, CPP, and CSID).

Method: The software program Analysis of Dysphonia in Speech & Voice (ADSV – KayPentax) was used to analyze vowels and connected speech across three age groups: 50 to 59, 60 to 69, and 70 to 79. This resulted in three different ADSV measurements (F_0, cepstral peak, CSID) for four different stimuli (vowels /i/ and /u/, CAPE-V Sentence, and The Rainbow Passage).

Results: This study did not find significant differences in measurements of CPP, F_0, and CSID in different speaking conditions among 50, 60, and 70 year-old speakers.

Conclusions: Results may be due to the use of cepstral/spectral measures, sample representation within each age group, sample size, or professional voice use in the current sample. Alternatively, there may not be a true difference between 50, 60, and 70 year-old speakers and the results of this study may accurately reflect reality. Either way, future research is needed.