The Effects of Singing on Speech in Geriatric Voice

An Acoustic Study

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Honors Thesis

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The Effects of Singing On Speech In Geriatric Voice

Singing is often cited as offering biological and psychological benefits. Some examples are: 1) alleviating anxiety through the regulation of the heart beat and releasing of endorphins, a chemical that works with receptors in the brain to minimize the perception of pain (Horn, 2013, Sadler, 2015). 2) The releasing of oxytocin, a hormone that is linked to feelings of contentment, calmness, security and memory function (Horn, 2013). 3) The reduction of cortisol, an adrenal hormone that is known to reduce stress (Horn, 2013). 4) An increase in amounts of cytokines, small proteins that influence cell signaling (Horn, 2013). However, it has yet to be proven thoroughly that singing affects speech. (Linville, 2001, Mendes, 2004)

As a professional singer and a vocal coach, I have regularly perceived longitudinal changes in my students' speech alongside their improvements as singers. Singing and speech share the same anatomy: the respiratory system, the larynx, the vocal tract, the nasal passage, language and brain function. Whether singing can be proven to impact motor control of speech, breathing, articulation and brain function is a question I have wanted to answer to for many years.

Scientifically, it has been noted that the voice undergoes many changes with age, most of which occur more intensely after 65 years of age in men and after menopause in women. Changes include reduction in pitch for women and an increase in pitch for men, decreased volume, voice breaks (or creaky voice), increased breathiness, vocal strain and hoarseness and overall, the aging human tends to see a decline in vocal function (Linville, 2001 and Sebastian et al, 2008). Anatomical changes in the lungs, chest wall and thoracic skeleton lead to physiological changes related to breathing which affect speech (Linville, 2001). Considering that the population of the United States is facing the largest volume of retirees in history: expected population 83.7 million by 2050 compared with 43.1 million in 2012 (*U.S. Census Bureau, 2010*), if singing training can improve motor control of speech, breathing, articulation and brain function, then singing could be influential in improving and maintaining language function for the elderly.

To speak of long term benefits in working with the elderly, I see potential for the development of speech therapies through singing. I also see a thread between this research and cognitive processes of aging and fine motor control in the adaptation to physical changes of one's body. A large motivating factor in conducting this research is to get closer to the fundamental details that may assist in paving the way not just for improved speech in the elderly, but for repairing speech as well. For example, studies investigating music and the brain with respect to language speak of an emotional component connected to long-term memory, but prove that there is validity to singing for improved mental recall for those with Alzheimer's and dementia (Maguire, 2013). My grandfather suffered from Alzheimer's disease. English, his second language was lost early on, but he maintained his native dialect of Paternese[1] until quite late. After this faded, he didn't speak at all, but could still sing in Paternese. If singing can stimulate these same articulators and muscles that we use for speech through the use of long term memory and song, it would be interesting to see if singing can reach more mechanical uses of the same functions for speech through singing training. If it is possible to improve speech through singing, then it brings us closer to tools with which to repair speech

[1] Dialect found in Paternopoli, located in the Campania region of Italy.

[2] The singer's ring or singer's formant is a proven phenomenon that refers to the way sound energy of the professional singing voice is able be distributed across various frequencies. (Sundberg, 1970)

[3] H_2O measurements reference the use of U-Tube Manomenter, which uses water levels

function associated with Alzheimer's disease and other degenerative diseases that impact speech through hemispherization and neuro-linguistic programming.

We know that breathing is required to sustain life. The act of respiration delivers oxygen to the body and expels carbon dioxide. Therefore, breathing is crucial to the body's circulation and regulating fluids in the body. Breathing requires the use of the lungs, along with the anatomical features included therein: the trachea, bronchi, bronchioles and alveoli, the nasal passage and the oral cavity. There are at least ten muscles that can be engaged in inhalation and eight for exhalation. Inhalation involves the following muscles: diaphragm, intercostal muscles, scalenes, pectoralis minor, serratus anterior, sternocleidomastoid, levator costarum, upper and superior trapezius, latissimums dorsie and subclavius. Exhalation involves the internal intercostals, obliquus internus, obliquus externus, levator ani, triangularis sterni, transversalis pyramidalis and rectus abdominus (Bartelby, pg 383). (Appendix #6 and appendix #7). Breathing is integral to the production of voice, and its function is largely unconscious. Meaning that while there may be times where breahting is a conscious act, in general, one doesn't consciously inhale and exhale for each breath nor does one consciously inhale for each utterance. The movement of air (gas) through the larynx, the pharynx and the mouth allows for phonation. In sum, without breath, one cannot speak. To deepen the importance of this, strength of exhalation can influence speech factors such as; f0 (pitch), intensity (volume), speed, fluidity and motor control of speech.

In order to test whether or not singing can impact speech I worked with a group of senior citizens at the South Berkeley Senior Center. I conducted a pre-test/post-test experiment over the course of two months. My motivation was to test whether 8 weeks of singing could alter the aging voice in any quantifiable way. This was an acoustic study and I see this as a base study with which to build from for future studies that hopefully will lead to testing the aforementioned complex questions.

My theory is that regular and repetitive singing training, with an emphasis on thoracic breathing and articulatory tension exercises, would improve strength of exhalation, motor control of speech, see a decrease in jitter and shimmer, an increase of harmonics to noise ratio (HNR) and alter the fundamental frequency of one's speaking voice through engaging the respiratory system and the vocal tract in regular exercise.

II – Background/Literature Review

Literature reviewed for this study, comes from papers, articles and books on singing technique, singing therapy, acoustic studies of speech related to and unrelated to singing and geriatric voice. The most salient findings are outlined here in order of relevance to this study. Linville's (2001) "Vocal Aging" lays out several effects that aging has on the anatomy of the elderly. In particular, breathing for speech has been proven to be a significant age related deterioration due to loss of tissue elasticity and muscle weakening. Thoracic cavity stiffness along with loss of respiratory muscle strength causes the whole system to become impacted over time. Laryngeal tissue weakening also coupled with muscle weakening causes the adjustments required for pitch levels, vocal fold positioning and vibration to be affected. Articulatory gestures of tongue and lip movements, in conjunction with the timing of supraglottaic and glottic action for voiceless stop production are often slower. Laryngeal muscle weakening lowers the larynx which leads to weakened pharyngeal musculature, which shortens the duration of vocal fold vibrations during the closure for voice onset time (13). Linville (2001) presents this as the "weakening and stiffening" model of aging and adds that while this is valuable it does not always account for gender differences, environmental factors and cultural differences, and while these factors can be significant, the full story is still unclear. Tay, Phyland & Oates (2012), 'The Effect of Vocal Function Exercises on the Voices of Aging Community Choral Singers' found that vocal exercises do have the potential to mitigate the effects of vocal aging physiologically. Their study was conducted over five weeks and the findings were deemed preliminary yet showing potential. Tay et al. measured maximum phonation time through long sustained [a] sounds and phonatory stability components such as breathiness and hoarseness. With respect to the vocal methods for teaching singing, they conducted this study using a system of voice technique designed by Stemple et al (1995) called Vocal Function Exercises, (VFE). A practice regimen of exercises for singers, it is described simply as "a series of voice manipulations that were designed to strengthen and balance the laryngeal musculature and to balance airflow to the muscular effort. It is a systematic program of exercises targeting therapeutic and rehabilitative effects on voice production." Once taught the exercises, the subjects were left to their own devices to study and practice, with scheduled sessions on four occasions throughout a 7 week study, with 5 weeks only of vocal practice. After 3 weeks of initial "at home" practice, there was a 30- minute check in with a speech pathologist. Five weeks is a relatively short time to accomplish any vocal training success in general, but especially without more regular one to one instruction. The fact that this study was predominantly self-guided and that it still showed improvements among the experiment group compared with the control group is very encouraging. Professor Julene Johnson, PhD a cognitive neuroscientist at UCSF is currently working on a study called *Community of Voices*, a 5-year longitudinal study that will examine whether singing in a community choir is a cost-effective way to promote health and well being among culturally diverse older adults. The goal of this study is to compare physical strength, balance, memory and emotional components of those in the study versus those who are not. In an interview with SF Gate, Johnson stated, "Scientific study on the benefits of singing is still in its infancy, but a meta-analysis of the available research found that singing can activate certain regions in the brain and strengthen neural connections." (May, 2103)

A speech and singing study conducted by Mendes et al. (2003), "Effects of Singing Training on the Speaking Voice of Voice Majors" found no conclusive evidence that singing improves speech. Here the subjects were college students, but it was relevant for comparison, methodologies and general data for what is known of this hypothesis. However, this study also does not report on what was offered in terms of voice training. Also, I would propose that the results might have been more profound in participants who are experiencing decreased language function or less fine motor control in their speech muscles.

An interesting study to understand differences between the speaking voices of people who sing, compared with the speaking voices of those who don't was led by Barrichero et al. (2000), "Comparison of Singer's Formant, Speaker's Ring, and LTA Spectrum Among Classical Singers and Untrained Normal Speakers." This study recorded subjects producing a low sustained [a], along with a reading of 'The Rainbow Passage' and compared singers and non-singers' vocal tract resonant frequencies as well as frequency of vocal fold vibration and found that there is value in singing training on the resonance of the speaking voice and that singers' formants had more energy concentration in the spoken vowel area. Barrichero concluded, "… our singers' spoken vowels were different from the non-singers' spoken vowels. Further study of the effects of [ed] singing training may demonstrate that such training is helpful in producing more resonant voices in voice-disordered patients" (349). While this study was not focused on the "singer's ring"[2] area, it was helpful for the pilot study, in the consideration of formants and how they may alter the speaking voices of singers versus non-singers. It

[2] The singer's ring or singer's formant is a proven phenomenon that refers to the way sound energy of the professional singing voice is able be distributed across various frequencies. (Sundberg, 1970)

was surprising that there was no indication that the pitch selected for production of [a] was systematic for each recording. To understand how singing may benefit speech, for this research I used, documented and referenced pitch information in held vowels. A perception study conducted by Rothman, et al. (2001) out of the Department of Communication Sciences and Disorders, University of Florida, Gainesville, Florida in 2000, "Acoustic Analyses of Trained Singers Perceptually Identified from Speaking Samples." proved what I had hoped to find in my pilot study, and that is that singers had more variation in their f0 than non-singing speakers and also, had longer duration in intervocalic segments. This study determined that perceptually, people who took this test could determine from the speaking voice, who was the singer and who was not. This suggests that singers' formant structure can be detected by their speech.

To look at studies for singing as therapy, the Music Therapy Department at the Melbourne Conservatorium of Music led by Tamplin, Jeanette, et al (2014) conducted a study, "The Effect of Singing Training on Voice Quality for People With Quadriplegia." This involved 24 subjects over 12 weeks with a pre test, post test and follow up test and found that the singing training affected voice projection and phonation length, however the perception of these factors did not change significantly for either the control group or the experimental group. Ultimately it was not concluded whether singing training affects these variables for quadriplegics, which may have been a by-product of the small sample size or the short amount of time to impact change through singing in general, but also a short amount of time with which to work with a population who do not have control of their muscles below the neck region. However, as quadriplegics suffer from similar voice issues to geriatrics, this study was valuable to look at existing therapies and consider how my findings might be able to support other populations in the future.

Further looking into geriatric voice, a study to come out of India by Sebastian et al. (2012) “Acoustic Measurements of Geriatric Voice Across the Age of 60 -80 Years Old” whereby they measured f0, F1 & F2, jitter and shimmer. The main finding of this study was the difference of the f0 in geriatric voice when compared with 18 – 25 year olds. In females, the mean of f0 was 187.48Hz for 60 – 80 year olds and 228.26Hz for 18-25 year olds. For males, f0 was logged at 140.28Hz for 60 -80 year olds and 131.62Hz for 18-25 year olds. However they found no distinct differences in f0 between the ages of 60 – 80. They did find, loss of elasticity of lung tissue, weakening of respiratory muscles and stiffening of the thorax, which will alter the lung volume and has an effect on phonation. This study was helpful in terms of further analyzing the issues documented in geriatric voice and confirmed that females sees a decrease in pitch where men see an increase, but the methodology of the study seemed unproductive for analysis. They took the 40 participants and divided them by gender, which is fair, but then divided them by age brackets of five years, which resulted in very small sample sizes for each group. The data might have been more robust and telling had they analyzed the 20 men and 20 woman as two groups rather than eight.

The literature on singing unearthed an unusual study by Schutte, Harm. et al (2003), “Change in Singing Voice Production Objectively Measured”. This was a longitudinal study conducted on one subject over the course of 20 years. The study measured the higher values of sub-glottal pressure in tenor singing analyzed at 30 years old and then again at 50 years old. Sub-glottal pressure for conversational speech when objectively measured is 7 to 10 cm H_2O[3], for loud speech around 10 to 12 cm H_2O but for shouting it is raised to around 40 cm, which more closely resembles singing in the tenor range, which reaches 40 to 70cm according to Schutte (2003). Sub-glottal pressure reflects a difference in pressure between the atmosphere and the pressure in the trachea. Sub-glottal pressure is an area often addressed in singing, because of the greater use of pressure required. Measuring sub-glottal pressure and the changes from one age to another is helpful when considering the affects of phonation. While Schutte's methodology may seem outside the box for this study, it offered some nice details about vocal techniques and how the changing of one, had an impact on the changes in pressure. It was also informative that a trained professional singer, showed a substantial difference in measurements from 30 years old to 50 years old. With rigorous and dedicated training, he still lost strength in his ability to sustain high levels of sub-glottal pressure, which confirmed some deterioration factors of geriatric voice with attentive singing not having an impact.

Lastly, in order to review human anatomy as it pertains to voice production, and to better understand how this differs from speech to singing, the literature of Brad Story and Dr. Richard Miller were imperative. Story's (2016), "The Vocal Tract In Singing" is an excellent source to refresh the science of phonation, but in parallel terms with speech and singing. Findings I found interesting were the outline of singing and speech mechanics and how both of these disciplines require an individual to morph existing anatomical structures that are required to perform tasks such as speaking, breathing, chewing and swallowing to controlled singing tasks. Singing tasks such as, vowel

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[3] H_2O measurements reference the use of U-Tube Manomenter, which uses water levels to measure pressure differences.

manipulation, pitch control, breath management, volume and tone. These features, which Story (2016) says, "define singing" are expressed through "the precise control of the vocal tract during vowel production." Furthermore, vowel identity is "largely based on the first two formant frequencies" (Peterson & Barney, 1952; Hillenbrand et al., 1995), and what we usually refer to as "timbre," is represented in the upper formants F3, F4, and F5 (Story, 2016). This helped me to understand more clearly the Barrichero paper on the singer's ring or singing formant structure as being controlled by an amalgamation of these formants. If we think of this area as F3, F4 and potentially F5 as being attracted to the first resonance frequency of the throat cavity, (aka epilaryngeal resonator, pharyngeal cavity, epiglottal funnel etc.), Story states, "Thus, the term "singing formant" or "singer's formant" (figure 1) must not be thought of as a vocal tract resonance, but rather a special case where several resonances occupy a similar region of the spectrum." Richard Miller (1996), "The Structure of Singing – System and Art in Vocal Technique" was invaluable to read with fresh eyes, eyes that have since studied phonetics and had experimented with acoustic and articulatory data. Miller, who was a professor at Oberlin College Conservatory of Music noted something that supports my hypothesis; the need for using one's voice like a well oiled machine is tantamount to keeping the voice healthy and alive, "if one keeps the voice going, daily, it will reward one, whereas inactivity will produce nothing but silence" (239). Working with the seniors, many reported living in

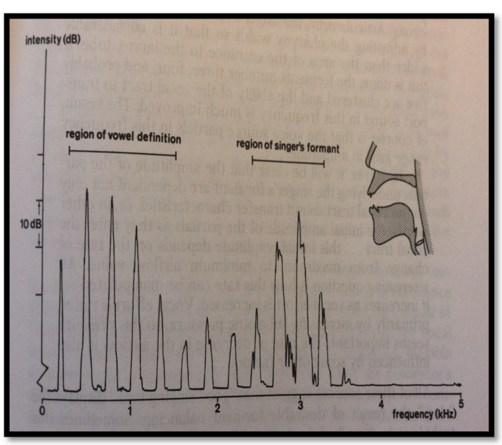

Figure 1: The Singer's Formant or The Singer's Ring as discovered by Johann Sundberg (1970) whereby the frequencies around 3000Hz mirror f0 and F1 more closely.

silence, and the mere use of their voice on a daily basis was enough to affect change.

Miller's (1996) anatomical review piqued my interest as I moved forward to work with geriatrics. Especially the section on the infrahyoid muscles, sometimes known as the laryngeal depressors. These muscles are responsible for lowering the larynx and consist of the sternohyoid muscle, the sternothyroid muscle, the omnihyoid muscle and the thyrohyoid muscle. The sternohyoid muscle is connected to the posterior surface of the manubrium of the sternum, the sternoclavicular ligament and the medial end of the clavical (251), and inserts into the border of the hyoid bone at the lower end. It depresses the larynx and the hyoid bone, and then, if and when the hyoid bone is fixed, it raises the sternohyoid bone, thus raising the sternum. Something that beginning singers find hard to do, is keep their sternum raised, and therefore, according to this description of the musculature of the larynx, if the sternohyoid is not strengthened than the hyoid bone cannot be fixed and the sternum will not stay raised during exhalation. Breathing, or exhalation, is influenced by the strength of the laryngeal depressors and laryngeal depressors influence pitch and motor control of speech. The other muscles listed, work alongside the sternohyoid muscle, working together like an elevator, to move the larynx up and down. If the ability to keep the sternum in a raised position aids with elevating the larynx, it would no doubt have an effect on the ability to vary one's f0 and would improve control of the muscles that control and support the vocal folds. Additionally, if enhanced control to lift and lower the larynx, aids to keep the sternum raised, then singing, (which directly builds control of larynx muscles and respiratory system) would improve breathing in tandem. Considering Linville's (2001) 'weakening and stiffening' model of aging whereby the laryngeal muscles weaken, thus lowering the larynx, perhaps the activation of a larger set of muscle groups, the sternohyoid, the sternocleidomastoid and the triangularis sterni could support this deterioration, and help lift the larynx.

III - Pilot Study

Pilot Study - Acoustic Measurements of Speech - Singers and Non-Singers

This pilot study analyzed differences in the speech of singers versus non-singers. The intention was to test methodology and to find results that would guide analysis of the data I would collect from the seniors.

The Subjects: Five females and four males attended the study, which was conducted in the Phonology Lab at UC Berkeley. Subjects were labeled M_X and F_X for anonymity[4]. All subjects were speakers of American English. Of the four males, two reported themselves as singers; M_2 and M_3 and two as non-singers; M_1 and M_4. M_2 and M_4 were both between 30 - 35 years of age, whereas M_1 and M_3 were between 20 - 25 years of age. Of the five females, three reported themselves as singers; F_1, F_2, F_3 and two did not F_4 and F_5. Of the female subjects, F_3 was between 30 - 35 years of age and others were between 20 and 25 years of age. Subjects completed a short questionnaire asking about their singing status (Y/N) and if Y, filled out a detailed timeline of their training. Information regarding any throat or voice issues (dry throat, phlegm etc.) and of any previously diagnosed throat issues such as polyps or nodules was also recorded, of which there were none. The singing aptitude of each subject was not tested and at no point did any of the subjects sing, engage in a vocal lesson, warm up their voices for the task or discuss singing during the study. When producing sustained vowels, all subjects were asked specifically not to think about singing. Their declaration of being a singer was taken on good faith, as was the declaration of being a non-singer. This is an important distinction to the research due to the fact that there are singers who

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[4] Female subjects had an underscore as a way to distinguish between two definitions: F_1 = female subject 1, F1 = Formant 1

are not trained and singers who are, and one is not necessarily better than the other. What interests me for this study is how often a person "trains" their voices through systematic practice and what results this may produce for singing and for speech.

The Experiment: Subjects were asked to complete 3 tasks; 1) Read the first verse and chorus lyrics of The Beatles' song 'Imagine'. 2) Sustain the vowels [i], [u] and [a] for as long as possible and 3) Read a short passage about the *7 Towers of Kahroun* which was approximately 8 sentences long. For analysis in R studio and Excel, *singer* was given the value of 1 and *non-singer* was given the value of 0 and *Male* or *Female* accounted for gender. The data was analyzed in Praat for vowel duration in seconds, vowel intensity, range of f0 in individual subjects, consistency of formants in the sustained vowel and length of VOT was measured for certain stop consonants. No statistics were analyzed.

The Results: I will not report on the results for intensity, consistency or any measurements take for F1 or F2. These results did not produce any systematic differences between singers and non-singers worth noting and were not ultimately useful for this thesis. I will report on the results for f0, length of vowel production and length of VOT. To measure f0, the mean was taken from the mid point of all the sustained vowels, and for singers (figure 2) f0 was naturally higher than for non-singers, however the range of values was greater for non-singers than for singers. Plotting the same f0 information by gender, singer vs non-singer (figure 3), was more revealing than the previous plot because we can distinguish between genders,

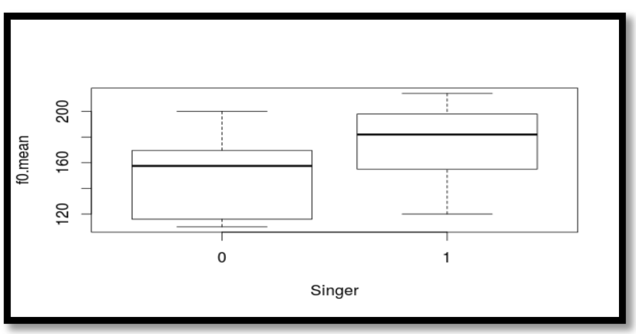


Figure 2: Shows the mean of f0 on the y-axis 158Hz for all 3 vowels. All non-singers (0) compared with all singers (1) on the x-axis 180Hz.

which would have a direct affect on the f0 results.[5]

According to figure 2, female singers showed a greater difference between non-singers in their mean of f0 than male subjects. Male singers showed slightly lower f0 than female singers when compared with their non-singer counterparts and again, this plot depicts all vowels collectively. In geriatric voice, it has been noted that women's natural f0 lowers with age, whereas men's natural f0 rises with age (Sebastian, 2012). This finding might speak of benefits to singing for maintaining a healthy f0 through the aging process for women.

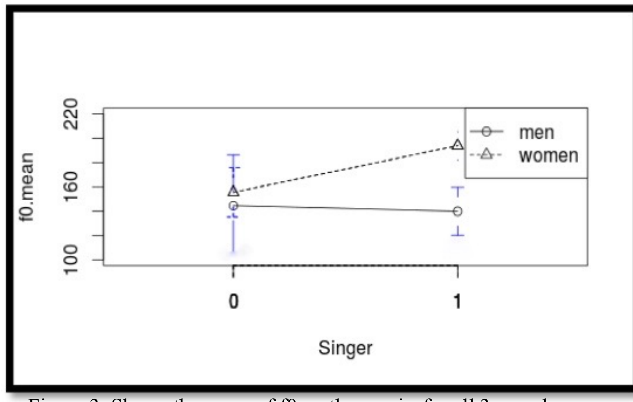


Figure 3: Shows the mean of f0 on the y-axis, for all 3 vowels separated by gender and non-singers (0) and singers (1) on the x-axis. 0 = 145Hz men and 158Hz for women and 1 = 140Hz men and 190Hz for women.

To assess whether or not there was one particular vowel causing these results I separated the data by vowel. Figure 4 shows the mean f0 for each of the three vowels; [a], [i] and [u] and is separated by *Female* and *Male* for the non-singers and figure 5 shows the same data for the singers. For

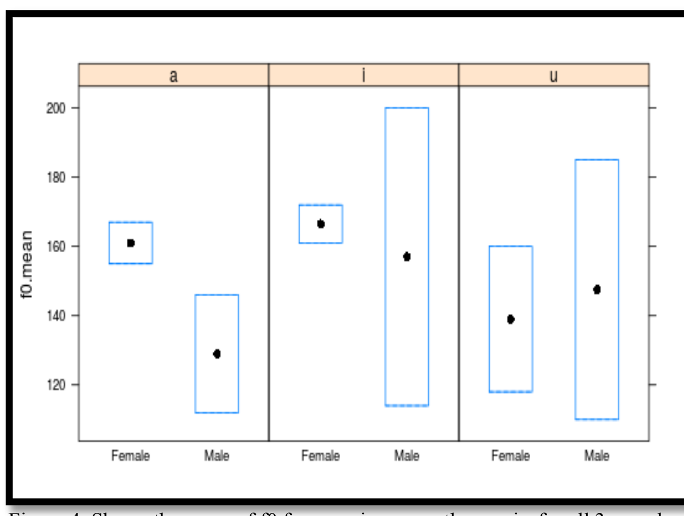


Figure 4: Shows the mean of f0 for non-singers on the y-axis, for all 3 vowels [a], [i] and [u]. Gender is separated on the x-axis. f0 = [a] 160Hz for females and 130Hz for males, [i] 168Hz for females and 158Hz for males, [u] 140Hz females and 148Hz for males.

5 There were an uneven number of female participants and therefore one more singer (1) than non-singer (0).

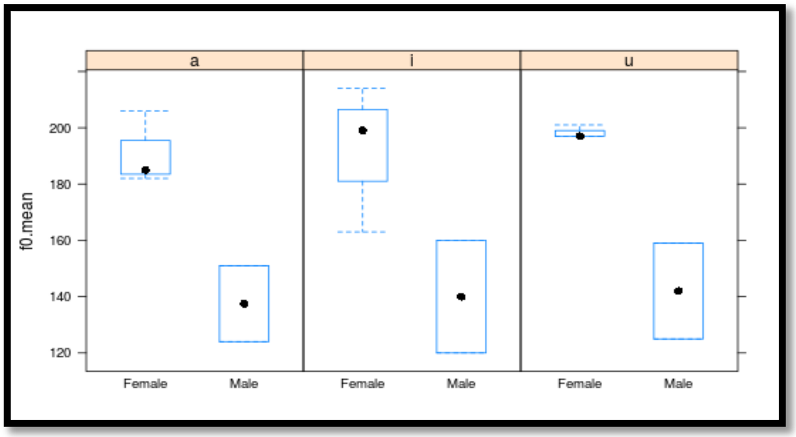


Figure 5: Shows the mean of f0 for singers on the y-axis, for all 3 vowels [a], [i] and [u]. Gender is separated on the x-axis. f0 = [a] 185Hz for females and 138.5Hz for males, [i] 200Hz for females and 138Hz for males, [u] 199Hz females and 145Hz for males.

[a], the f0 mean for female non-singers was 162Hz, for singers it was 185Hz. For male non- singers it was 130Hz and for singers it was 138.5Hz. For [i] the f0 mean for female non-singers was 168Hz and for singers it was 200Hz. For male non-singers it was 165Hz and for singers it was 138Hz. Lastly, for the vowel [u] the f0 mean for female non-singers was 138Hz and for singers it was 199Hz. For male non-singers it was 148Hz and for singers it was 145Hz.

The results of f0 show that the female subjects were more in line with my hypothesis, that singers would have a naturally higher f0, whereas males showed less of a difference, and with respect to [i] an inverse difference, which shows a higher f0 in the male non-singers than the singers. Given that men naturally have a lower f0 and in terms of singing, therefore naturally have more of a chest voice than women, (i.e. a lower pitched range overall with little to no head voice[6] unless cultivated) this is not surprising.

[6] The higher singing registers are often referred to as head voice, falsetto, loft voice or upper register.

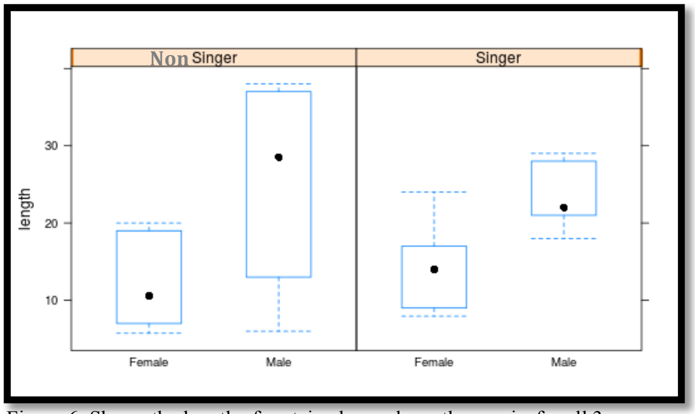


Figure 6: Shows the length of sustained vowels on the y-axis, for all 3 vowels [a], [i] and [u]. Gender is separated on the x-axis. Mean duration for female non-singers and 11seconds and for male non-singers 28seconds. For female singers,14 seconds and for male singers 22seconds.

Next I separated the data by gender and singer (figure 6). The square on the left is *non-singer* and the square on the right is *singer*, but the vowels are collective, (knowing now that the higher values will come from [u]). Overall it looks as though the male non-singers for this study had better ability to sustain their breath throughout the duration of the vowel, when compared with the singers. Male non-singers show that they are sustaining vowels for upwards of 40 seconds with a mean of 30 seconds, whereas the male singers are below 30 seconds and the mean is closer to 20 seconds. Female singers were slightly above in duration than non-singers for [a] and [i] and 5 seconds above for [u]. On further investigation I looked at duration of vowels within the sub-population of non-singers, to see if this was collective or the result of one subject in particular. Results are shown here in table 1.

As this table will reflect, subject M_1 was the cause of the higher numbers in the mean data seen for male non-singers. Curious as to why this may be, I consulted the questionnaires. M_1 reported musical ability, he dances, plays the drums and he raps.

Length	M_1	M_4
a	38	20
i	37	13
u	37	6

Table 1: Shows the actual length of sustained vowels by each vowel [a], [i] and [u] for M_1 and M_4 (non-singers).

Even though M_1 listed himself as a non-singer, being a rapper is a grey area that wasn't considered. What this means is that he does use his voice in a musical way and while the pitch range within which he uses it is most likely less than a trained singer, it does suggest that he exercises his voice more regularly than a non-singer, strictly speaking, and does manipulate his voice to pitch for musical reasons. There may also be a need to account for things like physical fitness and other extracurricular activities that require strong breathing in the questionnaire, like swimming, running, etc.

It has been noted in previous findings that trained singers have longer VOT, due to enhanced breath support and increased lingual pressure (supra-glottal) (McCrea and Morris, 2005). VOT was measured for voiceless stops [p], [t], [k] from segments taken from both pieces of prose. From The 7 Towers of Kahroun (appendix 1) [p] was measured from '*and a park*' which was the last word in the last sentence of the piece, [t] was measured from '*after the conversion of towers*' in the middle of a sentence in the middle of the piece and [k] was measured from '*a coffee shop*' which was the beginning of a list, found about two-thirds into the piece. From Imagine (Appendix 2): [p] was measured from '*imagine all the people*' which was the last word in the fifth line of the 1st stanza, [t] was measured from '*and no religion too*' which is the last word of the fourth line of the 1st stanza and [k] was measured from '*imagine there's no countries*' which is the last word in the first line of the 1st stanza.

Overall singers did have longer VOT as is reflected in figure 7 on the next page, which supports the theory that singers do have longer VOT.

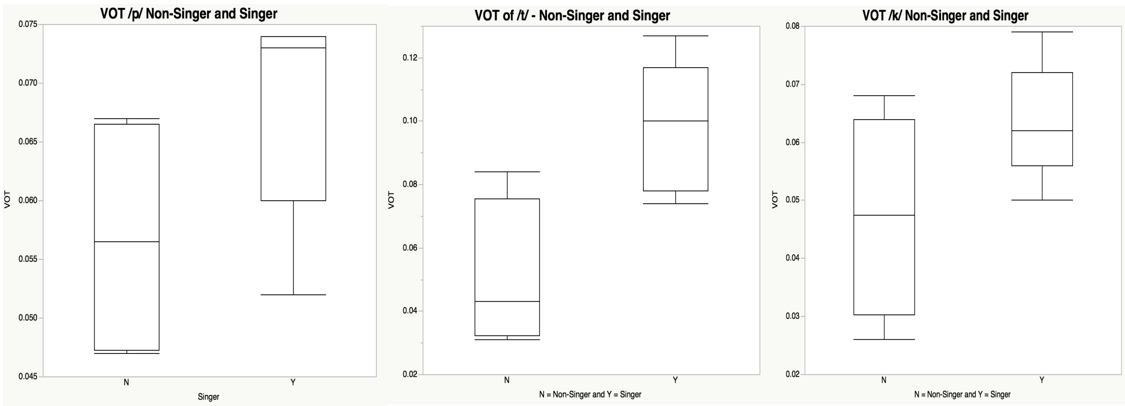


Figure 7: Shows the mean length of VOT for /p/ (left), /t/ (middle) and /k/ (right) on the y-axis. The x-axis shows N = Non-singers (left) and Y = Singers (right). /p/ N = 0.0556, Y = 0.074. /t/ N = 0.043, Y = 0.10. /k/ N = 0.048, Y = 0.062.

<u>Conclusion:</u> As previously stated, several points that were analyzed in the pilot study were not reported here. Results that were useful in preparation for my experiment with the seniors: female singers had a naturally higher f0 than non-singers but male singers did not exhibit great differences in f0 when compared with non-singers. Other than one subject, who may be an anomaly, all singers had longer duration of vowel production than non-singers and all singers had longer VOT than non-singers.

In preparation for the next phase of study with an elderly population, the pilot experiment assisted me in better preparing for the pre-test and the post-test design. The ability to test the methodology of the experiment was profoundly useful and helped me to gain confidence in working with human subjects. I was able to create a more effective, prompt and redesign my questionnaire to consider other musical abilities, physical fitness and lifestyle choices. This pilot also resulted in the knowledge that I needed a more controlled methodology for measuring breath through the use of an apparatus. The decision to collect the sustained vowels to a chosen pitch for better control of the f0 measures by group was also a factor. The ability to conduct an analysis for data with singers and non-singers allowed me to address certain hypotheses and led to the creation of a more defined hypothesis. Results such, as f0 being higher in women and lower or unchanged in men, along with longer vowel duration and longer VOT can be referenced as a way to determine results from the pre and post-test in the next phase.

IV – Thesis Experiment

In this section a number of things will be outlined: the methodology of the experiment; the equipment used and the type of analysis taken from the pre and post-tests. Information will be given on the participants themselves, summarized information taken from the questionnaires which participants completed both before and after the training and experiment, and lastly, details will be given on the methodology of the singing training.

i. Preparation and Subjects

Approval was granted by the IRB May 24th 2016 (CPHS #*2016-03-8511)* to conduct research with human subjects, along with, approval from the South Berkeley Senior Center to conduct a pre and post test experiment with 8 weeks of classes at their facility seeking participation from their members. A notice was placed in their monthly flyer 'The Nugget' stating that in June and July of 2016 singing training was being offered as part of a linguistics experiment on geriatric voice for UC Berkeley. Ten seats were allotted for two classes, ten seats for a females' only class on Monday and ten seats for a males' only class on Wednesday. They were segregated by gender so that the range of the singing voice would be consistent for each class, thereby making the class easier for the students. The South Berkeley Senior Center took the names and numbers of interested participants and 30 participants applied for the study, 20 women and 4 men. Each participant was contacted by phone so that the study, the singing lessons and anything else that was deemed pertinent by either the researcher or the potential participant could be discussed. After these discussions, the subject pool was reduced to 20 participants, 17 woman and 3 men. Two women didn't show up for the pre-test and one woman didn't return my call. One male subject was verbally antagonistic and was not accepted.

Ultimately, due to the lack of male interest in the class, Wednesday's class became a mixed class of women and men. Each subject was given a code for anonymity, F_X or M_X with an alphabetized system, F_A, F_B etc. Two females were between the ages of 60 and 65, three were between the ages of 65 and 70, two were between the ages of 70 and 75, five were between 75 and 80, two were between 80 and 85 and one was between 85 and 90 years of age. Of the three male participants, one was 65, one was 68 and the other was 81 years of age. All participants were fluent speakers of English.

In terms of voice issues, nearly every participant reported having trouble with hoarseness and excessive throat clearing. Two subjects reported having asthma and feeling short of breath. Two subjects reported difficulty with articulation due to dentures. One subject complained of having low volume and feeling too soft-spoken. Two subjects complained of breathing too much during speech and experiencing low stamina. One subject reported concerns over losing her voice regularly and not having enough stamina in conversations. Two subjects reported feeling that their voice was so connected to their emotional state that their voice would break too often in stressful circumstances. No subject reported every having had any official singing training, but some of the subjects had sung in choirs in school or church mostly for fun. Nobody reported anything that would be considered professional training or regular systematic practice on his or her voice. In terms of existing musical ability or training, four of the female subjects and one of the male subjects were part of a ukulele group that met once a week for fun, two of the female subjects played piano seriously, one female subject was an accordionist, one of the male subjects played piano and guitar and one of the other male subjects played the cornet very well.

ii. Pre-Test Methodology

The study was designed with a pre-test and post-test methodology to best assess the results of the singing lessons. Pre-Tests were required before commencing the singing class, and were conducted June 1st, June 6th and June 8th between 10am and 12pm. After the pre-tests the viable subjects were reduced to 17 participants. During the pre-tests it was discovered that two ladies were below the age of 65 and therefore not eligible for the study and one lady didn't show up. Therefore, subjects F_H, F_O and F_R were discarded as research participants. F_O was the daily caretaker for one of the eligible subjects and F_R was a stage-4 cancer patient, so they were allowed to remain in the class. The initial questionnaire, was filled out during the phone consultation and during the pre-test the subjects were asked to review it and to add, delete or edit whatever they felt necessary. We discussed the research, the experiment and the classes ahead. I answered questions and addressed concerns before the pre-test. Also (as per request of the IRB), I used this time to determine that each subject was of sound mind, and able to retain information and communicate adequately.

The pre-test consisted of two reading tasks, the sustaining of three vowels and exhalation into a peak flow meter. The first reading task was to read the lyrics for the first verse and chorus of The Beatles' song "Imagine" (see appendix 2, Read 1 = "Imagine"). This was followed by the sustaining of vowels to assigned pitches, [a] to A3 (220Hz), [i] to C4 (262Hz) and [u] to E4 (330Hz) for the females and [a] to A2 (110Hz), [i] to C4 (131Hz) and [u] to E3 (164.8Hz) for the males. Pitches were assigned to vowels as a way to measure f0 from the pre-test to the post-test and as a way to gauge improvements in the control of f0. In the cited literature, many of the studies did not assign a pitch to the sustained vowel tasks, and as this is a singing to speech study, it seemed important to me to monitor this closely. Pitches were given using a small Casio keyboard. Understanding a lot about modal voice as a lower register and upper register (falsetto or head voice) in singing, the pitch assignment to each vowel was given based on natural position of the vowel (low back versus high front) and how different sounds are easier to produce in different ranges as a singer. For example, to reach high notes, it is usually easier to do this on [u] than [a], whereas lower notes sit more comfortably on [a] or [ə]. The second reading was an excerpt (Paragraph "Happiness lies…" see appendix 3, Read 2 = "Happiness") from Franklin Delano Roosevelt's first inaugural address given on March 4th 1933. The last task was to measure breathing using a peak flow meter (PFM), which was chosen over a spirometer to test my hypothesis that exhalation would prove to be more integral to strength of phonation than inhalation. An SDI Spirotube Type A was used, with disposable mouthpieces for each participant. Each subject attempted the task three times and the best score was recorded.

The recording device used onsite was a Marantz PMD660 portable solid-state recorder connected to a Shure SM10A-CN cardioid dynamic headset microphone, which each subject placed on his or her head. The microphone was positioned two finger spaces away from the subject's mouth. After a microphone level check, each subject commenced with the prompt.

Following completion of the phone consultation, the meeting and the completion of the pre-test, subjects F_A, F_B, F_C, F_D, F_E, F_F, F_G, F_I, F_J, F_K, F_L, F_M, F_N, F_P, F_Q and M_A, M_B, M_C were accepted for the study.

iii. Voice Lessons Methodology

During the course of voice lessons, subjects F_A and F_M dropped out of the study and henceforth will no longer be accounted for. Singing lessons started on the 1st of June, but the final list of active research participants was not complete until the following week, due to late starts, and subjects adding and dropping. Classes met on Mondays and Wednesdays at 12pm for one hour. At each class, we started with a circle where the group was free to talk about their experiences with singing, ask questions about singing and essentially this was used as a way to defuse nerves and to try to create a communal group that would be comfortable for all participants. Once I had explained the agenda of the class, next we would move around the piano and work on vocal exercises. These exercises usually centered around sequences of notes taken from a major scale. For example, using C major scale as a guide (figure 8), with each note being part of a configuration of intervals which can be described in numbers, 1 2 3 4 5 6 7 8 from C through to the next C (an octave above[7]). The exercises used from the major scale used the following configuration of intervals; 1, 1 2, 1 2 3, 1 2 3 4 5, 1 3 5 8, 5 4 3 2 1, 8 7 6 5 4 3 2 1, 1 8 1 (see appendix 4). Some exercises utilized a chromatic scale where each note on the piano is used in succession (note the scale seen in figure 9 below compared with the scale above figure 8). Unlike a major scale, the chromatic scale hits every single note as it moves up and down the piano, whereas the major, has some space between notes, utilizing whole steps and two half steps.

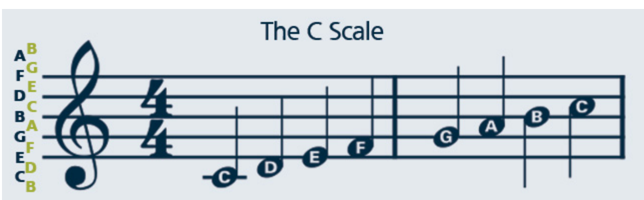


Figure 8: A C major scale shown on the treble clef.

[7] An octave is eight notes apart.

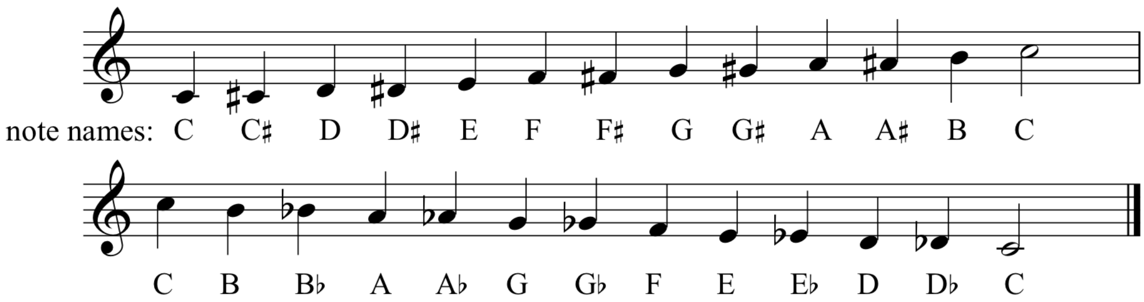


Figure 9: The chromatic scale shown on the treble clef, ascending and descending.

Looking at the intervals of the chromatic scale numerically it could be described as follows: 1, 1½, 2, 2½, 3, 3½ and so on. Using this rule, the chromatic vocal exercises were: 1½ 1 1½ 1 1½ 1 and 1, 1½, 2, 2½, 2, 1½, 1, 1½, 2, 2½, 2, 1½, 1.

The main techniques attended to were thoracic breathing with a focus on exhalation, tongue tension, jaw tension and upper register voice[8]. For breathing work, each subject received a hand out on anatomy, outlining the basic functions of the lungs, the larynx and the mouth. We did breathing exercises inhaling and exhaling through the mouth with hands placed on the ribs, the stomach area, the back and the sternum. Without sound, we did short quick breaths to engage the diaphragm, abdominal and intercostal muscles. We did short inhales with long exhales to engage the abdominal and intercostal muscles and to raise the sternum. We also did long inhale and long exhale exercises for stamina. We then added a note to this exercise, so that participants would connect exhaling as a means to produce sound. We repeated all of the above with an open [ə] sound as a guide, and participants used this or equivalent such as [a] or [ɑ]. The exercise was known as “hold a note” and was given at the start of each session. Once this was

[8] ‘Upper register voice’, also referred to as ‘head voice’, ‘loft voice’, ‘falsetto’ and many other terms. In singing, this is the voice that is removed from modal voice, and is felt generally in the soft palate or anywhere else in the head or mouth.

comfortable we added one of two separate elements at a time when producing the open note, either 1) the tongue resting on the bottom lip, or being held out of the mouth and 2) the jaw gently moving side to side with fingers acting as a guide to avoid "over-swinging" the jaw action. Once this was comfortable, we advanced one note at a time up the scale and gradually moved up and down the piano. At first this was an A (220Hz) and went to about Middle C (262Hz) but by the end of the sessions this went up at least an octave (8 notes) or more. We would then move on to [a], [i] and [u] sounds to the aforementioned exercises along with the exercises shown in appendix 4. To extend this, I added exercises, [lu,əh] 'loo ah', [u] 'oo' and [ə] 'ah' to extend the breathing work to longer phrases. We added consonant sounds for articulation work such as [gɪ laɪ] 'guy lie', [kju əks] 'q x', [gəg] 'gug', [gi] 'gee', [niŋ] 'ning', [p, t, rəm] 'ptrum' and sustained bilabial trills and tongue trills called 'rolling tongue' and 'rolling lips'. These exercises engage the root of the tongue and/or the tip of the tongue, in repetitive systematic movement with breathing and pitch attached, to build muscle strength. Lastly, exercises with a [ni] 'nee' and [nay] 'nay' were added to incorporate nasal sounds so as to help participants feel sensation in their mouth, in either the hard palate, the soft palate, the nose or wherever possible.

After 20 to 30 minutes of vocal exercises, we sat back in a circle and sang a song together. The songs were selected from participant's suggestions taken at the second class. At the second class, each subject who was present submitted 5 songs that they would like to sing and from this list, 6 songs were selected for the singing list for the class, with 2 other selections by me. By the 3rd class, each subject had a working list of the songs we would be doing, along with a CD or Dropbox with the songs accessible for download. A lyric sheet was provided each week for each song, and I sang and played the song on guitar or piano as a guide. (See appendix #5 for song list)

In addition to a song CD, each subject was given either a CD to take home with all the exercises that would be introduced to them in class, and/or access to a dropbox with the exercises online. Each week, at the end of class, they were given a handout with a written guide on what to practice during the week. Due to the amount of questions about technique and practicing at the start of each lesson, I added an optional one on one check in at week 5 before both of the classes. 14 of the 17 subjects signed up for this and attended. Each session was 20 minutes and was used to clarify techniques, homework exercise and any other questions they had. Some of the subjects wanted to sing for me for an assessment and some just wanted to talk. Also, at the close of the 8 weeks, we added an extra group class for both the Monday and Wednesday class to sing a medley of the songs learned in class all together.

iv. Post Test Methodology

The post-test experiment was identical in execution and utilized the same equipment as the pre-test, except for the time and place. The post-tests were conducted in a different room from the pre-test. The pre-tests were conducted before the classes commenced, (or before the subject commenced the classes), however the post-tests were completed after the classes ended.

IV – DATA ANALYSIS

Post-test data was collected from 12 women and 3 men at the end of the 8-week study. The results reported here however will represent just the 12 women who completed the post-test[9]. In this data analysis results will be presented for the following measurements: 1) breathing with an emphasis on exhalation, 2) voice acoustic measurements reporting on jitter, shimmer and HNR, fundamental frequency (f0), intensity and Voice Onset Time (VOT). All statistical analysis in R-studio or JMP was conducted using a paired t-test at the 95% confidence level drawing a non-conservative p-value.

i. Breathing and Aerodynamics

Breathing was measured in the following ways; peak force of exhalation through the use of a Peak Flow Meter, duration of sustained vowels [a], [i] and [u] and durations of [æ] in the word *imagine* (x2) taken from the first reading (Read 1 = Imagine) and the words *happiness* and *mad* taken from the second reading (Read 2 = Happiness). A Peak Flow Meter (PFM) is a device that assesses strength of exhalation through the measure of lung capacity. It measures how effectively air flows from one's lungs in one fast "peak" of exhalation. This is different from a spirometer, which measures strength of inhalation. Since my hypothesis posits that speech (and singing) rely heavily on exhalation for the production of sound, this was the chosen device and measurement for this study. The American Lung Association offers the following standards for measures of exhalation for each age group: (appendix #8)

[9] The men were excluded after brief analysis, due to the small subject pool, variation in the ages, erratic participation and ultimately the amount of high irregularity seen in the data.

65 years old - approximately 160 cm height = 360 L/min

70 years old - approximately 160 cm height = 350 L/min

75 years old - approximately 160 cm height = 335 L/min

80 years old - approximately 160 cm height = 320 L/min

85 years old - approximately 160 cm height = 305 L/min

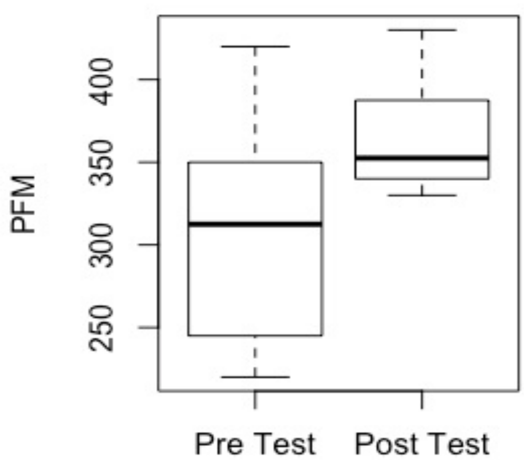


Figure 10: Shows the mean results from the Peak Flow Meter readings for the pre-test and the post-test. Mean result for the pre-test was 335L per minute and 350L per minute for the post-test.

The box plot (figure 10) to the left outlines the mean results from the pre-test and post-test. The mean of the pre-test was 335L/min with a variability of 220 to 420 L/min. The post-test shows the mean at 350 L/min with a variability of 330 to 430 L/min. A paired t-test showed that the post-test performance was reliably different from the pre-test performance ($t[11] = 3.09$ $p > 0.005$*) and is significant.

In order to see this delineated by participant, Table 2 (seen on the next page) outlines the age of the subject (or approximate), the measurement taken from the best of the three attempts from the pre-test, the measurement taken from the post-test and the standard reading as outlined by the American Lung Association.

Subject	F_C	F_N	F_L	F_B	F_P	F_I	F_G	F_Q	F_D	F_M	F_F	F_J
Age	65	67	69	75	77	78	79	80	80	83	84	88
Before	420	330	220	325	335	400	240	300	250	375	225	280
After	430	350	430	332	375	400	340	340	370	355	330	340
Standard	360	345	349	335	327	326	321	320	320	313	312	300

Table 2: Shows the Peak Flow Meter readings delineated by participant on the top, reflecting age (or approx.), the pre-test reading, the post-test reading and the standard reading as offered by the American Lung Association.

The greatest difference shown from pre to post-test was a difference of 210 L/min and the least difference was 0. These results are graphed as seen in figure 11.

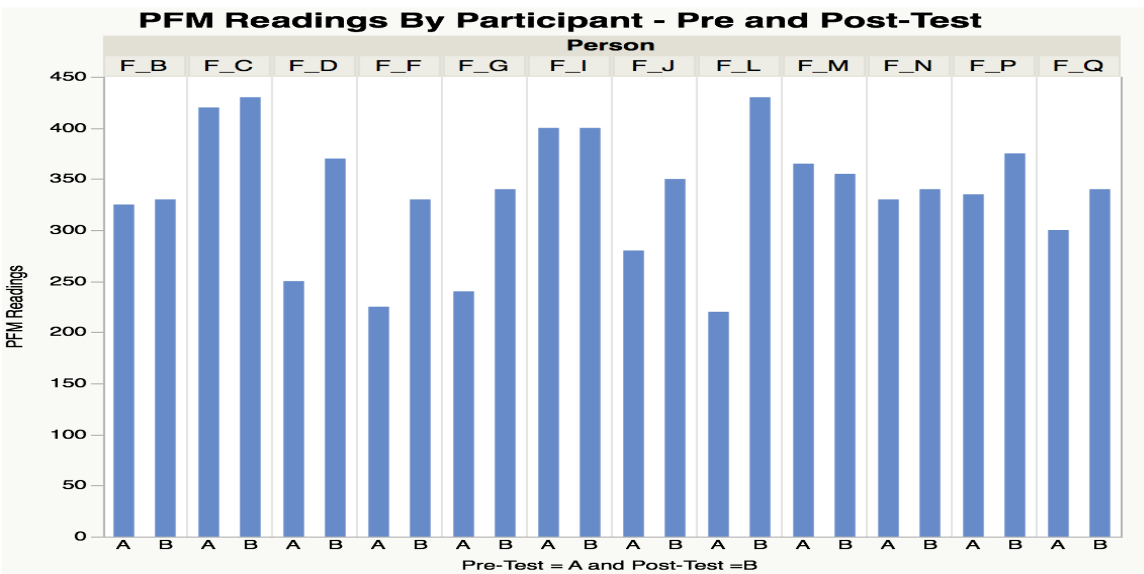


Figure 11: Shows the Peak Flow Meter readings delineated by participant on the top. The y-axis shows the range of measures for the PFM readings, the x-axis shows the pre-test (A) and the post-test (B).

Here we can see that F_D, F_F, F_G, F_J, F_L were the most improved the others show minimal to no change.

In order to consider exhalation for speech with regards to inhalation, I calculated the amount of breaths taken throughout the duration of the readings. Figures 12 and 13 below give a depiction of the number of breaths taken by each subject during pre-test (A) and post-test (B) in both 'Imagine' and 'Happiness'. In 'Imagine', in the case of F_J, F_L and F_M the results were consistent. In the case of F_N, the amount of breaths taken was increased. However, for the other 8 subjects, there were less breaths taken which may imply more strength with which to sustain speech using the inhaled breath.

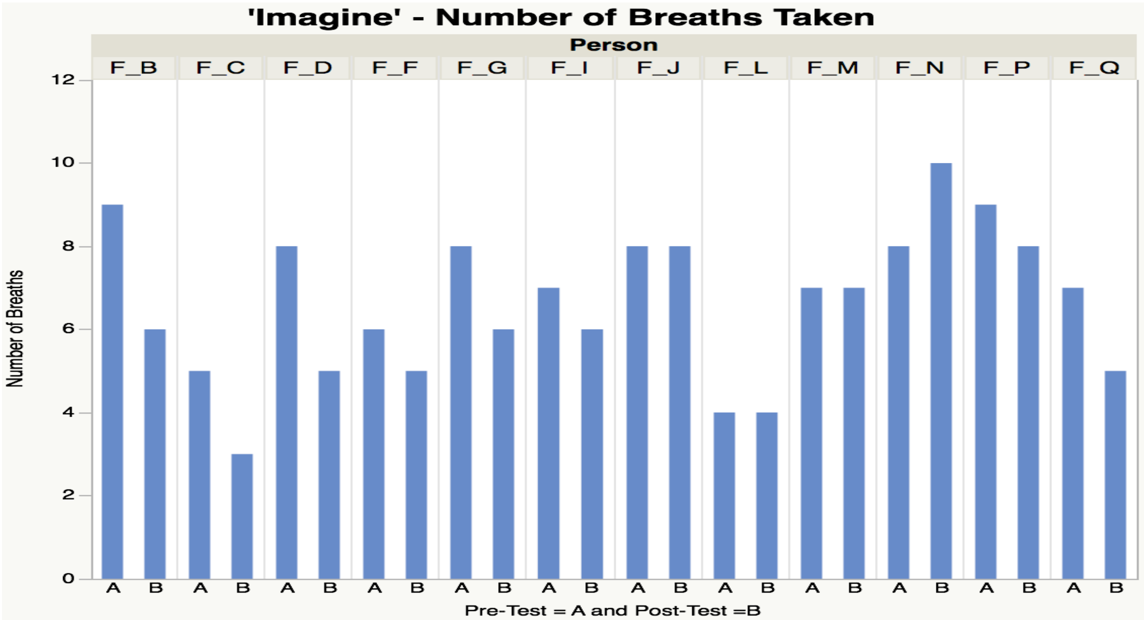


Figure 12: Shows the number of breaths taken throughout the first reading, 'Imagine', delineated by participant on the top. The y-axis shows the range of breaths taken throughout the reading; the x-axis shows the pre-test (A) and the post-test (B).

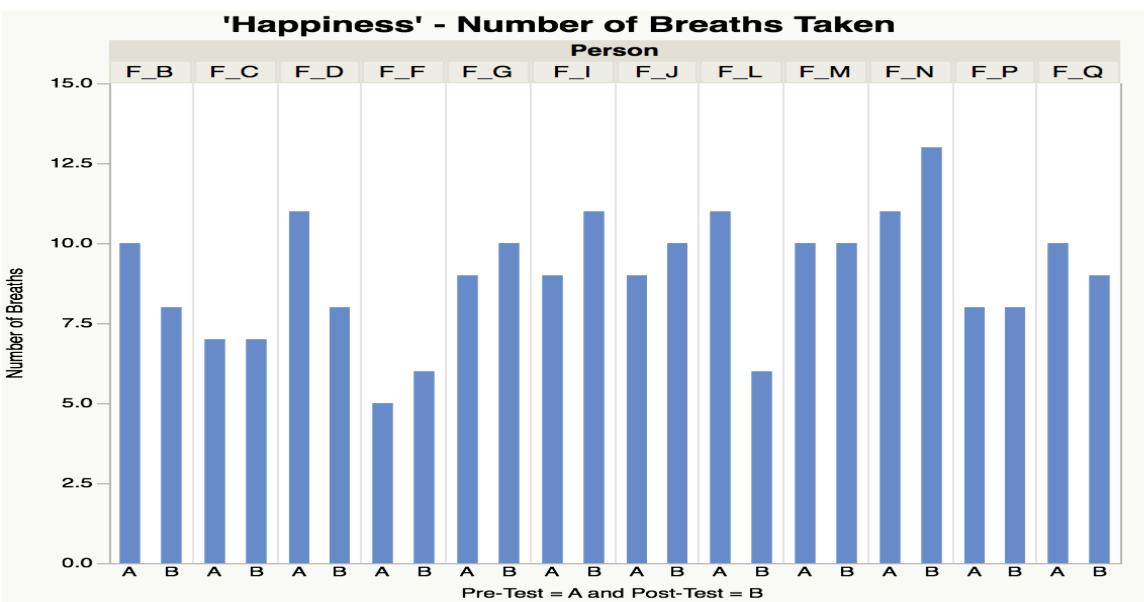


Figure 13: Shows the number of breaths taken throughout the second reading, 'Happiness', delineated by participant on the top. The y-axis shows the range of breaths taken throughout the reading; the x-axis shows the pre-test (A) and the post-test (B).

Looking at 'Happiness', we see the following results: F_C, F_M and F_P show no change in the amount of breaths taken, F_B, F_D, F_L and F_Q showed fewer breaths taken throughout the reading, but the remaining four subjects showed an increase in breaths taken through 'Happiness'. The mean result of the breaths taken during both readings in the pre-test was 8.2 breaths and the mean result of the post-test was 7.5. Statistically, the first reading 'Imagine', showed a mean difference of -1.08 and a paired t-test analysis reflects ($t[11] = -2.6$ $p < 0.01$*) and is significant. The second reading 'Happiness' showed a mean difference of -0.33 and a paired t-test analysis reflects ($t[11] = -0.54$ $p < 0.29$) and is not significant.

'Happiness', taken from a speech by FDR had some less frequent words (i.e. evanescent) and longer, irregular phrases when compared with 'Imagine', (lyrics by The Beatles). With 'Imagine' there was an innate tendency to follow the phrases which were designed to be sung in a repetitive pattern with line lengths that match a rhythm, and so subjects tended to breathe accordingly. For example, most participants approached the task as follows: (breathe) "Imagine there's no countries" (breathe) "it isn't hard to do (breathe) and so on and so forth. 'Happiness' however was not so systematic: "Happiness lies not in the mere possession of money; it lies in the joy of achievement, in the thrill of creative effort." This passage was more indicative of regular speech, as it did not offer a rhythm or poetic meter for the reader.

Senior citizens often talk more slowly as they age, a condition known as dysarthria (asha.org 2016). In order to fully analyze the breaths and how they relate to this passage, the total read speed time of 'Happiness' was measured in the pre and post-tests. Figure 14 shows the measures for the speed of 'Happiness', which was measured in

Praat, taken from the entire phrase. Looking at subject F_L, there is a correlation between the speed of 'Happiness' and the number of breaths taken. Between the pre and post-test of 'Happiness' F_L inhaled approximately 5 times less and yet the speed of speech was almost identical between the pre and post test.

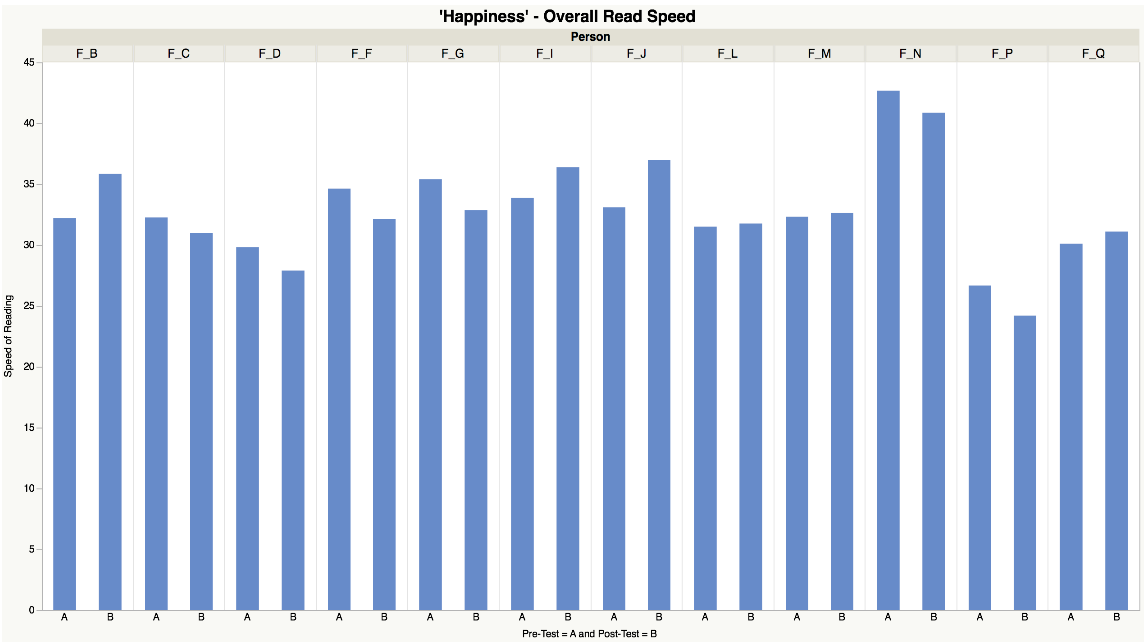


Figure 14: Shows the speed of the reading 'Happiness' as measured by the entire file, delineated by participant on the top. The y-axis shows the range of speeds measured throughout the reading; the x-axis shows the pre-test (A) and the post-test (B).

There is a similar result for F_D, less breaths, same read speed. However, the results from 2 subjects are not enough with which to draw a conclusion here. The number of breaths taken and the speed of the readings did not produce any significant results, but this may be a consideration for future studies.

Lastly, to measure exhalation we have the duration of [a], [i] and [u] from the sustained vowels and [æ] taken from both readings. Figure 15 below outlines the results from the three sustained vowels, in order of pitches low to high. In analyzing the duration of [a] from the pre-test to the post-test, the mean duration in the pre-test was 5.11 seconds with a SD of 3 and the mean duration seen in the post-test was 8 seconds with an SD of 2.

The difference between the means was 2.89 seconds. A paired t-test showed that the post-test performance was reliably different from the pre-test performance ($t[11] = 4.15$ $p > 0.001$*) and is significant.

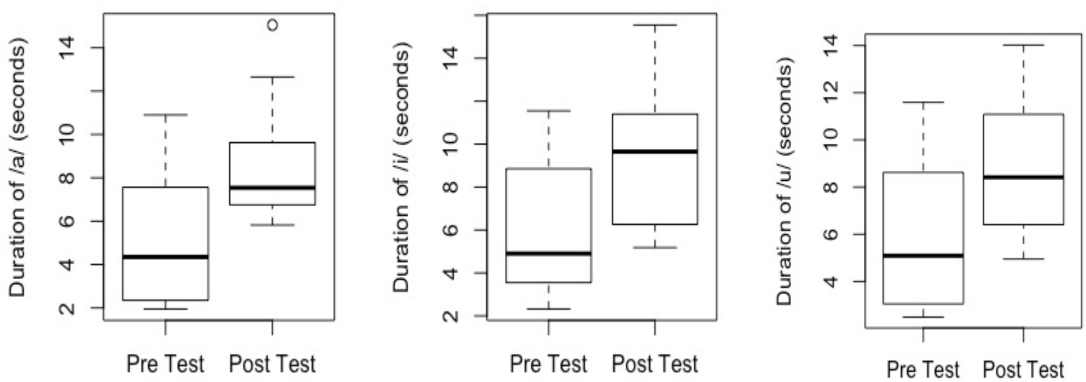


Figure 15: Shows the duration of the three assigned vowels, a, i, u. The y-axis shows the duration of the vowel in seconds and the x-axis shows the pre-test (A) and the post-test (B).

The duration of [i] from the pre-test to the post-test, showed the mean duration in the pre-test was 6 seconds with a SD of 3 and the mean duration seen in the post-test was 9.3 seconds with an SD of 3.2. The mean difference was 3.3 seconds. A paired t-test showed that the post-test performance was reliably different from the pre-test performance ($t[11] = 3.77$. $p > 0.003$*) and is significant. The duration of [u] from the pre-test to the post-test, showed the mean duration in the pre-test was 6 seconds with a SD of 3.3 and the mean duration seen in the post-test was 9 seconds with an SD of 3. The mean difference was 3 seconds. A paired t-test showed that the post-test performance was reliably different from the pre-test performance ($t\ [11] = 2.71$ $p > 0.02$*) and is significant.

The vowel duration taken from the readings to measure for speech was [æ] taken from *happiness* = [hæ.pi.n̩(ə)s], *mad* = [mæd] and *imagine* = [i.mæ.dʒn̩] from two different sentences. Figure 16 shows the difference between the pre and post-test. The mean duration of the vowel [æ] in the pre-test was 0.11 seconds with a SD of 0.04 and the mean duration in the post-test was 0.13 seconds with an SD of 0.03. The difference between the means was 0.02 seconds. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[47] = 4.16 p < 0.0001*) and is significant.[10]

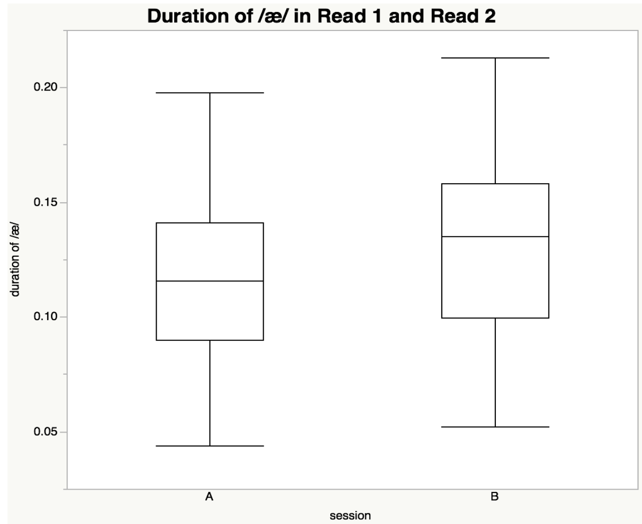


Figure 16: Shows the duration of [æ] from the word *Imagine* taken twice from Read 1 'Imagine' and the words *Happiness* and *Mad* taken from Read 2 'Happiness'. The y-axis shows the duration of the vowel in seconds and the x-axis shows the pre-test (A) and the post-test (B).

Looking at the results from the readings against the results shown in the duration of vowels, it would seem that after singing training, the sustaining of vowels, (a more conscious use of exhalation) and the duration of vowels in speech, (an unconscious use of exhalation) both shows improvement from pre to post-test.

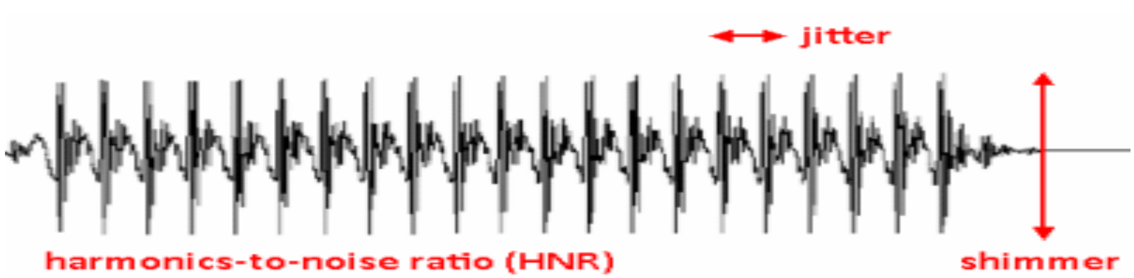
Going back to my pilot test singers naturally had longer vowels in speech, which is true of other research findings (McCrea, 2007). Therefore, it may be that these measures of exhalation, speak of stronger exhalation with respect to the speaking voice.

[10] The DF is 47 and not 11 due to the design of the spreadsheet for analysis of the readings. [æ] was measured for four words and these values were listed for each subject separately, therefore there were 48 samples from the readings. This will appear again for other measures from the readings where applicable. All other factors were the same.

The PFM readings and the extended duration of sustained vowels and vowels from readings in the post-test, show that there is merit to singing lesson in strengthening exhalation which is so crucially connected to phonation. However, this raises an important question with respect to the duration of vowels for speech. Can extended vowel measurements in speech account for improved speech? Therefore it was necessary to look at other factors that cannot be as consciously controlled, such as jitter, shimmer and harmonics to noise ratio (HNR).

ii. Voice Acoustics

In this section of the data analysis we will look at factors such as f0, intensity, shimmer, jitter and HNR. These factors are important to a study of this nature because these are elements of the voice that are less able to be controlled and are fundamental measures for the motor control of one's speech. When we speak (in English specifically) we are not considering the pitch of our voice in most cases, and how steady that is throughout our speech. Perturbation measures of shimmer, jitter along with HNR are often analyzed when studying voice pathology and geriatric voice because combined they speak of irregularities in the human voice such as hoarseness, gravely or creaky voice, excessive breathiness and irregular volume or pitch. Here is a visual representation of how these measurements are represented.



Shimmer is measured as the change in amplitude from cycle to cycle in a sound wave (shown on the y-axis). Shimmer will detect the irregularities in amplitude, and measures the variability in the intensity of adjacent vibratory cycles of the vocal folds (Wilkinson, 2016). Shimmer contributes to the perception of hoarseness in the voice or weak, breathy toneless voice, which are common problems in aging voice. For shimmer, the amplitude perturbation quotient of five cycles was taken (APQ5) and was measured for both the sustained vowels and the vowels taken from the readings. For the sustained vowels, the entire mid section of the vowel was highlighted and APQ5 was recorded in Praat from voice report. For the vowels in the readings, [æ] was highlighted in the word (recall: *imagine* (x2), *happiness* and *mad*) and APQ5 was recorded in Praat from the voice report. Figure 17 shows the plots for each of the sustained vowels: [a], [i] and [u]. The mean percentage of APQ5 [a] in the pre-test was 0.041% with an SD of 0.019 and

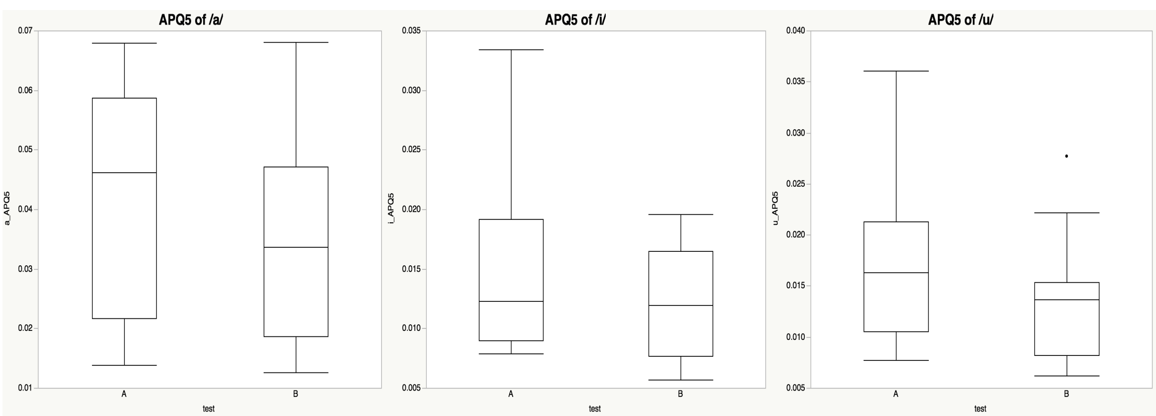


Figure 17: Shows the percentage of APQ5 for the vowels: [a] (top), [i] (left), [u] (right). The y-axis shows the measure of APQ5 in percent and the x-axis shows the pre-test (A) and the post-test (B).

the mean in the post-test was 0.034% with an SD of 0.018. The mean difference was -0.007%. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance ($t[11] = -1.20$ $p < 0.12$) and is not significant. The mean percentage of APQ5 of [i] in the pre-test was 0.015% with an SD of 0.008 and the mean in the post-test was 0.012% with an SD of 0.005. The difference between the means was -0.003%. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[11] = -1.24 p < 0.119) and is not significant. The mean percentage of APQ5 of [u] in the pre-test was 0.016% with an SD of 0.008 and the mean in the post-test was 0.014% with an SD of 0.006. The difference between the means was -0.004%. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = -1.99 p <0.03*) and is significant. In the vowels measured from the readings, [æ] we see the results for shimmer in Figure 18. The mean percentage of APQ5 in the pre-test was 0.048% with an SD of 0.027 and the mean in the post-test was 0.040% with an SD of 0.027. The mean difference was -0.008%. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[47] = -1.78 p < 0.04*) and is significant.

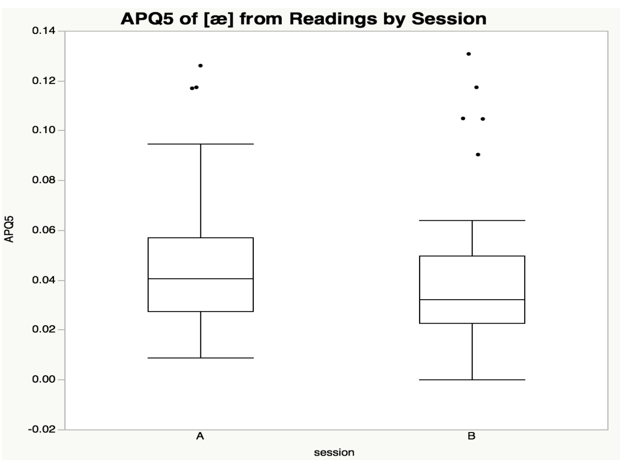


Figure 18: Shows the percentage of APQ5 for the vowel [æ] from the word *Imagine* taken twice from Read 1 'Imagine' and the words *Happiness* and *Mad* taken from Read 2 'Happiness'. The y-axis shows the percentage of Shimmer (APQ5) and the x-axis shows the pre-test (A) and the post-test (B).

Jitter is a perturbation measure of pitch, looks at the frequency of adjacent vibratory cycles of the vocal folds. That is, local frequency variation in relationship to f0. Increased vocal jitter is often associated with disorders in the voice (Baken, 2000) and voices that are pathological usually display a high percentage of jitter (Wilkinson, 2016). The same parameters were measured for jitter, pitch perturbation quotient 5 (PPQ5) as for shimmer on sustained vowels and the [æ] vowels taken from the readings as above. Because jitter is a measure of pitch perturbation, it is important to reiterate here that each sustained vowel was given a pitch, [a] being the lowest and [u] being the highest, as this may be a consideration in the analysis of the results, which directly relate to pitch.

Figure 19 depicts the results of the jitter percentage by PPQ5 for the sustained vowels and the readings. The mean percentage of PPQ5 for [a] in the pre-test was 0.004% with an SD of 0.003 and the mean in the post-test was 0.003% with an SD of 0.001. The difference between the means was -0.001%. A paired t-test showed that the post-test performance was reliably different from the pre-test performance ($t[11] = -1.89$ $p < 0.04$*) and is significant. The mean percentage of PPQ5 for [i] in the pre-test was 0.003% with an SD of 0.002 and the mean in the post-test was 0.002% with an SD of 0.001. The difference between the means was -0.001%. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance ($t[11] = -0.96$ $p < 0.177$) and is not significant. The mean percentage of PPQ5 for [u] in the pre-test was 0.002% with an SD of 0.002 and the mean in the post-test was 0.002% with an SD of 0.001. The difference between the means was -0.001%. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance ($t[11] = -1.36$ $p < 0.09$) and is not significant. The measurement of the [æ] taken from the readings (*imagine* x 2 from 'Imagine', *happiness* and *mad* from 'Happiness') was reduced to approximately half of the measure from pre to post-test; the mean of the pre test was 0.0103% with an SD of 0.017 while the mean of the post-test was 0.0053% with an SD of 0.005. The mean difference was 0.005%. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[47] = -1.91 $p < 0.03$*) and is significant.

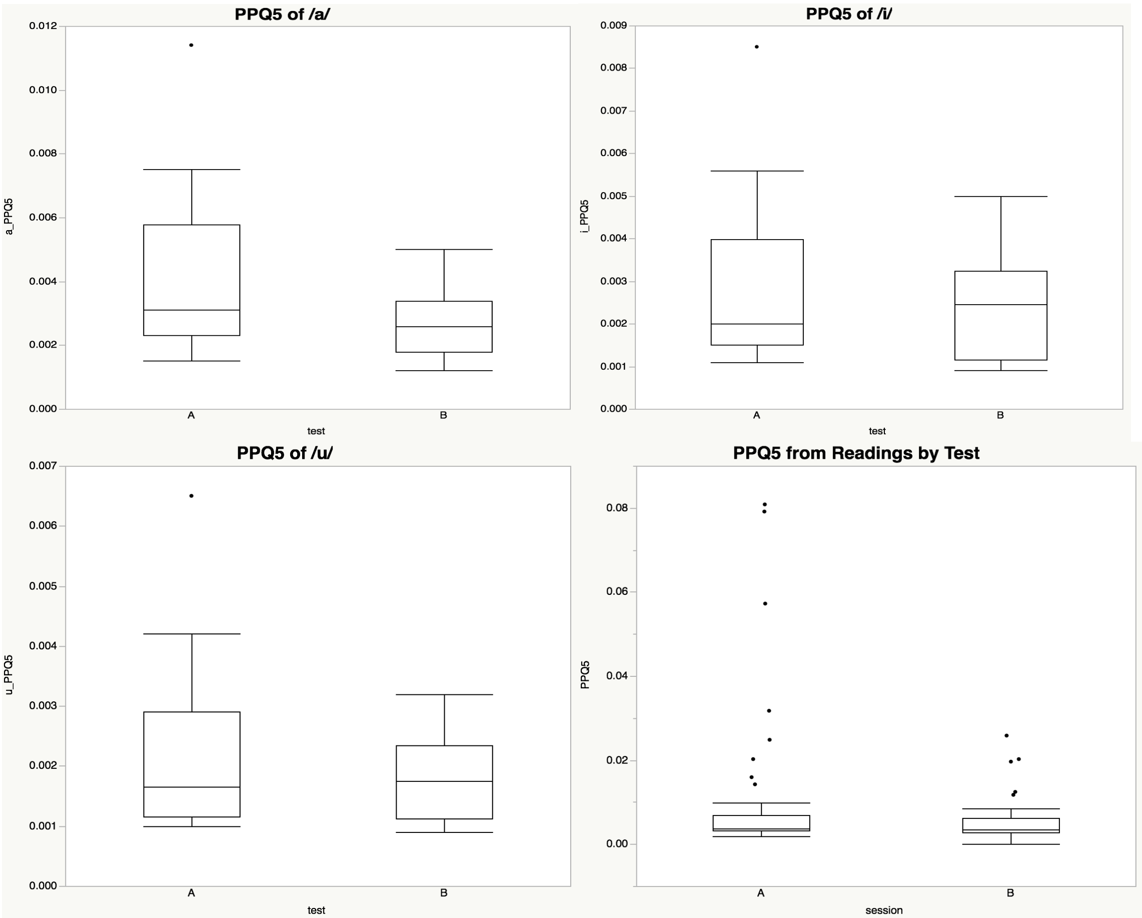


Figure 19: Shows the percentage of APQ5 for the vowels: [a] (top left), [i] (top right), [u] (bottom left) and the percentage of APQ5 for the vowel [æ] from the word *Imagine* taken twice from Read 1 'Imagine' and the words *Happiness* and *Mad* taken from Read 2 'Happiness' collectively (bottom right). The y-axis shows the measure of jitter by PPQ5 and the x-axis shows the pre-test (A) and the post-test (B).

The measure for [a] was significant along with the [æ] taken from the readings, however the measures for [i] and [u] were not significant. I was curious to see if the decreased measures were across the population or just seen in particular subjects for the [æ] taken from the readings. Figure 20 shows that subjects who had a high rating of jitter in the pre-test showed a significant reduction in the post-test; subjects F_C, F_F, F_I, F_J, F_L being the most improved. The fact that this was taken from a reading that was more indicative of regular speech (a more linguistics task than a controlled phonetic task such as the sustained vowels) demonstrates that the study offers preliminary evidence that this study was able to impact change on the speaking voices of those with a high jitter in their pitch perturbation.

Considering that 'Happiness' was not dictated by a rhythm when compared with 'Imagine', I wanted to see if the percentage of jitter was significant in each of these

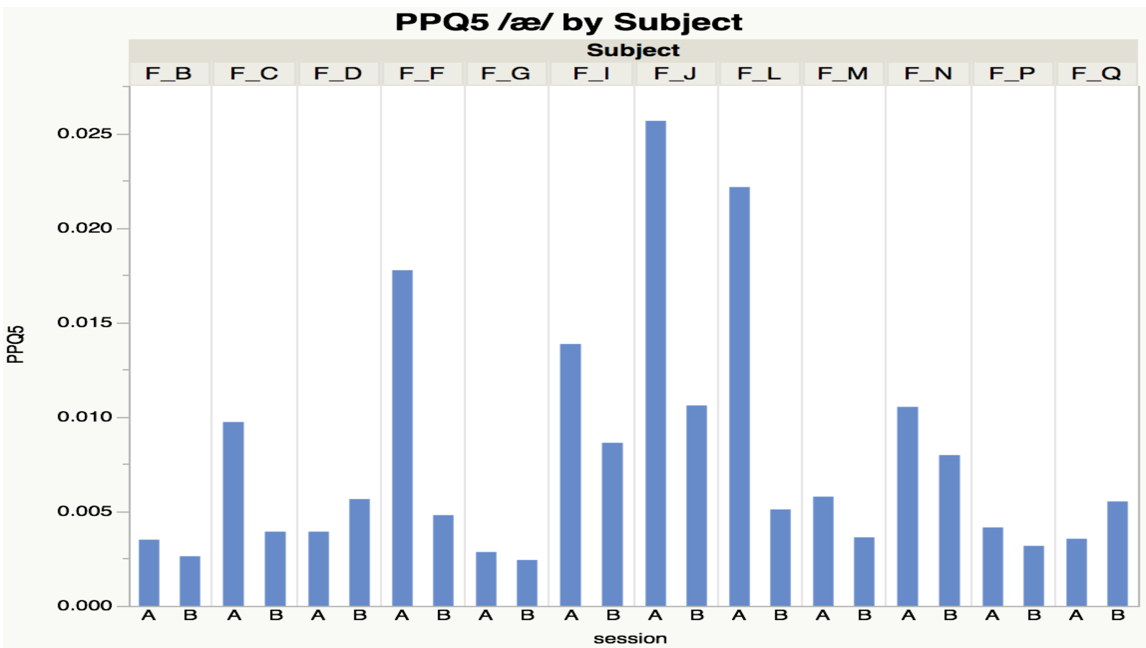


Figure 20: Shows the percentage of PPQ5 for the vowel [æ] from the word *Imagine* taken twice from Read 1 'Imagine' and the words *Happiness* and *Mad* taken from Read 2 'Happiness' by subject. The y-axis shows the measure of jitter by PPQ5 and the x-axis shows the pre-test (A) and the post-test (B).

readings. Figure 21 shows that there was a difference in the measurement of PPQ5 between each reading and each word token. From the second reading, 'Happiness', for the first word, I measured [hæ] from the word *happiness*, the mean of the pre test was 0.011% with an SD of 0.015 while the mean of the post-test was 0.009% with an SD of 0.007. The mean difference was -0.003%. For the second word, [mæd] from *mad*, the mean of the pre test was 0.019% with an SD of 0.030 while the mean of the post-test was 0.003% with an SD of 0.002. The mean difference was -0.016%. From the second reading, Imagine, the first word I measured was [mæ] from 1_*imagine* the mean of the pre test was 0.005% with an SD of 0.004 while the mean of the post-test was 0.005% with an SD of 0.002. The mean difference was 0%. For the second word, I measured [mæ] from 2_*imagine*. The mean of the pre test was 0.006% with an SD of 0.006, while the mean of the post-test was 0.005% with an SD of 0.001. The mean difference was -0.001%.

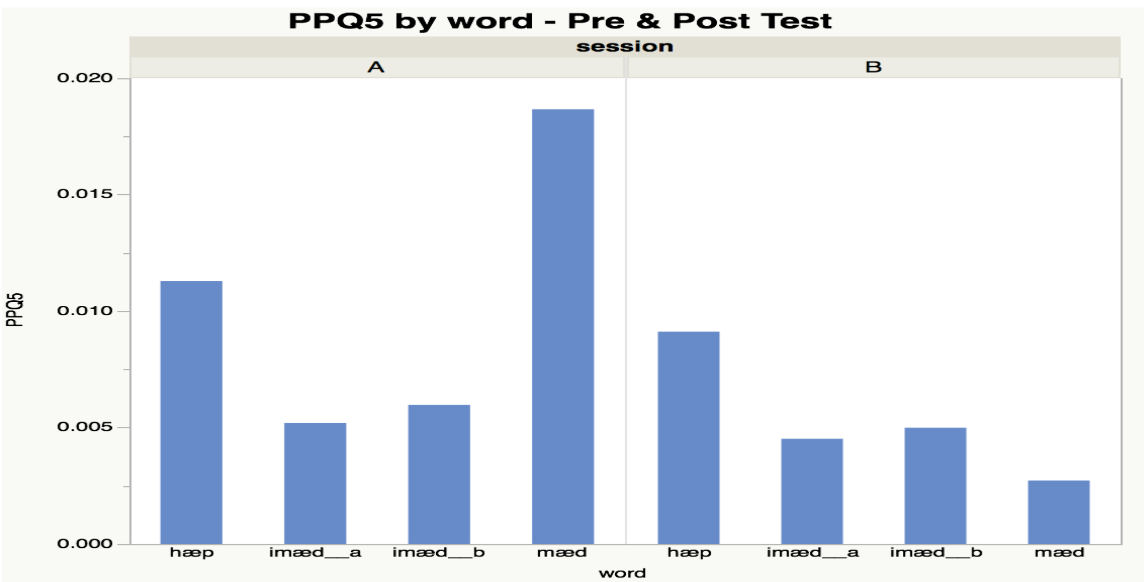


Figure 21: Shows the percentage of PPQ5 for the vowel [æ] by each word *Imagine* taken twice from Read 1 'Imagine' (1_mæ and 2_mæ) and the words *Happiness* (hæ) and *Mad* (mæd) taken from Read 2 'Happiness'. The y-axis shows the measure of jitter by PPQ5 and the x-axis shows words separated by pre-test (A) and the post-test (B).

While all word tokens saw a reduction, clearly, the word *mad* is driving the significant difference seen between the pre and post-test. A paired t-test showed that the post-test performance of this word was reliably different from the pre-test performance ($t[11] = -1.87$ $p < 0.04$*) and is significant. This is interesting because *mad* was produced in the middle of the more difficult reading, 'Happiness' and overall this reading required more stamina on the part of the reader. Additionally, this token was situated towards the end of a longer sentence, where we might expect to see more jitter due to reduced lung capacity, vocal fatigue and increased variance in the measures. Instead, we see reduced variance in the measurement of jitter in the middle of the prose reading.

Harmonics to noise ratio (HNR) is measure of periodic and aperiodic waves produced by the vibrations of the vocal folds. Aperiodic being noise that is produced by irregular adduction of the folds, essentially affecting the clarity of pitch and perceived as hoarseness. HNR was measured for the sustained vowels and the [æ] in *mad*, *happiness* and *imagine*, using the same methods as APQ5 and PPQ5.

In the sustained vowels, overall, we see an increase in the readings of HNR. The mean HNR for [a] in the pre-test was 17dB with an SD of 5.08 and the mean in the post-test was 20dB with an SD of 4.66. The difference between the means was 3dB. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = 1.81 p > 0.03*) and is significant. The mean HNR for [i] in the pre-test was 22dB with an SD of 4.19 and the mean in the post-test was 23.5dB with an SD of 4.60. The difference between the means of was 1.5dB. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[11] = 1.31 p > 0.107) and is not significant. The mean HNR for [u] in the pre-test was 26dB with an SD of 4.67 and the mean in the post-test was 28.8dB with an SD of 3.09. The mean difference was 2.8dB. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = 2.45p > 0.01*) and is significant.

The mean HNR for [æ] from the readings in the pre-test was 12.8dB with an SD of 5 and the mean in the post-test was 14dB with an SD of 4. The mean difference was 2.8dB. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[47] = 1.81 p > 0.03*) and is significant.

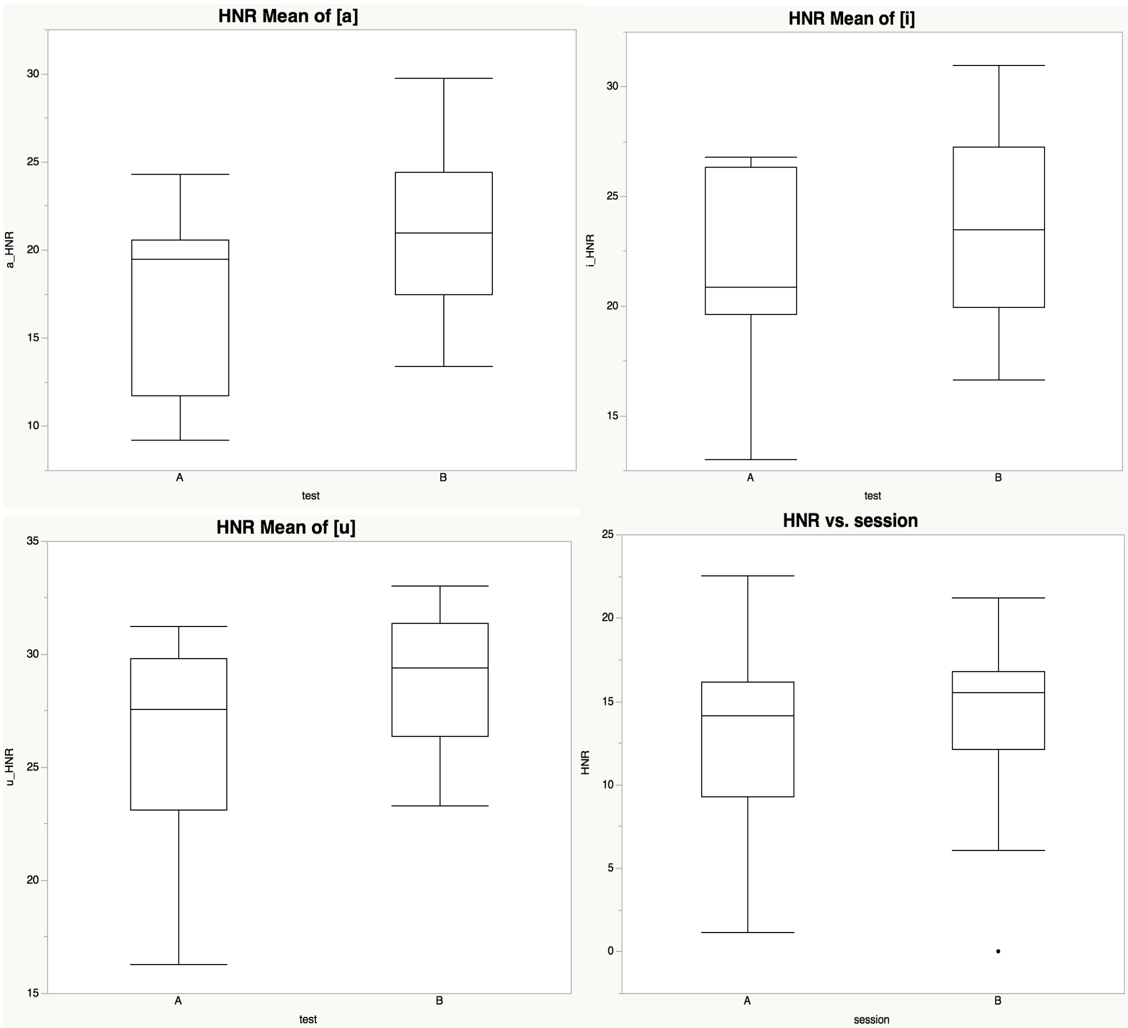


Figure 22: Shows the percentage of HNR for the vowels: [a] (top left), [i] (top right), [u] (bottom left) and the percentage of HNR for the vowel [æ] from the word *Imagine* taken twice from Read 1 'Imagine' and the words *Happiness* and *Mad* taken from Read 2 'Happiness' collectively (bottom right). The y-axis shows the measure of jitter by PPQ5 and the x-axis shows the pre-test (A) and the post-test (B).

It is interesting to note that the overall speech measures for HNR in the readings were lower than seen in the sustained vowels. This may indicate a more controlled phonation in the sustained vowel tasks. This, coupled with the significant increase in harmonics in the readings may speak of an overall ability to increase measure in speech over time through sustained phonation tasks enhancing the harmonics to noise ratio in the speaking voice.

In looking at the f0, fundamental frequency, (pitch) I had theorized that the female subjects would see an increase in overall f0 from the study, largely because it is known that females see a decrease in f0 as they age, especially after menopause. What we see here with the sustained vowels is that there is a lot of variation across the population in the pre-test, but there is less in the post-test. What this means is that overall the participants improved in their ability to match the assigned pitch and there was less variation across the board (performed to an assigned pitch). The reason why there may be less variation in the production of [u] seen between pre and post-test, is most likely because this vowel was assigned the highest pitch and was deliberately placed in upper register voice. In the pre-test, participants could either hit this note or not (note more outliers here). I chose the pitches to match what I know to be effective when working on “placement” techniques in singing ([a] low back vowel, had lower pitch, [i] high front vowel, higher pitch and [u] high back vowel, highest pitch). In my experience, students who cannot access higher notes in their range, have more chance of acquiring higher pitches on an [u] vowel. I believe this is largely due to the fact that in a high back vowel, resonance is felt more effectively in the soft palate when singing. However, these choices for pitch were instinctive to my voice training techniques and not to intrinsic pitch of vowels, where [i] would naturally have a higher pitch than [u] (Ohala, 1987) and [i] would have a higher palatal rise than [u]. Palatal resonance and elevation is known (in singing) to contribute to dimensions within the pharyngeal cavity and length of the vocal tract and is higher on front vowels than back vowels (Miller, 1996. Bloomer, 1953). Perhaps there may be merit to having the [i] be the higher pitch than [u], however this is what I know to be effective from experience, and from this study overall, the participants improved in their ability to match the higher pitch of [u], therefore expanding their range and their vowel space.

The sustained vowels were each assigned a pitch as follows: *A3 (220Hz), C4 (262Hz) & E4 (330Hz)*. Figure 23 shows the results for f0 for each vowel from pre to post-test. The mean f0 for [a] in the pre-test was 191Hz with an SD of 28 and the mean in the post-test was 209Hz with an SD of 12. The mean difference was 18Hz. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = 1.88 p > 0.04*) and is significant. The mean f0 for [i] in the pre-test was 244Hz with an SD of 19Hz and the mean in the post-test was 255Hz with an SD of 13Hz. The mean difference was 10Hz. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = 1.828 p > 0.04*) and is significant. The mean f0 for [u] in the pre-test was 311Hz with an SD of 27Hz and the mean in the post-test was 323Hz with an SD of 10Hz. The mean difference was 12Hz. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[11] = 1.92 p > 0.04*) and is significant. Taking the f0 measurement from the [æ] as seen in the readings, the difference was not significant. The mean f0 for [ae] in the pre-test was 204Hz with an SD of 33Hz and the mean in the post-test was 198.5Hz with an SD of 31Hz. The mean difference was -5.4Hz. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[47] = -0.98 p > 0.83) and is not significant.

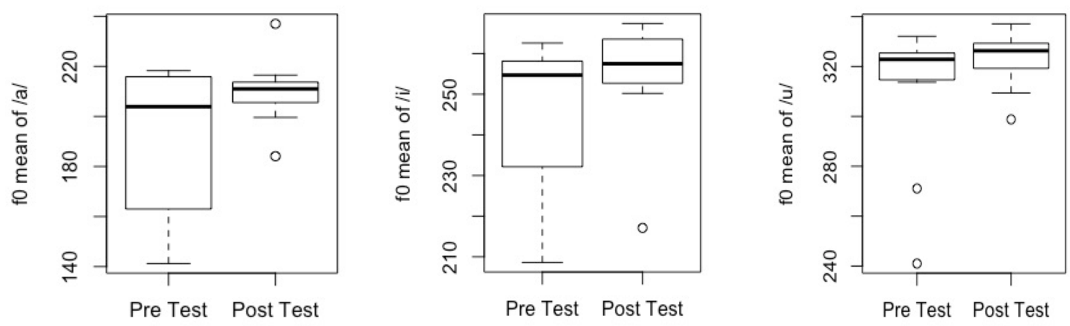


Figure 23: Shows the f0 for the vowels: [a] (left) [i] (middle), [u] (right). The y-axis shows the measure of f0 and the x-axis shows the pre-test (A) and the post-test (B).

The measurements of f0 were significant for [a], [i] and [u] but not for the [æ] taken from the readings. Participants overall showed less variation (as seen in the SDs) from pre to post-test and were closer to the assigned pitches which speaks of fine-grained motor control. Considering further the assigned pitches and the significance of reduced jitter, there was correlation to be seen between the f0 of [a] and the PPQ5 of [a], where the f0 went up from pre to post-test (191Hz - 209Hz) and the PPQ5 went down 0.004% - 0.003%, with both results being significant independently (figure 24). These results seen together raise the question as to the significance of pitch work and its potential relationship to perturbation measures for future research. Further testing is needed, especially on regular speech, but this is relevant to the hypothesis that singing training can alter one's f0 with respect to sustained vowels and in connection to reduced jitter, but not necessarily for speech.

Sustained vowels and the readings were measured for intensity. Vocal intensity depends on the interaction of sub-glottal pressure with the aerodynamics at the level of the vocal folds and the status of the vocal tract. The range of intensity that one voice can create is a solid indicator of vocal disorders (Baken, 2000). In a study by Weatherley, Worrall, Hickson (1997) it was found that the mean intensity in geriatric voice is 70.4dB, however if the speaker is hearing challenged, it is likely to go up, making the mean 72.6 dB with an [a] sustained vowel. Hearing was not accounted for at all in this study, so future studies should make note of this. The results for intensity as measured in the sustained vowels can be seen in figure 25. The mean intensity for [a] in the pre-test was 72.9dB with an SD of 5.2dB and the mean in the post-test was 75.1dB with an SD of 5.3dB. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[11] = 1.13 p > 0.14) and is not significant. The mean intensity for [i] in the pre- test was 65.9dB with an SD of 5.0dB and the mean in the post-test was 66.8dB with an SD of 4.6dB. The mean difference between was 1.1dB. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[11] = 0.65 p > 0.26) and is not significant.

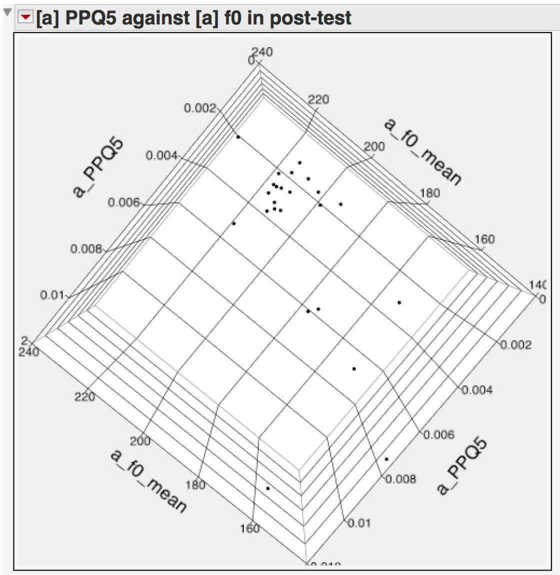


Figure 24. [a] PPQ5 against f0 measures sees a correlation between raised f0 and the reduction of jitter. Where the f0 raises, the PPQ5 decreases.

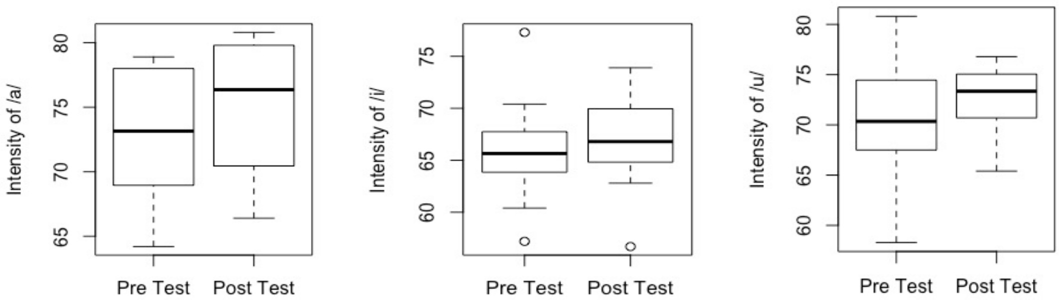


Figure 25: Shows the intensity for the vowels: [a] (left) [i] (middle), [u] (right) measured in dB. The y-axis shows the measure of dB and the x-axis shows the pre-test (A) and the post-test (B).

The mean intensity for [u] in the pre-test was 70.6dB with an SD of 5.8dB and the mean in the post-test was 72.5dB with an SD of 3.5dB. The mean difference was 2.2dB. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[11] = 0.95 p > 0.17) and is not significant. Taking the intensity measurement of [æ] from the readings, the difference was not significant either. The mean dB for [ae] in the pre-test was 74.26dB with an SD of 4.7 and the mean in the post-test was 76.99dB with an SD of 12.8. The mean difference was 2.73dB. A paired t-test showed that the post-test performance was not reliably different from the pre-test performance (t[47] = 1.39 p > 0.08) and is not significant.

Each of the sustained vowels saw in increase in intensity from the pre-test to the post-test however none of the measures were statistically significant. The greatest change in intensity between the pre and pots test was seen in the [a] vowel. It is interesting that the vowel that saw the greatest change in f0, which was set to the most natural pitch point for modal voice, also saw the greatest shift in intensity. Note that the [a] vowel was indeed around the mean of the 1997 study Weatherley, Worrall, Hickson but was raised to over 75dB for the post-test. This may speak of strength, exhalation improvements and consistency of voice production and speech motor control due to enhanced exhalation capacity.

In the pilot study VOT (voice onset time) was measured as a means to look at exhalation strength and speech motor control, based on previous studies of this nature (McCrea, 2007). Even though there were measures for breathing in this study such as PFM and duration of vowels, VOT was then measured to look at strength of exhalation in connection to pressure at the sub-glottal level in a more "speech-like" context. For this study, VOT was measured from [k] in *countries* ('*Imagine there's no countries*') and [p] in *people* ('*Imagine all the people*') from read 1 'Imagine'. From the read 2 'Happiness' [k] in *creative* (*'in the thrill of creative effort')* and [p] in *profits* ('*in the mad chase of evanescent profits*') was measured.

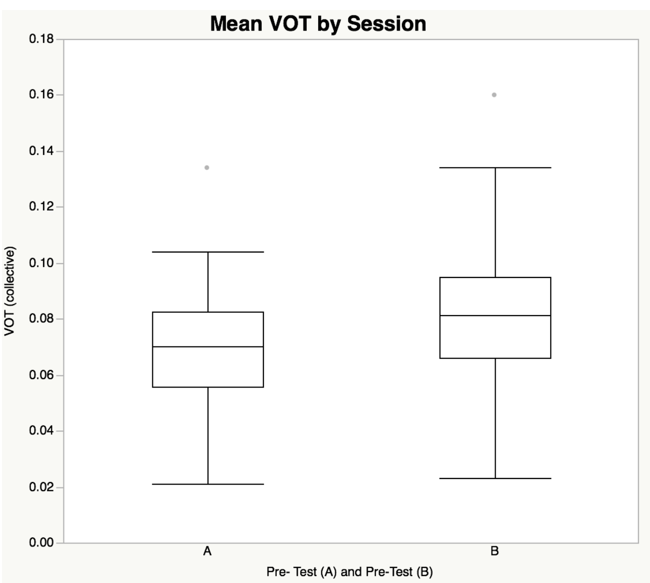


Figure 26: Shows the mean VOT measurement by session. The y-axis shows the measure of VOT and the x-axis shows the pre-test (A) and the post-test (B).

Figure 26 shows the mean VOT measurements taken from these voiceless stops. The mean VOT as seen in the pre-test was 0.070 seconds with an SD of 0.02 and the mean VOT in the post-test was 0.080 seconds with an SD of 0026. The mean difference was 0.010 seconds. A paired t-test showed that the post-test performance was reliably different from the pre-test performance (t[47] = 3.48 p > 0.0005*) and is significant.

Looking at this result by subject, which can be seen in Figure 27, the significant results are able to be narrowed down to certain participants, as was done for several other analyses. Here it is clear that subject F_D, F_I and F_J were the most improved among the population, with the others showing marginal or zero change.

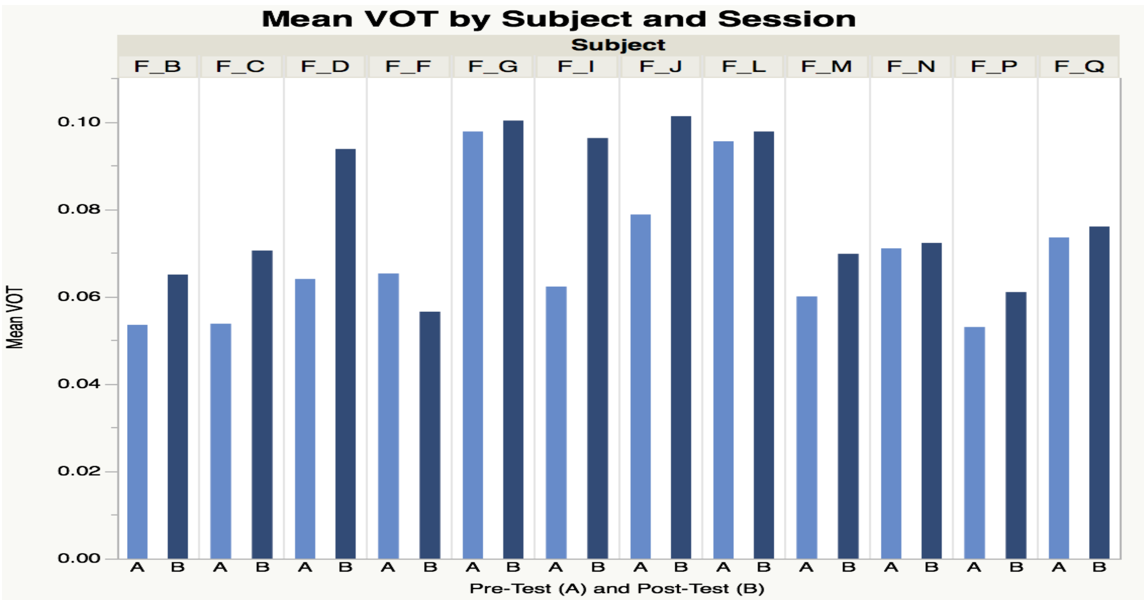


Figure 26: Shows the mean VOT measurement by subject. The y-axis shows the measure of VOT in seconds and the x-axis shows the pre-test (A) and the post-test (B).

Plosives are produced with pulmonic airflow (air from the lungs with respiratory muscles) in an egressive direction (out). As Linville's (2001) model of aging states, the aging voice will see a decline in the production of a voiceless stop consonant, reflected in the length, it may be pertinent to run this analysis by age for future research, as all of these women who improved were below 85 years of age.

In Ladefoged/Johnson's 'A Course In Phonetics' it states;

> "the maximum opening will occur at about the moment of release of the stop closure. The degree of aspiration will depend on the degree of glottal aperture during the closure. The greater the

> opening of the vocal folds during a stop, the longer the amount of the following aspiration." (160)

One way to interpret these results could be to simply state that the extended VOT speaks of enhanced egressive pulmonary airflow (McCrea, 2007). Another way to interpret the changes might be to look at the extended aperture of the vocal folds as able to enable an extended VOT, in other words the vocal cords can remain open for longer. This may also speak of an ability to handle increased pressure in the sub-glottal and supra-glottal sequencing before, during and at the onset of voicing. A deeper analysis would be required to answer these questions as to whether or not singing training lengthened the VOT of the speaking voice.

Summary

Significant results were seen in the measures for breathing from pre to post-test. Higher scores were seen in the PFM readings and longer duration of vowels in sustained vowels and vowels measured from the readings. Also, stronger use of inhalation for speech was seen in the reading of 'Imagine'. The measurements for shimmer (APQ5) were decreased in the post-test for the sustained vowel [u] and the vowel taken from the readings. The measurements for jitter (PPQ5) were decreased in the post-test for the sustained vowel [a] and the vowel taken from the readings. The harmonics to noise ratio (HNR) was increased for the sustained vowels [a] and [u] in addition to the vowel taken from the readings. f0 was increased in all of the sustained vowels and VOT for [k] and [p] was increased collectively from pre to post-test.

Results that were not significant were the number of breath measures for speech for the prose reading 'Happiness'. The shimmer measures (APQ5) were not decreased for the sustained vowels [a] and [i]. The jitter measures (PPQ5) were not decreased for the sustained vowels [i] and [u]. The harmonics to noise ratio (HNR) was not increased for the sustained vowel [i]. The measurement of f0 was not increased for vowels taken from the reading and no measures of intensity were significant for any sustained vowel or for the readings.

V. Emotional Perceptions and Observations

This section provides a report on non speech factors such as subjects' emotional responses to the study, perceptual reactions to subjects' own speech or singing voice, comments and reactions recorded during the class and observations/patterns taken from the final questionnaire. The singing sessions themselves brought about different emotional reactions that I personally observed or were directly communicated from the participants. At the end of each session, I recorded comments made in class and at the post-test I asked subjects to complete a questionnaire (see appendix #9). I will summarize these observations and perceptions. It was fairly commonplace for some participants to be moved to tears during the vocal warm ups - especially during or after the hold the note exercise. Something about the prolonged group production of vowels seemed to become meditative and had a cathartic effect. In fact if I didn't start with a hold the note exercise at the start of class, they requested it. At the start of class or during the song it became standard for participants to share stories from childhood or young adulthood about singing, music or school.

When I started the class, the seniors were verbal about their motivation, but physically, many of them moved slowly. During the first few classes, it took at least 10 to 15 minutes to get started. When we would start they would look slouched in their seats and many would look sad or depressed. When we would move to the piano most would bring a chair and sit. It was hard to attend to posture and anything that involved a physical core. During each class, I would see/perceive a shift in their physical stature and facial expressions. Everything seemed lifted; the face, the mouth, the body and the eyes. Towards the end of the 8 weeks, class started much more quickly and participants sat up straight and most stood around the piano instead of sitting.

The majority of the subjects who stayed with the class had strong feelings and took the process quite seriously. In this section I have also included comments and responses from one female subject who was ineligible to be a test subject but took the class (F_X) and one woman who was unable to attend the post-test due to an injury, but was a committed and enthusiastic subject right to the end (F_E).

Subject F_B attended all classes, the one on one check in and practiced 1 hour a week. At the start, F_B reported feeling frustrated with dentures, feeling as though they had changed her ability to speak clearly, and that she felt she lacked stamina in her speech as a result. She also exhibited some hoarseness and cleared her throat regularly. In the questionnaire she stated, “Singing has made me feel empowered and it was really fun. I feel like I speak more clearly. I have to get together with my daughters and sing with them. I feel like this will bring us together.” Subject F_C attended 6 classes and practiced 3 times a week. At the start, she reported that she had had nerve surgery in her neck two years prior and had been house bound and felt depressed ever since. During one class she stated, “I just feel so happy after this class. I feel so sad when I miss it”. In the last class she burst into tears and stated, “This class has truly changed my life. I was house bound for two years and now I’m out and about and feel stronger as a person. Amazingly, I am getting the feeling back in my hands after nerve damage and surgery and I have no doubt it is because of the singing." Perhaps this speaks of the stimulation of the muscles in and around the neck as causing some nerve response? Subject F_D attended all classes, the one on one check in and practiced 4 times a week. At the start she reported soreness in the back of throat, a vocal rasp, nasal drip, was prone to regular coughing and clearing of the throat and had chronic asthma. At the one on one check in she mentioned that had perceived changes in her speaking voice, "I have less hoarseness. I feel like I have to clear my throat less, especially after I do the warm ups." In the questionnaire she stated, "I feel more aware of my volume and projecting my voice. I am aware of opening of my mouth and its effect on production. Singing makes me happy. My range has expanded. I can sing higher." Subject F_E attended all classes, the one on one check in and practiced 4 times a week. At the start she reported that her voice had lost volume and felt weaker in her old age. During the early stage of the lessons she noted with frustration "I can only sing for 10 minutes" in that she would get winded or tired. At the final questionnaire, "I'm more aware of when I'm not speaking loudly enough. I can hold a note and sing for much longer. I try to remember to open my mouth more when I speak so people can hear me. Singing can really change your mood." Subject F_F attended all classes, the one on one check in and practiced 1 to 2 times per week. At the start of classes she reported that it was hard to catch breath and that she experienced tightness in tongue. At the end of the classes, she said that she was speaking louder and breathing better. Subject F_G attended all classes, the one on one check in and practiced 1 to 2 times per week. In the very early stages of the lessons she lost steam and felt discouraged. She stated, "I feel like I was more enthusiastic at the beginning and felt like I was improving, but now I feel like I have to force myself to show up. If I liked the songs better, then I think I'd like it more. Also, the exercises are hard and I don't understand them. I find the purpose vague." At the one on one check in, she stated, "I have not perceived any changes yet regarding my voice." In the final questionnaire she stated "During our last class yesterday, I became aware of two changes: I was able to sing higher tones than before, as well as lower ones without straining to do so. I felt my soft palate for the first time. That felt good. That made me realize, that noticeable changes do not usually occur until about the 7th session of classes. It was a good feeling to have concrete proof of the effect of the classes." Subject F_I attended 6 classes, the one on one check in and practiced 1 to 2 times a week. At the start she reported nasal drainage and a dry throat. In the questionnaire she noted experiencing a feeling of deeper breathing in her body since singing. Subject F_J attended all classes, the one on one check in and practiced 3 times a week. At the start she reported dry lips and mouth, hoarseness, dehydration due to medication and regular shortness of breath. In the questionnaire she stated, "There were no noticeable changes in my speaking voice. I am more aware of breathing and how not to strain my voice when I sing. (My) overall disposition has changed and I see a huge improvement in my singing voice. My voice feels stronger and I want to sing all the time." Subject F_L attended all classes, the one on one check in and practiced every other day. In the questionnaire she stated that she had noticed deeper breathing and had more awareness of her speaking voice in connection with breath production. Subject F_M attended all classes, the one on one check in and didn't practice at all. At two different times during the run of classes, F_M wanted to quit, and while she had the freedom to do so, she ended up staying every time. During the post-test she mentioned that she was grateful she had pushed through and admitted that she had a childhood fear of singing due to several bad experiences. She stated, "I am much more aware of my breathing and I feel like I can now sing well enough that I don't hate the sound of my voice." Subject F_N attended all 6 classes, the one on one check in and practiced 3 to 4 times a week. At the start she reported holding her breath during the day due to stress. In the questionnaire she stated, "I don't hold my breath anymore, which I did all the time. I have more stamina overall. I feel more relaxed and carefree." Subject F_P attended 7 classes, the one on one check in and practiced 1 to 2 hours a day. At the start she reported having scar tissue on lungs, allergies and post-nasal drip. She stated at the 2nd lesson, "This is changing my whole life. I have been living in silence." This subject was probably the most enthusiastic and she kept a diary on her experiences. In the check in she stated, "I can't stop crying, it used to be tears of joy but now it is tears of pain. As this class gets harder and the singing moves higher (in range) I feel such resistance to it. (As a child) I used to live in a basement in Chicago, I wasn't allowed to be vocal at all and I wasn't allowed to go upstairs. Now I feel like I'm not allowed to move out of the basement of my voice. It's very powerful. I am pushing through and I'm so grateful. This is divine intervention. I'm using my voice more in every way. I'm breathing better. I'm writing songs." At the final class she shared a song she had written called "Becoming Me More". In the questionnaire she stated that through the class she had become aware of deeper breathing, more space in the mouth and felt upper tones in her speech. "Vowel sounds triggered something in my brain related to memories, painful childhood experiences and I found I couldn't stop crying. (I have) no doubt my posture has improved as a result of this class, I feel taller. I have always had a curved spine. I don't feel that anymore. I feel bolder and feel more empowered to speak up for myself. Also, my sense of hearing has improved." Subject F_R attended 6 classes and practiced 2 times a day. F_R, was a stage-4 cancer patient who reported regular nasal congestion, post-nasal drip and chronic pain. During class she stated, "The only time I don't feel the cancer is when I'm singing. I don't want to stop. My oncologist asked me what I am doing!" In the questionnaire she stated, "I can breathe more deeply. My mood and overall disposition has changed. I have more energy. (This class has) greatly affected my healing and positive outlook on my treatment."

What struck me with many of these comments was not that the subjects felt they were improving, but that they were surprised that regular work on their voice could bring change. It was new to me to work with people who were unaware of the nature of improvements on the voice through exercises. While this was not the point of my study, these responses were substantial in confirming the emotional benefits of singing in tandem with the physiological benefits. Considering that I plan to further study the psycholinguistics of speech and singing in geriatric voice, I felt inclined to include this information.

VI. Discussion/ Conclusion

The effects of singing on speech in geriatric voice with respect to my theory that regular and repetitive singing training would improving strength of exhalation and motor control of speech, see a decrease in jitter and shimmer and an increase in harmonics to noise ratio (HNR) and would raise the f0 of females' speaking voices through engaging the respiratory system and the vocal tract in regular exercise produced some significant results, some preliminary results and some null results from the pre to post-test.

Strong results were found in the Peak Flow Meter scores after the singing training ($p > 0.005$*). Strong results were found in the extended duration of sustained vowels and the duration of vowels taken from the readings ([a] $p > 0.001$*, [i] $p > 0.003$*, [u] $p > 0.02$* and [æ] $p < 0.0001$*). Strong results were found in that there was a correlation between the number of breaths taken against the read speed with two subjects (F_L and F_D). These results prove that strengthened exhalation is a positive result of singing training in the voices of the elderly. Given that there was a strong emphasis on breathing practice with phonation in the singing lessons, and this outcome was a strong prediction before the pre-test it is not surprising for the sustained vowels, but is encouraging with respect to the measures taken from the readings.

Mixed results were found in the measurements of shimmer, jitter and harmonics to noise ratio. Reductions in jitter, shimmer and an increase in HNR showing reduced variation were found in all the measurements taken from the readings [æ] APQ5 $p < 0.04$*, PPQ5 $p < 0.03$*, HNR $p > 0.03$*). The measures for jitter analyzed against each word were the most exciting, showing that for the word *mad*, which was measured in the middle of the prose reading, 'Happiness', (where one would expect more variation of pitch in a croaky voice), there was a significant reduction and reduced variance ($p < 0.04$*). These results speak of preliminary evidence that singing can impact the acoustics of speech in the elderly, but more research is needed. The sustained vowels produced mixed results, for APQ5 (shimmer) the measurement for [u] was significant $p < 0.03$*), but for [a] ($p < 0.12$) and [i] ($p < 0.119$) it was not significant. It is interesting that [u] was the highest pitch of the three and this produced the most significant result. This may speak of pitch work, with an emphasis on extending pitch range in the voice, as creating a change in the amplitude perturbation in the speaking voices of the elderly. For PPQ5 (jitter) the measurement for [a] was significant ($p < 0.04$*), along with reduced variance in the data, and yet for [i] ($p < 0.177$) and [u] ($p < 0.09$) it was not significant. This is interesting for the opposite reason stated in the APQ5 results, in that [a] was the lowest pitch for the sustained vowels and produced a significant result. In singing training, low [a] sounds are usually harder to control for amateur singers and if there is gravel or creak in the voice, this is where it will be evident. This result is encouraging because it too may speak of the efficacy of pitch work as being able to deflect pitch perturbation issues in the voices of the elderly.

The results for f0 were significant for each of the sustained vowels ([a] $p > 0.04$*, [i] $p > 0.04$*, [u] $p > 0.04$*), but were not significant for either of the readings ($p > 0.83$). These results do not support the claim that singing can alter the f0 in the speaking voices of the elderly. While there was some slight change in the measurements of f0 from pre to post-test, the null result may be a reflection of the time span of this study. 8 weeks is a short time for singing training for any subject, but especially a population who are known to be less malleable. Given that the sustained vowels were strong, and this was a point that was practiced in the lessons and in the homework, it may mean that the more controlled phonation tasks of sustaining vowels to pitch, speaks of long-term effects in speech (which is less controlled) over time. However more research is needed to prove or analyze this further. There was a correlation between the results for f0 and the results for jitter, where f0 measurements increased, jitter measurements decreased. Future studies investigating pitch range, vowel space and acoustics measurements such as jitter, shimmer and HNR should consider this correlation.

Strong results were found for VOT, which reflected a higher mean value in the post-test and therefore showed an increase in VOT measurements ($p > 0.0005$*). This supports the findings of the pilot study and the aforementioned previous studies that singers have longer VOT than non-singers in speech tasks. This result proves that singing has a positive effect in the speech of the elderly with respect to the management of exhalation, sub-glottal pressure and adduction of the vocal folds and speaks of an improvement in motor control of speech.

Laryngeal muscles see a weakening and the larynx lowers in aging voice (Linville, 2001). In this study, the attention on thoracic breathing and exhalation, built strength in the ability to hold a note and bring more focus to posture and muscles in and around the rib cage. The training brought attention to the sternum, which expanded the rib cage and helped to lift and steady the larynx. The responses from this study were heavy on breathing results and the ability to be aware of one's breathing. The PFM results compared with the sustained vowels, duration of vowels in the readings, along with the breaths taken during the readings, reflect a distinct change in exhalation strength and was a significant result of this study. In future, to complement this I would use a spirometer to measure inhalation against exhalation. While many studies that measure acoustics collect data from sustained vowels, with a study of this nature that looks at singing and its effect on speech, sustained vowels are more indicative of changes in singing than speech. Therefore, further study or analysis is needed for changes to intensity, f0 and pitch work and overall, and measures that speak of changes to speech over results in singing tasks.

In general, it was harder to work with seniors than I had anticipated. They had many ailments and health problems, and social issues that they wanted to discuss. Physically and with respect to articulation, they deal with dentures and hearing issues that I had not considered thoroughly. There was a lot of dissatisfaction with the song selection, and the take home exercises and it seemed that no matter how many ways it was presented or explained it was still confusing. The students I have had in the past have either been singers, or were motivated to learn sing. The work required in doing the at-home assignments, they found to be tedious, and while most singers who do this kind of work would agree, the motivation needed to do the work is the desire to improve and/or maintain one's voice. Next time I run a study of this nature, I would work harder to provide better at home practice materials and offer a starting practice module. I think that participants would have practiced more if they'd found the homework materials easy to work with and I think the results would be better across all subjects if the practices were better controlled. I would in future conduct the study over a longer period of time and hold class session for a longer time, with more one on one attention. In the exercises themselves, I designed the lessons to have variation from class to class, and based on these results; I would change this and have less variation and more repetition. I would also conduct a far more thorough analysis of their hearing and overall health before commencing.

With that said, the results seem encouraging in that singing can lead to improved acoustic measurements of speech with less variability. The emotional benefits of singing were palpable, and while studies about this have been done, it would be interesting to account for these factors in conjunction with acoustics in another study. For example, what does the literature reflect with regards to the intonation of voices in depression and comparisons between this and acoustic measurements? How does singing affect posture and balance of the body? What about height and posture before and after singing? How does increasing pitch range alter the vowel space of geriatric voice? Professor Julene Johnson (May, 2103) stated that "the study of singing in speech is in its infancy" and I find it exciting that this study produced so many results alongside so many questions yet to be answered.

In conclusion, the PFM and duration measurements reflect an enhanced strength of exhalation capacity in the post-test measurements as a result of the singing lessons. The f0 measurements had a significant increase in the sustained vowels and smaller standard deviations but not in the speech measurements. The direct measurements of 'perturbation' APQ5 and PPQ5 reflect a decrease in variation and the HNR shows a correlated increase. The data shows a reduced variance after singing lessons in the breathing measures and duration measures for all vowels, some of the direct measurements of perturbation (APQ5, PPQ5 and HNR) along with the measurements of f0 and also the measurements of VOT show a difference from pre test to post test after the singing lessons.

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Images:

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Appendices

Appendix 1:

The **Seven towers of Kharoun** are located in Iran. They are the largest recreational center in the west of the Isfahan province. The seven towers of Kharoun are surrounded by a garden with an area of 3000 $meters^2$. The towers are 14 meters in height and are connected with each other by a cob wall with the height of 4 meters. After the conversion of towers to a recreational center, some facilities have been added to them. These facilities include a fountain, a traditional coffeehouse, an entertainment area, a space for cultural activities and a park.

Appendix 2:

Imagine there's no countries
It isn't hard to do
Nothing to kill or die for
And no religion too
Imagine all the people
Living life in peace...
You may say I'm a dreamer
but I'm not the only one
I hope someday you'll join us
and the world will be as one

Appendix 3:

"Happiness lies not in the mere possession of money; it lies in the joy of achievement, in the thrill of creative effort. The joy, the moral stimulation of work no longer must be forgotten in the mad chase of evanescent profits. These dark days, my friends, will be worth all they cost us if they teach us that our true destiny is not to be ministered unto but to minister to ourselves, to our fellow men." Franklin Delano Roosevelt.

Appendix #4

Song List for Seniors. **(Bold = my selection)**

'Why Do Fools Fall In Love' by Frankie Lymon

'In The Still Of The Night' by Fred Parris & The Satins

'Bare Necessities' by Louis Armstrong

'I Shall Not Be Moved' by Johnny Cash

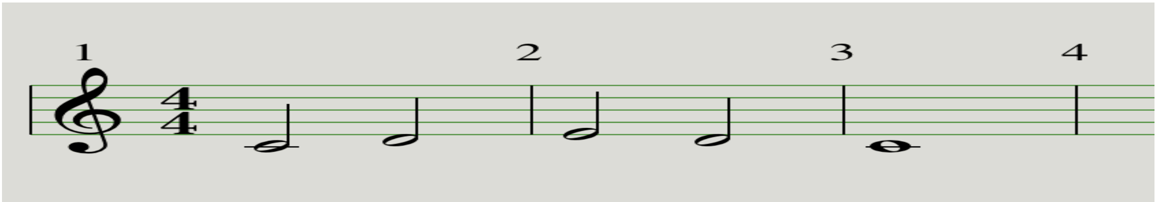
'Everybody's Talking At Me' by Harry Nilsson

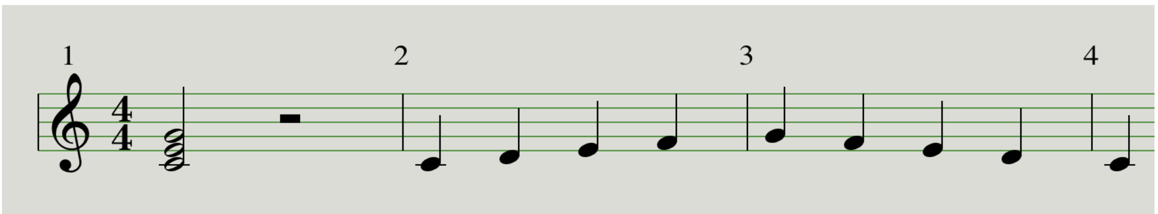
'Hey Jude' by The Beatles

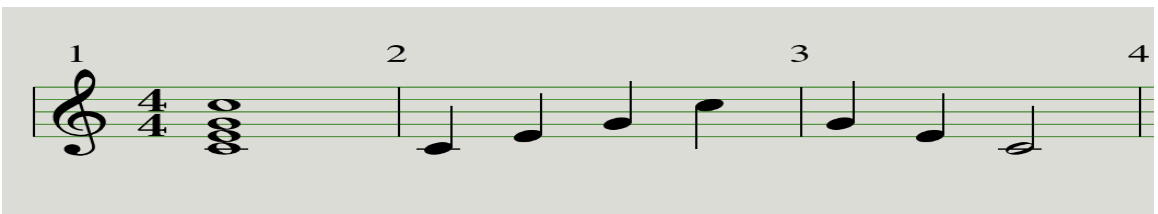
'We'll Sing in the Sunshine' by Gale Garnett

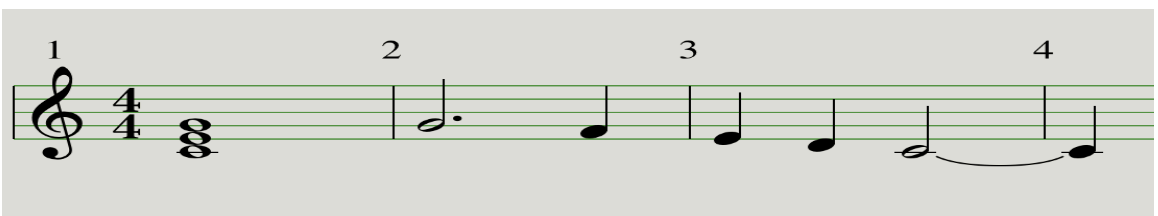
'Hallelujah' by Leonard Cohen

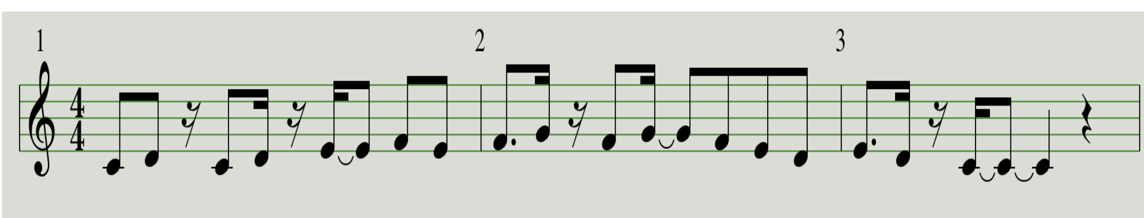
<u>Appendix #5</u>
(A few examples of the melodies used in the singing lessons.)

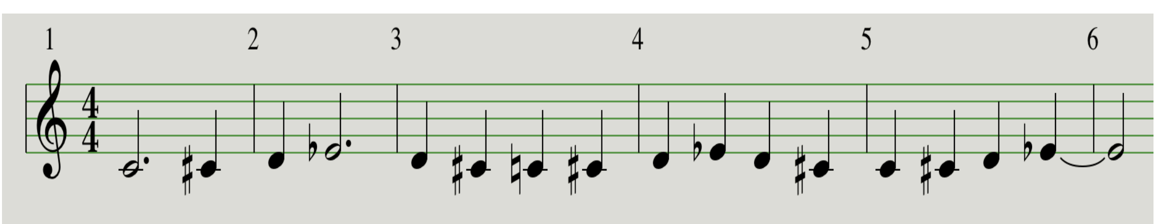












<u>Appendix #6</u> – Inhalation muscles

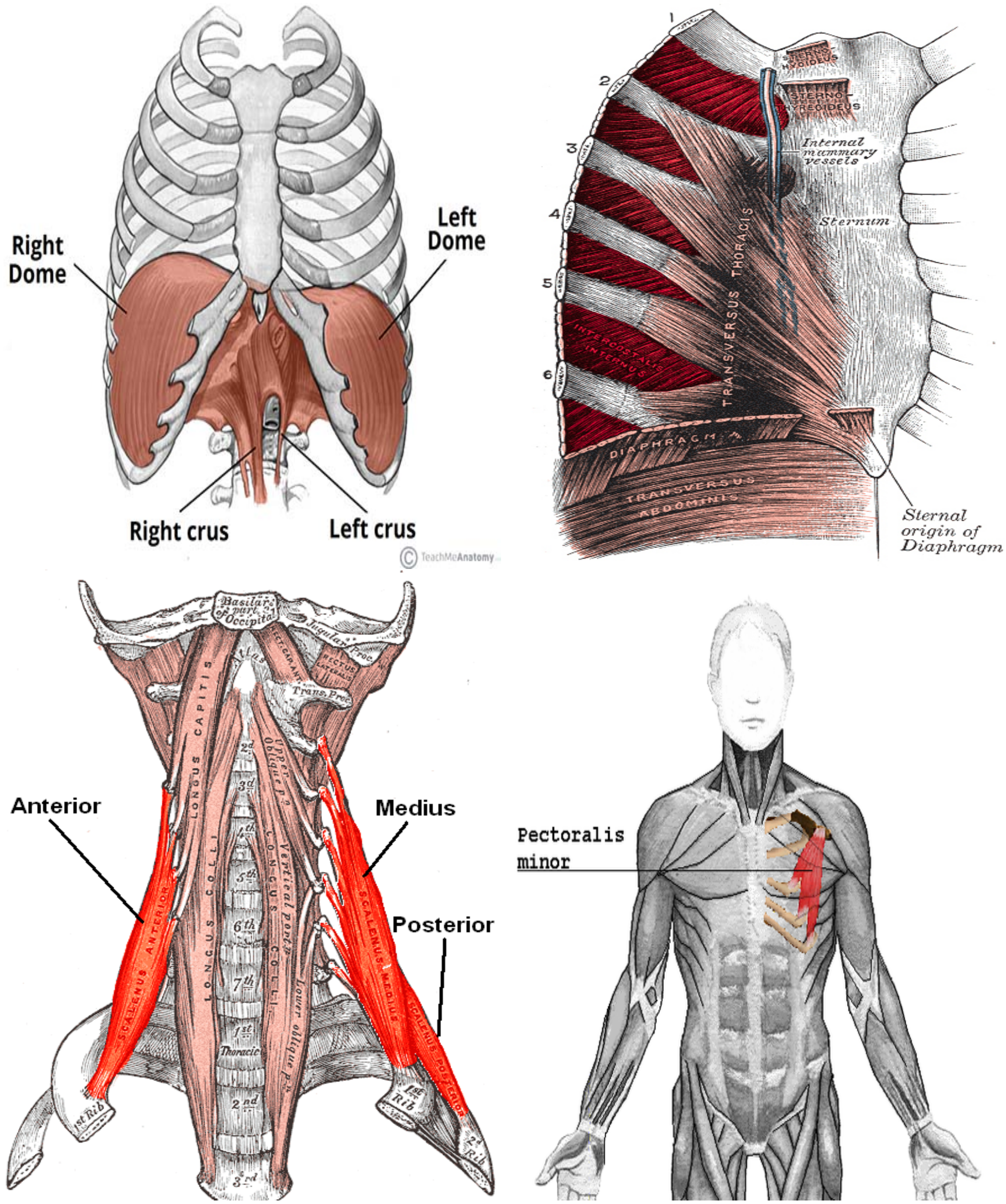


Figure 27: Top Left - Diaphragm. Top Right – Intercostals. Bottom Left – Scalenes. Bottom Right – Pectoralis Minor

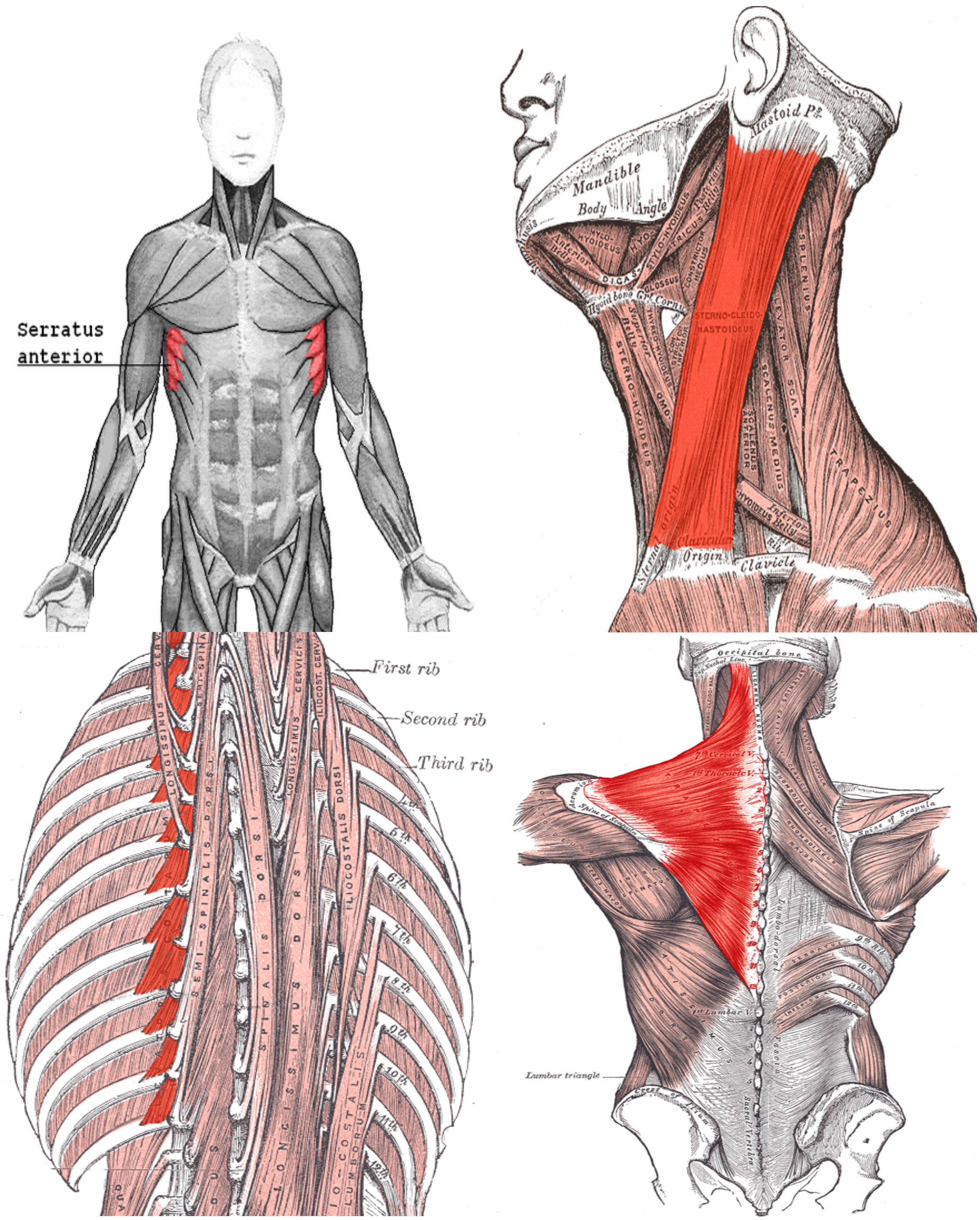
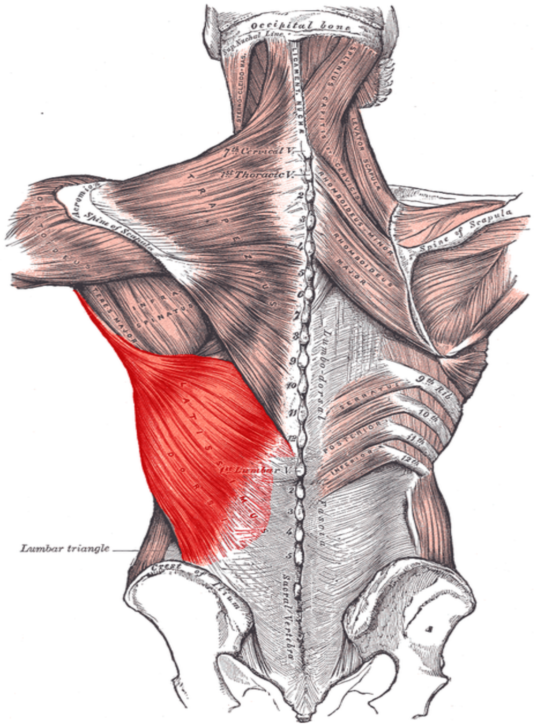


Figure 28: Top Left – Serratus Anterior. Top Right – sternocleidomastoid. Bottom Left – Levator Costarum. Bottom Right – Upper Superior Trapezius.



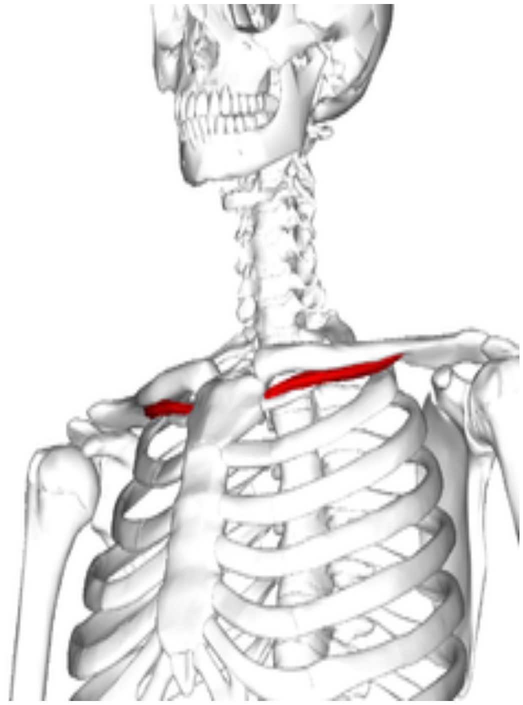
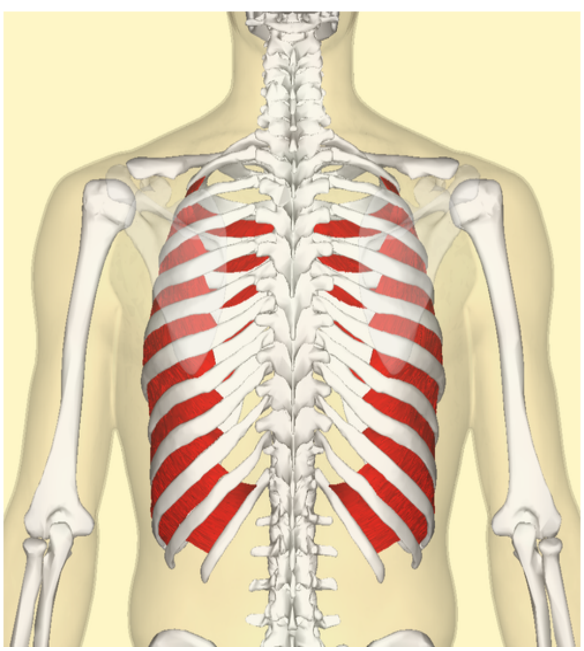


Figure 29: Top Left – Latissimums Dorsie. Top Right – Subclavius.

<u>Appendix #7</u> - Exhalation Muscles



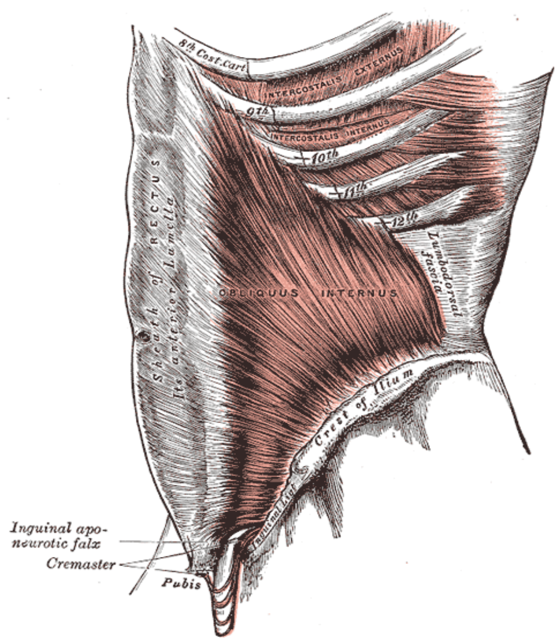


Figure 30: Left – Internal Intercostals. Right – Obliquus Internus.

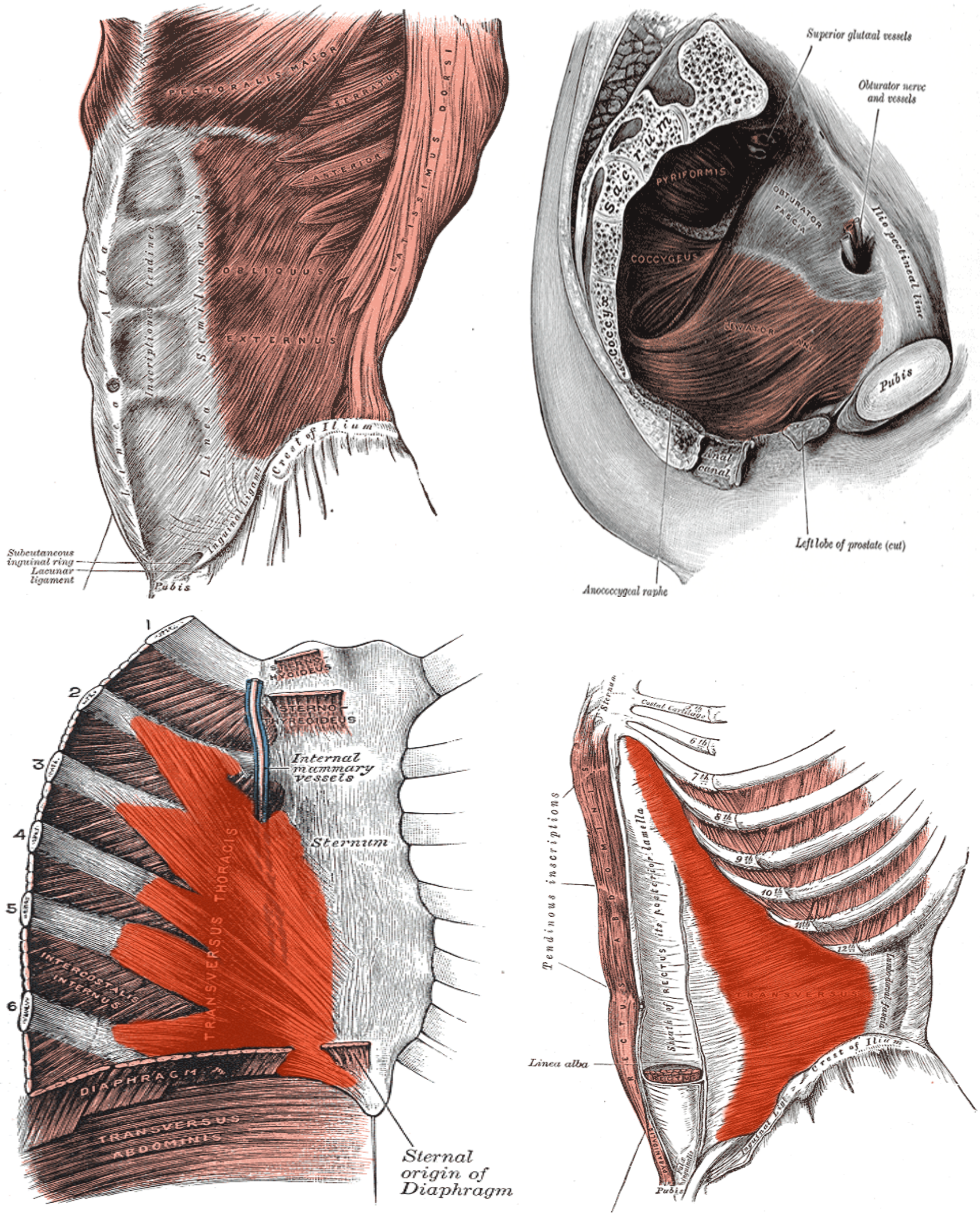


Figure 31: Top Left – Obliquus Externus. Top Right – Levator Ani. Bottom Left - Triangularis Sterni. Bottom Right – Transversalis Pyramidalis

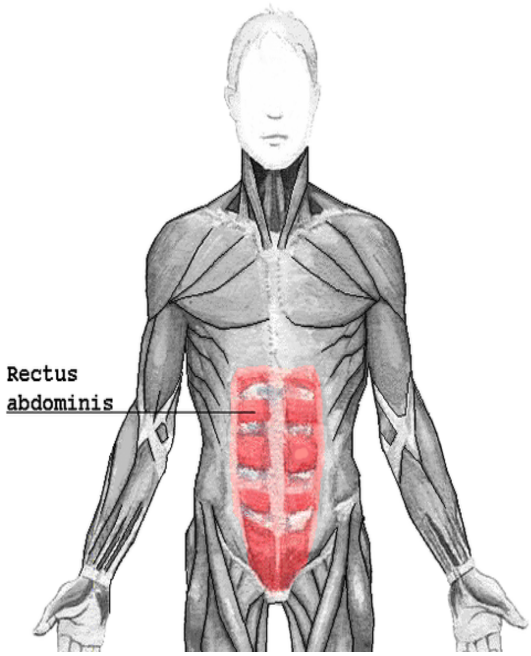
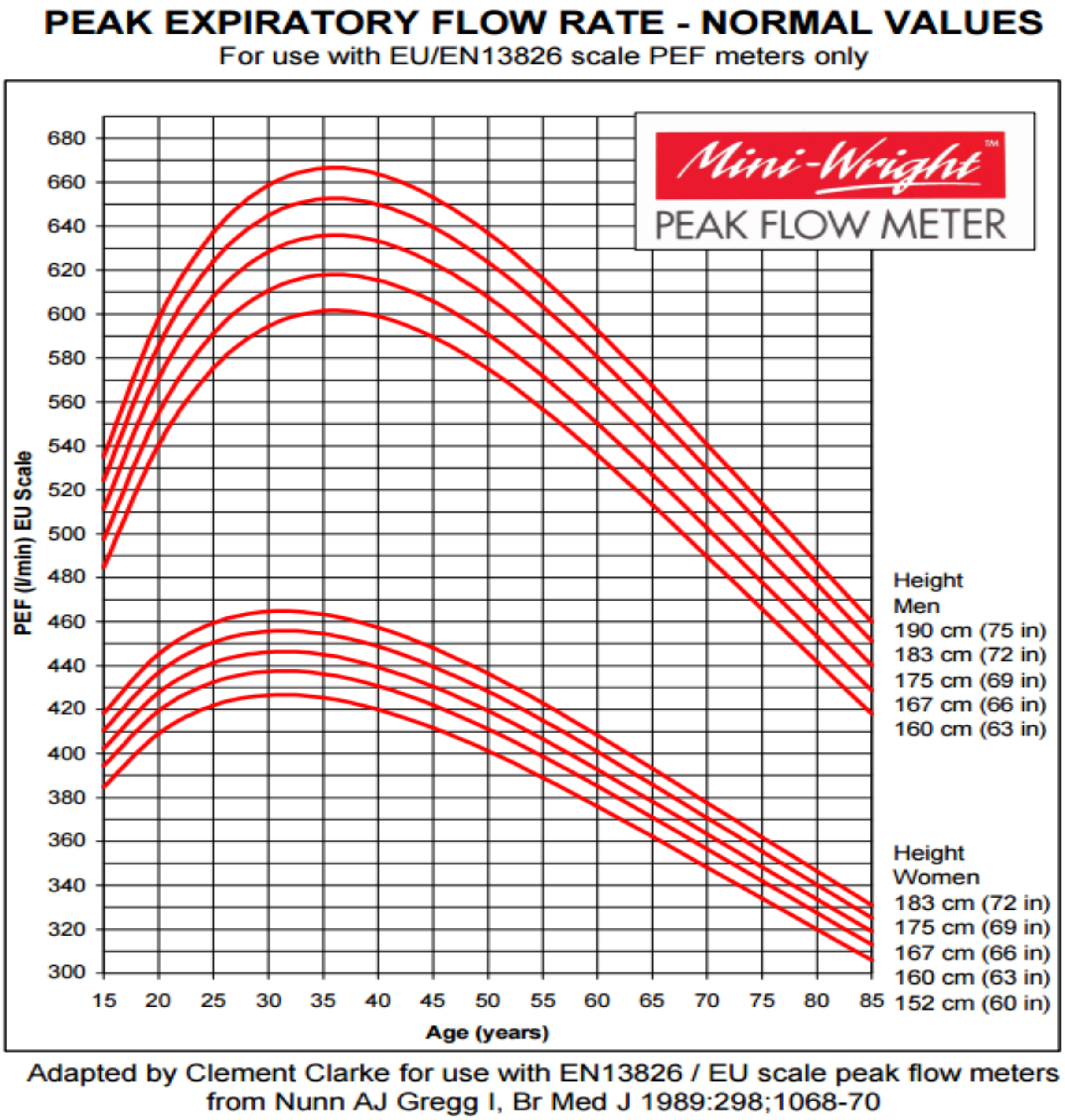


Figure 31: Top Left – Rectus Abdonmis

Appendix #8


PEAK EXPIRATORY FLOW RATE - NORMAL VALUES
For use with EU/EN13826 scale PEF meters only
Mini-Wright™
PEAK FLOW METER
PEF (l/min) EU Scale
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age (years)
Height
Men
190 cm (75 in)
183 cm (72 in)
175 cm (69 in)
167 cm (66 in)
160 cm (63 in)
Height
Women
183 cm (72 in)
175 cm (69 in)
167 cm (66 in)
160 cm (63 in)
152 cm (60 in)
Adapted by Clement Clarke for use with EN13826 / EU scale peak flow meters
from Nunn AJ Gregg I, Br Med J 1989:298;1068-70

Appendix #9 – Final Questionnaire

Name ____

Please complete this as thoroughly as possible. Feel free to use the back and/or additional paper if necessary. Thank you very much for your time.

1) Do you experience any voice issues; hoarseness, dry throat, etc.? (Please describe in detail.)

2) Do you experience any respiratory issues? (please describe in detail.)

3) Do you exercise? Yes___/No____. If yes, what do you do?

____

4) In what ways have you perceived changes in your speaking voice and/or breathing since taking this class?

____

____

____

5) In what other ways has learning more about singing had an impact on you or your life?

____

6) How many classes total did you attend?_____________________________________

7) How often did you practice the assigned exercises?____________________________

8) Did you do anything extra to practice/improve? Yes____/N0____?
If yes, please describe. ____

9) How did these lessons meet with or compare with your expectations of singing classes, learning to sing and/or history with singing in general?
____

____

10) Would you take a class like this again?_____________________________________

11) Do you have any feedback that you think would be helpful for this study?