# EFFECT OF PHONATION TYPES ON VOCAL FOLD ADDUCTION IN PHONONORMAL INDIVIDUALS

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**MAY 2019**

## CERTIFICATE

This is to certify that this dissertation entitled **"Effect of phonation types on vocal fold adduction in phononormal individuals"** is a bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Science) by the student holding Registration Number: 17SLP035. This has been carried out under the guidance of a faculty member of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru

May 2019

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## CERTIFICATE

This is to certify that this dissertation entitled **"Effect of phonation types on vocal fold adduction in phononormal individuals"** has been carried out under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
May, 2019

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## DECLARATION

This is to certify that this dissertation entitled "**Effect Of Phonation Types On Vocal Fold Adduction In Phononormal Individuals**" is the result of my own study under the guidance of Dr. R. Rajasudhakar, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any Diploma or Degree.

Mysuru **Registration Number: 17SLP035**

May 2019

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*"DEDICATED TO MY PERIPAA, GRANDMOTHER*

*MY LOVELY PARENTS AND TO MY ENTIRE FAMILY"*

*-WITHOUT WHOM I AM NOWHERE*

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*Dear I phone Sonia, maa fight partner, who seeks me and tortures me all time…. Friend with same mental disorder, nice having friend like you, loosuuuu gal be in touch.. I lovvee youuu alwayzzzz …*

*Dear Renita, my roomieee, the girl who is always close to ma heart and who shares with me all the time.. wanna thank your mom who alwayzz cares,bless and loves me like her daughter… love u alwayzz dear…thankyou for your love and concern….*

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## TABLE OF CONTENTS

# LIST OF TABLES

**List of Figures**

# Chapter I

# INTRODUCTION

Voice is the component of speech that gives the speaker with vibratory signal through which speech is carried. Today, the voice production is considered as powerful communication tool which serves as the melody of our speech. It helps in coupling our daily thoughts by providing with expression, feeling, intent, and mood.

A normal voice can be stated by pleasant quality, appropriate pitch, sufficient loudness, adequate flexibility, acceptable sustainability (Johnson, Brown, Curtis et al., 1995). Phonation is the process in which the expelled air from the lungs is transformed into sound via vibration of the true vocal folds.

A single vibratory cycle of the vocal folds is generally studied to comprehend the biomechanical behaviors and their perceptual correlates. There exists overlap between the normal and the disordered voice which can also be observed in vocal fold behaviour as well in the sound of voice. As the clinician frequently observes incomplete vocal fold adduction in dysphonic patients, it is easy to overlook that many speakers without voice problems have been shown to have glottis chink and a degree of vocal fold bowing (Hirano & Bless, 1993). It is the degree of inadequacy of vocal fold closure that is significant and, for the dysphonic individual, the extent to which it causes the voice to deviate from normal.

There are various non-invasive methods of determining vocal fold closure practiced across the world, which comprises "Electroglottography (EGG), aerodynamic measurements and acoustic analysis" of the voice signal. These would be very appropriate in clinical set up. Among this, one such widely used acoustic analysis system is the multidimensional voice program (MDVP). "The Multi-Dimensional Voice Program (MDVP)" is promising software for acoustic assessment which is widely utilized by many investigators in the field of voice for being very comprehensive. Thus, it is essential to study its particularities.

MDVP is an add-on application in the "Computerized Speech Lab (CSL 4500 model) by Kay Elemetrics (New Jersy, USA)". This program automatically extracts and shows 33 voice parameters that can then be compared to threshold values/database and displayed graphically. Out of all 33 parameters, SPI is one of the important parameter in MDVP that reflects the approximation of the vocal folds. "SPI is an evaluation of the weakness of high-frequency harmonic components that may be an indication of loosely adducted vocal folds during phonation (Deliyski, 1993)". SPI is corresponded to spectral slope. It represents "the average ratio of lower frequency (70–1600 Hz) harmonic energy to the higher frequency (1600–4500 Hz) harmonic energy" of the voiced areas in the analyzed signal. Even though, the spectral slope is known to get affected by the rigidity of the vocal tract walls, the main factor that determines the slope of the spectrum is signal of the voice source i.e. weaker the closure of vocal folds, the spectral slope is stronger. High values of SPI indicate incomplete vocal fold adduction or vocal fold contact isn't firm during vibration. Authors stated that when comparing the signal of normal phonation, breathy signal was found to have increased energy in the high frequency region (Hillenbrand, Cleveland & Erickson, 1994).

Another system which is extensively used to measure the variations in the contact area between the two vocal folds, as a function of time is Electroglottography, a noninvasive method (Fabre, 1957). The principle behind the EGG is that a high-frequency current, which is of low magnitude would be passed between two disk electrodes placed on either side of the thyroid cartilage at level of vocal folds. As vocal folds vibrate, the electrodes measure the change in the resistance. Since the electric current is conducted better by the tissue (i.e. when the vocal fold are in contact) than air (i.e when the air gap exists between the folds (glottis) or when vocal folds are apart), there will be increase in the resistance when the opening or opened phase of vocal fold take place and the drop in the resistance can be seen when the vocal folds undergoes closing or closed phase (Stemple, Glaze, & Klaben, 2009).

The ideal EGG waveform shows the result of laryngeal impedance variations and shows vocal fold contacting behaviors regarding the time and rate of glottal closure and opening. The waveform's landmarks are related to the relative movement and position of the vocal folds during phonation.

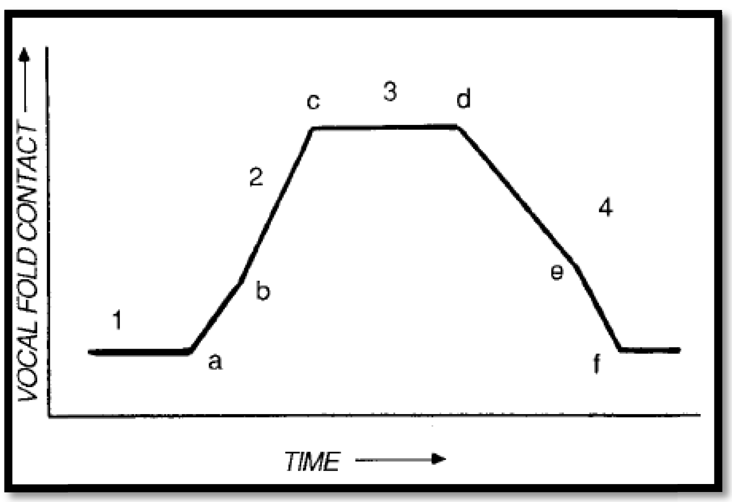


*Figure 1.* Ideal EGG waveform

EGG waveform's orientation is that an upward waveform corresponds to an increasing area of vocal fold contact. An acute increase in the EGG waveform corresponds to the rapid closure of the vocal folds and is followed by a gradual decrease in the waveform associated with the separation of the vocal folds as the pressure below the glottis is higher than above and the vocal folds tend to return to the equilibrium position.

In each cycle of an EGG output, a number of features are generally identified including amplitude of each cycle, closing phase, maximum closure, Opening phase, closed phase and open phase.

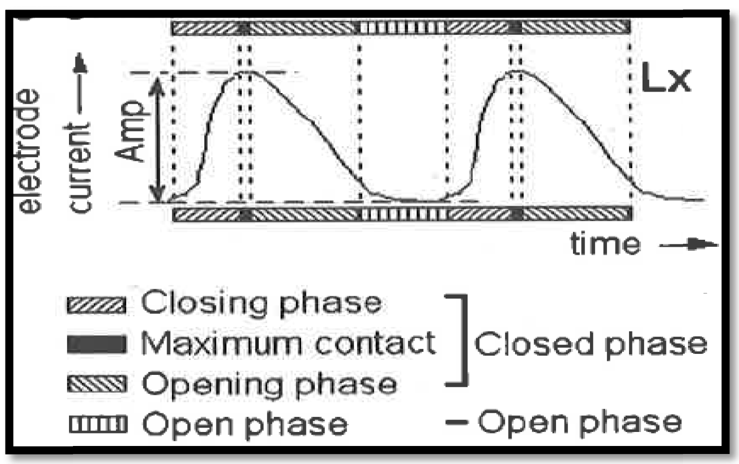


*Figure 2*. Cycle of an EGG Waveform

Rothenberg introduced a measure of the 'relative vocal fold adduction' (Rothenberg 1988), known as the 'contact quotient' or CQ. It is used to compare the duration of the contact phase to the period of the vibratory cycle. It is calculated as percentage of the cycle for which the vocal folds are in contact.

$$CQ = [(CP/Tx) X 100] \%$$

Titze theoretically examined the physiological relevance of the EGG signal, the latter discussing the effects of (1) increased glottal adduction, (2) glottal convergence (with vertical phasing), (3) medial vocal fold surface bulging, and (4) increased vertical phasing in vocal fold vibration.

The calculation of the $CQ_{EGG}$ is influenced by the choice of algorithms used to determine contact and de contact instants and must therefore be used with caution. (Kania et al., 2004 and Herbst and Ternström, 2006). For the purpose of calculating the $CQ_{EGG}$, either (1) applying a threshold criterion to the locally standardized EGG signal (Rothenberg and Mahshie, 1988) or (2) finding positive and negative maximums in the first mathematical derivative of the EGG signal (dEGG) reflecting the maximum rate of change of the EGG signal over time is estimated.

The complicating factor is that the edges of the vocal folds are not just moving together and separating as monolithic masses. It is now well established that the glottal margin's lower and upper segments have some independence, and their closing / opening motions are not synchronous, while regular, correlated, and quasi-periodic. Therefore, the glottal closure at the top and bottom of the vocal fold is not achieved simultaneously, nor does the opening begin at the same time through the depth of the vocal fold. Rather, vocal fold vibration is characterized by phase differences along both the inferior–superior (Titze et al., 1993) and anterior–posterior (A–P) dimensions (Equally important, in the horizontal plane, opening and closing often do not occur at once. Instead, the vocal folds may display zipper-like behavior, with closure / opening from one end to the other). These phase differences cause time-delayed contacting and de-contacting of the vocal folds along the respective axes. Therefore, there is no particular moment of glottal closure and opening, but rather an interval during which the closing and opening, respectively occur.

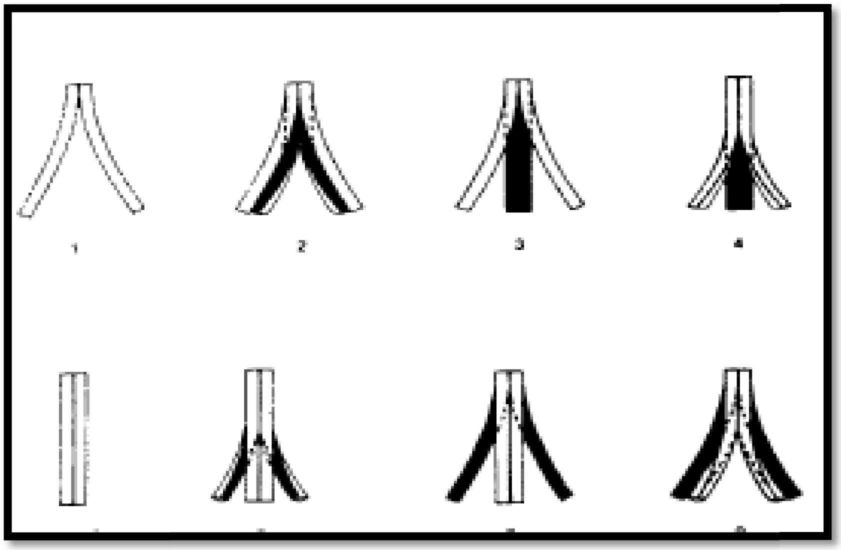

*Figure 3*. Geometric two mass model of vocal fold activity

Clear recording of the vocal fold contact area cannot be expected to simply reflect the extent to which vocal fold separation occurred (in the sense of the glottal extent or area visible in the upper view). Rather than, Lx suggests the complex changes in the contracting surface arising from the rolling of one vocal fold over the other in combination with the glottal lip scissoring approximation / separation.

EGG waveforms for typical voiced men versus women have been described in several studies. In a study comparing high-speed film versus glottographic methods, a" knee" (a characteristic concave-down region observed in the opening phase of the EGG waveform) was observed in the EGG signal for its male subject but not for their female subject and suggested that this was due to a more gradual opening of the glottis in them. Titze, suggested that male vocal folds adduct with a medial surface bulge and that the knee reflects both a vocal fold bulging and a rapid change in the contact-to-decontact vocal fold event. Titze's vocal fold contact pattern models, on the other hand, did not show this abrupt change in female vocal fold contact acceleration. As a result of vocal fold atrophy associated with aging, there is also reduced vocal fold closure. In older females, vocal fold edema was found to be more prevalent than in older males, presumably associated with hormonal fluctuations after menopause in older females.

Studies have shown that older speakers may found to have a slightly breathy voice quality. It had been found that there was an inadequate closure of vocal folds in both elderly women and elderly men during phonation (Honjo & Isshiki, 1980; Biever & Bless, 1989). CQ has also been helpful to make a distinction between breathy and pressed voice qualities and to correlate with the degree of perceived pressedness of phonation (Linville, 1992). Titze (1984) had stated that in breathy phonation the vocal folds are hypoadducted while the vocal folds tend to hyper adduct in pressed phonation.

Linville (1992) examined the configuration of glottal gap in women who were categorized into two groups. 10 young women with the age range of 21 to 23 years and 10 elderly women with the age range of 72 to 87 years were considered. Glottal gap configuration was observed across nine-pitch/loudness phonatory conditions using videostroboscopy and Visi-Pitch (Kay Elemetrics, 6087 Model) and it was reported that complete closure was more frequently attained in older women than a young woman. Also, data of both elderly and young women demonstrated a more incidence of glottal gaps and gap in the anterior region or spindle configuration was also noticed rarely. In contrast, the most common type of gap that was seen in elderly is anterior gap, most of time spindle was also occurring significantly. Young women displayed a particularly high incidence of posterior chink, a finding that supports several studies (Koike & Hirano, 1973; Biever & Bless, 1989). There’s exceptionally less information accessible within the literature with respect to the formative changes in vocal fold adduction which is vague.

The Primary aim of the study is to examine the effect of different phonation types (breathy, pressed, and normal) on vocal fold adduction mechanism by studying soft phonation index (SPI) from Multi-Dimensional Voice Program and CQ from Electroglottography . The secondary aim of the study is to determine the effect of age and gender on the vocal fold adduction mechanism and investigate the correlation between them.

## Chapter II

## REVIEW OF LITERATURE

### Studies related to Soft Phonation Index (SPI)

Koreman and Putzer (1997) aimed to determine which of the voice parameters like fundamental frequency, frequency perturbation, amplitude perturbation, tremor, subharmonic measurements, spectral energy (also called Noise-related measurements) and voice breaks (based on both the acoustic signal and EGG signal) could be used to distinguish normal speakers from breathy speakers with organic pathology (unilateral vocal cord paralysis and cordectomy). Group 1 had control group of 25 males and 25 females normal subjects whereas group 2 consisted of 17 males and 33 female subjects with unilateral vocal cord pathology in the age range of 35–77 years old. Neckband condenser microphone (NEM 192.15, Beyer dynamic) was used to record the signal. They analysed the recorded signal using the Multi-Dimensional Voice Program (MDVP, Kay Elemetrics model 4338). They reported that with the exception of SPI, the parameters derived from the EGG were better than those from the microphone signal. Authors found that the SPI effect was not strong, but could only distinguish patients with unilateral vocal fold paralysis with compensation from normal and breathy groups for sustained /u/ vowel phonation. SPI was found to be a better breathy voice indicator than EGG. Subjects with unilateral vocal fold paralysis with supraglottal compensation were also found to have the highest level of SPI than control group. Authors reported a mean SPI of 69 for their normal speakers (two males and two females). The participants in the experimental group were belonged to a wider age range (35-77 years) and authors did not provide enough details about patients with Cordectomy in the study.

Mathew and Bhat (2009) determined the sensitivity of the acoustic parameter, SPI in two groups of subjects, 35 males with normal vocal fold functioning and 35 males with unilateral vocal nodules. The phonation sample of /a/ vowel was recorded into CSL 4150 model of Kay Elemetrics. Results showed that the control group had greater SPI values with a mean of 24.87 than the calculated Western normative mean of adult males (7.534). The experimental group (subjects with unilateral vocal nodules) was found to have greater SPI values (37.00) than the control groups. Only one gender (males) was considered.

The applicability of SPI as an indicator of vocal fold adduction in normal, breathy and pressed phonation samples produced by twenty-eight normal female subjects aged between 21 and 44 years was investigated by Roussel and Lobdell (2004). A significant increase in SPI for breathy as well as pressed phonations was observed compared to normal phonation and higher SPI values were found for the breathy condition compared to the normal condition. The mean SPI for the group of female subjects in normal phonation condition was 13.05, which was found to be below the suggested threshold of 14.12 given in the database from the MDVP manufacturer. The author did not comment regarding the lower mean SPI threshold that was obtained in their study. Since, there is no published mean SPI for normal population the author found it difficult to determine its clinical significance.

## NORMATIVE VALUE OF SOFT PHONATION INDEX (SPI)

Xue and Deliyski (2001) attempted to establish normative acoustic data of voice for elderly male and female speakers and investigated the educational implications of the impacts of the effects of aging on few acoustic parameters. A total of 44 participants (21 elderly men and 23 elderly women) with the mean age of 75.43 years included. Voice samples of sustained phonation of vowel /a/ was collected using "digital tape recorder (DA-P1 Tascam,TEAC, Japan) and it was analyzed using MDVP (Model 4305 of the Computerized Speech Lab, Kay Elemetrics, USA)". 15 acoustic parameters were measured which includes, "Average fundamental frequency (F0 Hz), Absolute jitter (Jita ms), Jitter percent (Jitt %), Phonatory fundamental frequency range (PFR semitones), Relative average perturbation (RAP %), Smoothed pitch period perturbation quotient (sPPQ %), Standard deviation of the fundamental frequency (STD Hz), Fundamental frequency variation (vFo %), Amplitude perturbation quotient (APQ %), Shimmer in decibels (ShdB dB), Shimmer percent (Shim %), Noise-to-harmonic ratio (NHR), Soft phonation index (SPI) and Voice turbulence index (VTI)". The results showed that elderly speakers had significantly poorer vocal performance on all the considered acoustic parameters when compared with young and middle-aged adults. Similarly, with respect to SPI the mean value of elderly speakers (14.50) was found to be significantly higher than young and middle aged adults (7.23). The significance of developing acoustic norms and thresholds for elderly men and women was documented by authors from these findings. They also emphasized the need to use these acoustic parameter standards to make diagnostic measurements of the elderly speaker. Limitation of the study was not mentioned by the authors and only elderly individuals had been participated in the study whereas other groups were compared from another study and the age range of young and middle aged group was wider.

Hema, Mahesh, and Pushpavathi (2009) established normative database for voice variable of Multi Dimensional Voice Program (MDVP) in Indian population and they also compared it across gender & with the existing Western norms. Thirty male and thirty female participants with the age range of 18 to 25 years were selected. Participants were asked to sustain the vowel /a/ for 4 seconds at their comfortable pitch and loudness level. Each sample was recorded and analysed using Multi Dimensional Voice Program (Model 3950) and 33 acoustic parameters were extracted which was classified into 6 groups (Fundamental frequency, frequency perturbation, amplitude perturbation, noise and tremor evaluation, voice break, subharmonic and voice irregularity, miscellaneous). Authors found significant differences on only few parameters across the gender like $F_0$, tremor, intensity and degree of subharmonics. With respect to Soft Phonation Index, the mean SPI of males (17.59) were higher than mean SPI of females (14.47). Similarly, when the mean SPI values were compared with Western norms (6.77), Indian norm showed higher value (17.59) of the same. Result showed overall difference between the Western and Indian population was more in female group than male group. Limitations would include less number of subjects, only younger age adults were considered and the results are not validated.

**Studies related to Contact Quotient (CQ)**

Ma and Love (2010) evaluated the effects of age and gender on selected vocal fold vibratory behaviours during vowel prolongation and connected speech using electroglottography (EGG). Authors recruited 46 young and older individuals (23 males and 23 females) with normal voices and the parameter measured was contact quotient. They reported that EGG data was found to be similar and consistent with Higgins and Saxman (1991) results where they found significant interaction between age and gender for mean contact quotient. Younger adult males were found to have increased vocal fold contact compared to younger adult females, smaller contact quotient was found in older males compared to young males, and greater contact quotient (i.e increased vocal fold contact) was found in older females than young females.

Paul, Kumar and Chatterjee (2011) aimed to find out the effects of vowel and gender differences on the vocal fold vibratory patterns in different registers using EGG electroglottography system of Dr. SPEECH software, Tiger DRS Inc, Vocal assessment. The recordings of 10 young adults (5 males and 5 females) were taken while the subjects phonated the three vowels /a/, /i/, and /u/ each in two vocal registers, modal and vocal fry and contact quotient (CQ) was measured. Results has showed a significantly higher CQ values in vocal fry than modal phonation for both males and females and significantly longer contact phase was noticed in young adult males (Mean- 70.32) than females (mean-67.8368) in both the vocal registers (vocal fry and modal) which indicated that the males are predisposed to greater vocal fold constriction. No significant vowel effects was found at both the phonatory conditions either for males or for females.

**VARIOUS METHODS TO CALCULATE CQEGG:**

Kania et al. (2004) tested the significance of different criterion levels for calculating Glottal Contact Quotient (GCQ) and also the significance of other voice related variables like F0, intensity which are likely to influence the normative values of GCQ. Totally twenty healthy male subjects in the age range of 25 to 39 years were participated. They were asked to sustain vowel /a/ for 3 times and it was recorded and analyzed using the EGG laryngograph (Laryngograph Ltd, London, England). The SESANE software was used for acoustic signal acquisition. The parameters studied were fundamental frequency, intensity and Glottal Contact Quotient (GCQ). GCQ values were calculated using criterion levels from 10% to 40%, with 5% increments. It was found that the mean GCQ was decreased with increment in the criterion level. A significant difference was found when the criterion level was higher than 25%. Authors found a significant correlation between GCQ and F0 and also between GCQ and intensity for criterion levels above 25%, A significant positive correlation was demonstrated between GCQ, F0 and intensity for all criterion levels, except at the 10% criterion level. Authors did not explain the result obtained from the statistical analysis sufficiently in the discussion section. Limitation of the study was quoted, only male subjects and less number of participants were considered.

Herbst and Ternström (2009) compared different (EGG-based) methods to measure the EGG contact quotient ($CQ_{EGG}$) to the closed quotients derived from simultaneous videokymographic imaging ($CQ_{KYM}$). 2 male subjects who were professionally trained singers participated. Subjects were asked to phonate in 2 different registers (falsetto and chest) with independent control of the degree of glottal adduction and they were also given training for the same. The videokymographic samples were recorded with a Lambert Instruments Kymocam CCD camera using 90 and 70 degree rigid endoscopes and a Wolf 5131 light source. DECOM algorithm was used for data analysis where DEGG and CQ were calculated. Authors found that the average value of $CQ_{KYM}$ was higher for both the registers than the $CQ_{EGG}$ values (0.562 & 0.455) as inferred by most of the other methods. The result showed $CQ_{EGG}$ data calculated with criterion-level methods with low thresholds (20% or 25%) was found to have good agreement with the respective $CQ_{KYM}$ data. Sample size is very less and only males were chosen are the two limitations of the study.

Kankare, Laukkanen, Miettinen and Pylkkanen (2012) investigated the effect of using different amplitude threshold levels to calculate $CQ_{EGG}$ in different phonation types (normal, breathy & pressed) and also to find out whether perceptual assessment is consistent with the $CQ_{EGG}$ calculation outcomes. Authors recruited 30 normal female subjects with the age range of 20-57 years. They were asked to sustain the vowel /a/ for 5 seconds, three times in three different phonation types (normal, breathy & pressed) at their conversational pitch and loudness level which was recorded using dual channel EGG (Glottal Enterprises). Parameter measured was $CQ_{EGG}$ by calculating period length from EGG signal at 25%, 35% and 50% threshold levels. Fundamental frequency and sound pressure level was also measured. Experienced voice trainers were made to perceptually judge the degree of firmness of phonation. Result demonstrated a significant difference in contact time of vocal folds between the different phonation types at all three amplitude threshold levels. SPL was not found to be explaining any variation in $CQ_{EGG}$ values. There was no correlation found between $F_0$ and $CQ_{EGG.}$ Authors concluded that while using 25% amplitude threshold level in CQ in EGG waveforms, it was better distinguishable of phonation types. Limitations of the study were not mentioned in the article. Only females were recruited in the study and participants of the study were students and teachers of vocology and logopedics. They had received vocal training and practiced the tasks before recording which could have influenced the outcomes.

Bier, Watson, and McCann (2013) analyzed age differences in adult speakers using the perturbation of the contact quotient by employing laryngograph EGG. The study included two groups: group I had 15 young male subjects with the age range of 20-26 years and group II had 15 old male subjects with the age range of 56-71 years. Both the groups were instructed to phonate vowel /a:/ and /i:/ at different pitch (low, mid and high) and loudness levels (quiet, normal and loud) for 3 seconds. The Parameters assessed were Fundamental frequency (F0), Contact Quotient (Qx), Contact Quotient Perturbation (CQP), Sound pressure level (SPL), Jitter, and Shimmer. The authors found that jitter was greater for older speakers (0.87%) and significant reduction was found in the contact quotient (Qx) for older speakers (42.5%) than young speakers (46.1%). The result also showed a significant increment in CQP for older speakers (3.54%) than young speakers (1.55%). Among the three target loudness levels, the Qx was prominently increased for louder vowels, and they did not found any significant interaction between age and the target loudness but contact quotient perturbation was found to be significantly lower for louder vowels. Authors also found significant interaction of CQP with both age and target loudness as it was greater for the older speakers (6.0, 2.6, and 2.0 for quiet, normal, and loud) when compared to young speakers (1.9, 1.4, and1.4 for quiet, normal, and loud). This result also illustrated that CQP gives the quantifiable information about interaction of other variability (age and loudness) with that of the vocal fold stability than the conventional jitter alone. Authors thus documents that CQP serves as a physiological measure which helps to quantify the changes that takes place in vocal fold behavior with progress in age. Study included only one gender i.e. males and females were not included. Thus, it fails to discuss the above measured parameters with respect to gender difference.

Shaheen and Jordan (2013) evaluated the gender effect on measures of electroglottographic contact quotient (CQ) using EGG criterion thresholds method and derivative based method. 25 male and 25 females with the mean age of 22.78 were included and they were instructed to phonate vowel /a/ for 3 seconds. EGG waveforms were extracted using electroglottograph (Glottal Enterprises) and Contact Quotient was calculated using eight criterion thresholds (25–60% in 5% increments). EGG derivative (DEGG) was computed using EGG Plant program. The result showed greater mean CQ in male when compared to female (0.44 & 0.37) at 25% criterion threshold level and the same result was found significantly using DEGG. It was seen that higher the threshold levels, gender contrast in mean CQ was found to be faded. Authors used the DEGG method to discriminate between ‘‘knee’’-shaped opening phases in EGG waveforms and it was observed in 76% of the men but in 64% of the women ‘‘knee’’ opening phases was not observed. This result can be confined only to young adult men and women. Continuous speech would have been used to evaluate the gender differences in CQ in which continuous phonatory adjustments are needed, the relationship between EGG and DEGG (contacting and de-contacting regions of vocal folds) should have been observed using high-speed video imaging methods to provide the possible gender differences.

Herbst, Schutte, Bowling, and Svec (2016) quantified $CQ_{EGG}$ using few specific algorithms which could provide the relation to their corresponding closed quotients. Authors also explored the extent of $CQ_{EGG}$ deviation from the closed quotient which was derived using videokymography at varied configurations of laryngeal system. Participants involved in this study were 13 trained and untrained singers, among them 6 were females and 7 were males who was instructed to phonate 4 singing types: "abducted falsetto (FaB), adducted falsetto (FaD),abducted chest (CaB), and adducted chest (CaD)". Phonation was recorded and monitored by simultaneous acoustic and EGG recordings, and videokymographic (VKG) endoscopy. Totally 3 algorithms were used in this study. $CQ_{EGG}$ was calculated using Criterion threshold method (threshold at 20%, 25%, and 35%) and Derivative based method (DEGG), $CQ_{VYG}$ and glottal configuration was also simultaneously documented through embedded endoscopy. The result showed that the $CQ_{EGG}$ values produced using the above-mentioned $CQ_{EGG}$ algorithms differed significantly from the respective $CQ_{VKG}$ with standard deviations of around 20 percent of cycle duration. Authors found a greater difference between $CQ_{VKG}$ and $CQ_{EGG}$ for lower $CQ_{VKG}$ phonations, and a greater contrast was also found for low-quality EGG signals with a ratio of signal to noise less than 10dB specifically in phonations with incomplete glottal closure (FaB) whereas phonation in which fully adducted chest register (CaD) was found to have the good correlation between $CQ_{VKG}$ and $CQ_{EGG}$ irrespective of the algorithm used. With respect to criterion threshold method, there was decrease in $CQ_{EGG}$ values with greater threshold values but best criterion threshold values are not explained as it has to be re-studied in singer populations with larger subjects. $CQ_{EGG}$ values which was obtained using $CQ_{EGG}$ algorithm operated on the derivative of the EGG signal

(DEGG) was found to have good agreement in relation to its corressponding closed quotient data and also with $CQ_{VKG}$. The results showed that the terms “closed quotient” and “contact quotient” cannot be used interchangeably which are related to different physiological phenomena itself. Limitation of the study would include, the number of trained and untrained singers participated in this study was not specifically mentioned.

**EGG IN DISORDERED POPULATION**

Zagolski & Carlson (2002) determined the variations that occur in the electroglottographic parameters by comparing female individuals with and without vocal fold palsy. Authors recruited two groups of female individuals where one group consisted of 16 healthy controls and other group had 22 individuals with unilateral vocal fold palsy with the age range of 24–75 years. All the subjects were checked with laryngeal mirror and identified the position of the paralysed vocal fold and this condition had been occurred post thyriodectomy in all 22 females. These individuals were asked to perform sustained phonation of vowel /a/ and vocal functions were assessed using an electroglottograph (Fourcin Laryngograph Processor). All the data was collected and evaluated using SPEECH STUDIO software (version 1.04). The parameters calculated were open quotient (OQ), opening quotient (OpQ), closing quotient (ClQ), Fundamental frequency, % Irregularity and contact quotient (QX). QX was assessed using a sentence also. The result had shown an obvious difference of contact quotient (QX) i.e the mean value of QX was found to be smaller in the individuals with vocal fold paralysis (43.5%) than control subjects (48.5%). This was attributed that this would due to prior opening and late closing of the vocal folds so there will be smaller contact duration of the vocal folds in the vocal fold paralyzed subjects when compared to healthy control. Not only

QX, considerable difference was obtained in all the EGG parameters between both the groups. Further, improvement in the values as well as in the degree of dysphonia was observed in all the parameters during the successive follow ups. Thus, author attributed that this could be due to the recovery and functional compensation that take place in the vocal fold paralyzed individuals and concluded that EGG is helpful in tracing the long term changes in the clinical conditions like vocal fold mobility disorders and other dysphonic conditions. Limitation of the study is not quoted by the authors in the study and also studied only female individuals whose age range was wider as well. So there might be age related changes which may influence the results indirectly.

Zagolski (2008) determined the parameter of EGG that measure the changes in the voice followed by vocal cord paralysis. Author also investigated the EGG measure that correlated well with the dysphonia. The study consisted of twelve elderly individuals in the age range of 65 to 78 years in which eight were women and 4 were men who had unilateral vocal fold palsy followed by thyroid surgery and ten normal elderly individuals with the age range of 65-77 years in which 5 were women and 5 were men. An electroglottograph (Fourcin Laryngograph Processor, Laryngograph Ltd., London, UK) and Speech Studio software (version 1.04) was used to collect and analyse the data. Vocal fold palsy and its position was diagnosed using laryngeal mirror. Subjects were asked to phonate the vowel /a/ and to say a short phrase in Polish at their most comfortable pitch and loudness. The parameters that were elicited are open quotient, opening quotient (OpQ), closing quotient (ClQ), Fx, % irregularity (frequency perturbation) and Contact Quotient (Qx) and each data was perceptually rated using four point rating scale. Author found significant difference in the values of % irregularity between individuals with vocal fold palsy and healthy elderly individuals. Results showed significant correlation between the irregularity and closed quotient with the perceptual ratings of dysphonia. Author concluded that electroglottography is able to objectify dysphonia in elderly patients with vocal fold paralysis and could be an appropriate noninvasive device for following the long-term improvements in elderly patients. Likewise, % irregularity found to be well responsive to the vocal-fold dysfunction in elderly patients with vocal fold palsy.

Yamout, et al (2012) compared the mean and standard deviation (SD) of the contact quotient (CQ) of the sustained vowels [a] and [e] in Multiple Sclerosis patients and healthy subjects. Totally 39 subjects were participated and they were made into two groups, where one group had 24 subjects with Multiple Sclerosis and other group consisted of 15 healthy individuals. Laryngeal examination was done for all the subjects and severity of disease, fatigue and depression in Multiple Sclerosis patients were assessed using its respective rating scales. Subjects whose cutoff point was 4 were considered further for the study. It was identified that only five individuals developed phonatory symptoms in MS group. For data collection and analysis, “Electroglottogram amplifier model 6103 by KayPENTAX (Pine Brook, NJ) and Real Time EEG Analyzer software package model 5138 (KayPENTAX)” were used. All the subjects were asked to phonate vowel /a/ and /e/ at their natural pitch and loudness level. From these two tasks parameters such as the fundamental frequency, mean closed quotient (CQ), SDs, and jitter were measured. Authors did not found any significant difference in the mean closed quotient of vowel /a/ and /e/ between MS group and healthy individuals group [/a/- 43.90 Vs 45.53 and /e/- 44.75 Vs 43.63]. Authors had reasoned out this minimal difference in the MS group as changes in subglottal pressure and compromised respiratory muscle strength. Also, study did not found any significance in other parameters as well between the two groups except, a greater jitter value was noticed in MS group than normal group (3.38 Vs 1.82). This had been attributing to slowing down of electrical impulse via the demyelinated neurons which causes variations in contraction of phonatory muscle thereby leading to greater phonatory instability in MS group. Significant association was found between the mean CQ and the FSS score (r value- 0.36) which indicates a moderate correlation. Other variables like duration of the disease, extent of disability, and depression score, were correlated with the mean CQ where no significant relation was noted by the authors. This was found due to the reason that all the individuals in the Ms group were in the remitting relapse stage and not in the progressive illness. Limitations quoted in the study are less number of individuals in MS group showed phonatory symptoms, nearly 1/3 of the individuals presented with the history of smoking. Authors did not employed spontaneous speech task where most of the vocal symptoms would be prominent in MS group and restricted with vowel phonation samples.

Miguel Vaca et al (2015) determined the diagnostic protocol to examine the glottal competence in the presbylarynx by adding several tests that are widely used to evaluate the glottal gaps and they also looked into the accuracy of these tests. It was a cross- prospective study in which 104 health individuals (68 women and 36 men) with the age range of 65 years and older were taken for the study. The diagnostic methods and tests included were laryngostroboscopy, "a digital flexible laryngostroboscope Olympus OTV (Olympus Medical Systems, Tokyo, Japan) with ATMOS Endo-Stroboscope L light source (ATMOS Lenzkirch, Germany)” was used to visualize the glottal closure, s/z ratio, continuous light endoscopy was used to predict the changes of the senile larynx in terms of its morphology. Electroglottography analysis was done using a Kay PENTAX 6103 electroglottograph (Kay PENTAX, Montvale) and Contact Quotient (CQ) was derived and aerodynamic analysis of the voice were carried out using the voice efficiency protocol of the Kay PENTAX PAS 6600 (Kay PENTAX, Montvale) and the parameters considered were mean airflow during voicing, mean peak air pressure, and aerodynamic efficiency. All the individuals were asked to phonate the vowel /a/ at the comfortable pitch and loudness for all the tests. A Spindle shaped gap and vocal fold bowing was identified in more than 47 individuals and authors found the mean CQ value of 47.7% from the EGG analysis and it was reported that accuracy for predicting the age related voice changes of CQ was poor. This was attributed to various laryngeal changes or supraglottis hyperfunction that interfere with decreased impedance associated with a glottal gap, thereby limiting EGG’s reliability for presbylarynx. Authors concluded by saying s/z ratio and continuous light endoscopy had good specificity and sensitivity of 91% and these two are the most useful tool for early detection in the case of age related dysphonia.

Tan (2017) explored the difference exist between 3 different phonation types (normal, breathy and pressed) using EGG Contact Quotient values in four different ranges in 10 female singers. Their mean age was 36 years and they had teaching experience of 2-18 years. The participants were instructed to choose any four pitch ranges from their vocal range i.e. lowest, speaking, modal and highest range. Then they were asked to perform all five vowels (a, e, i, o, u) in each phonation type for one to three seconds each. All the samples were recorded in the sound treated room and EGG signal were recorded using two channels of a dual-channel Glottal Enterprises instrument. For deriving Contact quotient values 35% criterion threshold level had been chosen. The values of CQ had been extracted for all vowels and the pitch ranges. The mean CQ values found was 0.44 for normal and 0.564 for pressed, and authors did not found any definite trend of normal and pressed phonations. But the pressed phonation yielded higher CQ values than normal phonation and they also said that an inspection is required to assist in order to determine the degree of pressed sensation and its strength on the CQ value. Breathy phonation was not considered for the analysis since EGG itself is important in providing information about vocal fold contact as mentioned. Result did not showed any significant fashion of CQ values across the pitch range as well. It was discussed that CQ is not suitable to measure the pressedness in the higher range because while doing the pressed phonation the impact stress would be more and high, which cannot be separate in the EGG signal.  Other measurements such as imaging techniques than CQ can be more apt for measuring vocal fold impact stress in higher frequencies, thus, one can better distinguish normal from pressed singing. The drawback of the study was fewer samples were considered thereby difficult to generalize the outcomes and only females were included. Also, EGG electrode placement was not changed when the subjects phonating in the higher range where the larynx tends to move up from their normal position. This could have influenced the results.

## Need for the study

One of the main aspects of laryngeal function is the extent of vocal fold closure or adduction during phonation which helps for diagnostic purposes, because majority of the vocal fold pathologies shows abnormalities in approximation. Now-a-days, acoustic measures are considered as an easily obtainable and noninvasive way to quantitatively analyze the differences in voice quality, and many studies have also taken this approach. Before a variable can be used to pathological conditions it is important to the study the valuable relation to the normal voice and its production ability.

Some of the parameters which have been found to be sensitive to track the vocal adduction mechanism are Soft phonation index, Contact quotient and so on. Roussel and Lobdell (2004) studied the applicability of SPI as an indication of vocal fold adduction using three phonation types (normal, breathy and pressed) where the author found opposite trend towards a significant increase in the SPI for pressed phonation which was contradicting their hypothesis. Authors included only 28 normal female subjects which is less to arrive at a comprehensive picture of the parameter used. Mathew and Jayashree (2009) also tried to determine the sensitiveness of SPI where they took only male subjects (35 normal subjects and 35 subjects with unilateral vocal nodules). Only one mode of phonation was employed (Normal phonation) in their study that raised a need to study SPI in different phonation types.

Regarding the SPI values, it was found higher SPI mean values for control group and experimental group than the Western normative mean which was provided as database in the MDVP software and similar findings was reported by Roussel and

Lobdell (2004); Koreman and Putzer (1997) also reported a mean SPI of 69 for their normal speakers (two males and two females) that is higher than the MDVP database. Munoz et al. (2003) reported mean SPI values only for male subjects and did not projected the values of females in their study. The sample of 47 normal male speakers had a mean SPI of 10.42 which is lesser than the database and other published studies. From this review, it is evident that there exists an unequivocal result on SPI across studies.

From the above literatures, one can understand that there is dearth of information pertaining to the studies on SPI. Till date, normal vocal fold adduction mechanism on diverse phonations isn't precisely studied. Most of these studies had a poor representation of subjects where only fewer age groups and population were considered and published data are also hazy in the literature. In addition within the Indian context, essentially less number of studies have explored with regard to vocal fold adduction and acoustic parameters like SPI, CQ which are being substituted by extrapolating the information from Western studies.

Hence, the present study made an attempt to document the sensitive parameters (SPI and CQ) that serve as an indicator to measure the vocal fold adduction mechanism by including more number of participants, diverse age groups (young, middle and elderly aged people), both the genders and different types of phonation (normal, breathy and pressed) which will help the clinician to utilize these parameters to distinguish the typical voice from the pathological voice across the age.

**Aim of the present study:** To determine the effect of age, gender and phonation types on vocal fold adduction mechanism in phono-normal individuals.

**Objectives**

The objectives of the study are:

1. To investigate the effect of three different phonation types on vocal fold adduction mechanism.
2. To explore the correlation between two important parameters, soft phonation index (SPI) from MDVP and closed quotient (CQ) from EGG on vocal fold adduction mechanism for 3 different phonation types.
3. To evaluate gender difference (if any) in vocal fold adduction for 3 phonation types.
4. To measure differences in young, middle, and elderly aged individuals (if any) on vocal fold adduction mechanism.

# Chapter III

# METHOD

## Participants

Three groups of participants were took part in the study. Group I consisted of 30 young phono normals in the age range of 18 to 23 years; Group II consisted of 30 middle aged phono normals within the age range of 38 to 43 years and Group III consisted of 30 elderly phono normal individuals in the age range of 58 to 63 years. Each group included 15 males and 15 females. All the participants were randomly chosen from general population from Mysore city.

Participants were selected based on the below mentioned inclusion criteria and it was screened out in detail before commencing the testing procedure.

1. Participants with no history of speech, language, hearing and neurological problems.
2. Participants did not report of any upper respiratory tract infections at the time of recording.
3. Participants did not report of any nasal or oral deformities.
4. Participants with no history of hormonal problems and they were not under medication for any of the health conditions.
5. No history of blood sugar and blood pressure or any systemic disease.
6. None of the participants had previous history of vocally trained or professional voice users.

The objectives of the study were explained to the participants and the written consent was obtained.

**Instrumentation**

- "Multi-Dimensional Voice Program (MDVP)" and Electroglottography (EGG) of "Computerised Speech Lab (CSL) Model 4500 (Kay Pentax, USA)" was used to analysis and interpretation of the data.
- "Digital Voice Recorder (Olympus Digital Voice Recorder WS- 100)" was utilized to record the voice samples for further perceptual analysis.

**Procedure**

The subjects were asked to sit comfortably in a chair and voice samples were recorded individually in a quiet and isolated room. They were provided with clear instructions and video demonstration (the task was also demonstrated by the experimenter) prior to the recording for producing three types of phonation tasks.

Instruction:

1. Normal phonation: The task involves taking a deep breath and sustaining vowel /a/ at their comfortable pitch and loudness level.
2. Breathy phonation: The task involves initiating voicing with /h/ and maintaining breathy voice quality throughout the phonation.
3. Pressed phonation: The task involves initiating voicing with a hard glottal attack and also maintaining tightness in the laryngeal area.

Each participant was asked to produce three repetitions of each phonation types. All these phonation samples were recorded using "digital voice recorder (Olympus Digital Voice Recorder WS- 100)" for analyzing the samples perceptually.

In Electroglottography recording, participants were placed with two surface electrodes on either side of the thyroid cartilage and they were instructed to perform the above three phonation types with three iterations each. For MDVP recording, the microphone was placed at a mouth to microphone distance of 10cm and the sampling frequency settings was kept at 44100 Hz and 16-bit quantization. Participants were instructed to perform three phonation types with three iterations each.

**Analysis**

Two types of analysis were employed: a) Perceptual analysis and b) acoustic analysis.

**Perceptual Analysis:** Four speech-language pathologists were participated in the study who served as listeners/ judges. They all had minimum 5 years of clinical experience in the area of assessment and management of voice disorders at the time of their participation. Listeners were instructed as follows: All voice samples of three phonation types were made into tokens and each token consisted of 3 trials of each phonation types. Listeners were asked to carefully listen to each of the tokens given and mark the best trial which resembled very close like normal, breathy and pressed phonation. The listeners were provided with a response sheet in which they marked the best trial of each phonation types identified and these tokens were provided randomly. The closest trial chosen by the listeners were compiled and majority of listener's agreement was considered and that sample was subjected to acoustic analysis.

**Acoustic Analysis**

The selected trial of voice samples from the three phonation types were subjected for acoustical and physiological measures, where Soft Phonation Index (SPI) was measured using MDVP software and Contact Quotient (CQ) was analyzed using EGG software. The values were extracted for the selected trial of voice samples.

## Statistical analysis

### Test of Normality

The extracted data of both the parameters (SPI & CQ) was initially been subjected to Shapiro- wilks test for normality to check whether these data follows normal distribution. The result of this test revealed that SPI data had followed normal distribution where the significance level was greater 0.05 ($p<0.05$). So Parametric tests were carried out further. Whereas for CQ, the data was found to be deviated from the normal distribution ($p>0.05$). Hence, the further analysis was carried out using Non Parametric tests.

Descriptive statistics was done to find the mean and standard deviation of the measured parameters (SPI & CQ) in the study. A Parametric test of Mixed ANOVA was done to check the main and interaction effect for SPI between all the dependent (three phonation types) and independent variables (age, gender). Repeated measures of ANOVA was carried out to observe the effect of three phonation types with respect to gender (males, females) as there was an interaction effect between them. Paired comparisons using Bonferroni's adjustment for multiple comparisons was done to find the differences among the three phonation types and specify the direction of the differences. The CQ values across the three age groups were compared using the non Parametric Kruskal Wallis H test. The gender effect of three phonation tasks was carried out using Mann- Whitney U test. Comparison of all three phonation tasks (Normal, Breathy, and Pressed) was done using Friedmann test. Further, Wilcoxon Signed Rank test was done to compare the tasks which have got significant differences and also compared with all age groups and both the gender.

# Chapter IV

# RESULTS

The present study made an attempt to investigate the effect of different phonation types on vocal folds adduction mechanism in phono-normal individuals. 90 participants were divided into three groups and each group comprised of 15 males and 15 females. Group I consisted of 30 young aged phono-normal individuals with the age range of 18-25 years; Group II had 30 middle aged phono-normal individuals with the age range of 38-45 years and Group III include 30 elderly individuals in the age range of 55 – 63 years. The acoustic and physiological parameter considered in this study includes Soft Phonation Index (SPI) and Contact Quotient (CQ), respectively. The extracted data was subjected to the statistical analysis using Statistical Package for Social Sciences (SPSS) software version 21. The Statistical tests that were performed to interpret the data comprises of;

1. Shapiro-Wilks test of normality
2. Descriptive statistics
3. Mixed ANOVA
4. Repeated measures of ANOVA
5. Kruskal Wallis H test
6. Mann Whitney U test
7. Friedmann test
8. Wilcoxon Signed rank test

The results of the present study are discussed under three subheadings:

1. Soft Phonation Index (SPI)
2. Contact Quotient (CQ)
3. Correlation between Soft Phonation Index (SPI) and Contact Quotient (CQ)

**1. Soft phonation Index:**

The results of SPI are discussed under three subheadings:

(i) Results of descriptive statistics on SPI

(ii) Between group comparison

(iii) Within group comparison

1) Gender difference on SPI
2) Phonation type difference on SPI
3) Gender-wise phonation difference on SPI across three phonation types

**Results of Descriptive Statistics**

The Means and standard deviation of Soft Phonation Index (SPI) measured for 3 phonation types across three groups are tabulated in table 1.

Table 1:

*Mean and standard deviation (SD) of SPI value for three phonation types – across three groups and between genders*

| Age Groups | Phonation Types | SPI | | | |
|---|---|---|---|---|---|
| | | Males | | Females | |
| | | Mean | SD | Mean | SD |
| Young (Group I) | Normal | 12.36 | 3.94 | 12.60 | 4.51 |
| | Breathy | 24.27 | 6.44 | 29.08 | 6.09 |
| | Pressed | 13.66 | 5.40 | 14.81 | 4.76 |
| Middle (Group II) | Normal | 14.57 | 3.71 | 12.34 | 3.67 |
| | Breathy | 23.83 | 5.05 | 26.50 | 5.90 |
| | Pressed | 12.38 | 1.97 | 13.91 | 5.60 |
| Elderly (Group III) | Normal | 13.64 | 4.30 | 12.08 | 3.73 |
| | Breathy | 25.31 | 4.50 | 27.50 | 5.90 |
| | Pressed | 15.43 | 4.78 | 15.93 | 4.12 |

From table 2, it may be seen that among the three age groups mean SPI value (13.64) of normal phonation were higher in the group II than the group I (12.48) and group III (12.86). Similarly on observing mean SPI values of breathy phonation across three age groups, group I has increased mean SPI value (26.68) when compared to group II (25.31) and group III (26.40).

Table 2:

*Mean and Standard deviations of SPI for three phonation types across three groups*

| Age Groups | Phonation Types | SPI | |
|---|---|---|---|
| | | Mean | SD |
| Young (Group I) | Normal | 12.48 | 4.16 |
| | Breathy | 26.68 | 6.26 |
| | Pressed | 14.23 | 5.04 |
| Middle (Group II) | Normal | 13.64 | 4.30 |
| | Breathy | 25.31 | 4.5 |
| | Pressed | 15.43 | 4.79 |
| Elderly (Group III) | Normal | 12.86 | 4.03 |
| | Breathy | 26.41 | 5.2 |
| | Pressed | 15.68 | 4.39 |

On observation, the mean SPI value of pressed phonation across three groups, the higher SPI was found in group III (M=15.68) when compared to group I (M=14.63) and group II (M= 15.43).

**(i) Between group comparison**

A parametric mixed ANOVA was carried out with three groups for the between subject factor (age) and gender (male & female) and 3 phonation types (normal, breathy and pressed) as within subject factor. Also, to check the main and interaction effect of these variables (if any). Table 3 shows the results of mixed ANOVA for SPI comparison across 3 groups, phonation types and between gender.

Table 3

*Results of mixed ANOVA for comparison of SPI across groups, phonation types & between genders*

| Source Factors | df | F | Sig |
|---|---|---|---|
| Age | 2 | 0.62 | 0.53 |
| Gender | 1 | 1.76 | 0.18 |
| Phonation types | 2 | 352.25 | 0.00* |
| Age* Gender | 2 | 0.45 | 0.63 |
| Phonation types * Age | 4 | 1.73 | 0.14 |
| Phonation types* Gender | 2 | 7.59 | 0.001* |
| Phonation types* Age*Gender | 4 | 0.361 | 0.83 |

(* shows statistical significance at 0.05 level)

The results of mixed ANOVA did not show any significant main effect for age [$F(2, 87) = 0.62$, $p>0.05$], gender [$F(1, 87) = 1.76$, $p>0.05$] and significant main effect was noticed for phonation types [$F(2, 87) = 352.25$, $p<0.05$]. The results also revealed that there was significant interaction effect between genders X phonation types [$F(2, 87) = 7.59$, $p<0.05$]. Interaction effect was not seen for other variables. So as to get extended understanding of this interaction effect, repeated measures of ANOVA was carried out in order to see the effect of phonation types with respect to gender and further pairwise comparison of different phonation types was done using Bonferroni's adjustment for multiple comparisons.

(ii) **Within Group Comparison**

**a) Gender difference on SPI for 3 different phonation types**

Table 4:

*Mean and SD of SPI for 3 phonation types in males*

| Phonation Types | Mean | SD |
|---|---|---|
| Normal | 13.53 | 4.00 |
| Breathy | 24.47 | 5.30 |
| Pressed | 13.82 | 4.40 |

Table 5:

*Mean and SD of SPI for 3 phonation types in females*

| Phonation Types | Mean | SD |
|---|---|---|
| Normal | 12.34 | 3.90 |
| Breathy | 27.70 | 5.93 |
| Pressed | 14.88 | 4.83 |

The mean and SD of SPI for 3 phonation types for males and females are depicted in the table 4 and 5, respectively. From these tables, it was found that the breathy phonation has got increased mean SPI value than normal and pressed phonation in both the gender. While comparing the mean esteems of SPI, result had shown elevated SPI value in females (27.70) than males (24.47). Likewise, for pressed phonation, the SPI was higher in females (14.88) and lesser in males (13.82). On the other hand, SPI during normal phonation was higher in males

(13.37) and lesser in females (12.34). Though the SPI values are higher in females for breathy & pressed phonation and lower in females for normal phonation, these differences were not statistically significant for any of the phonation types.

**b) Phonation types difference on SPI**

*Table 6:*

*Results of Repeated measures of ANOVA for comparison of phonation types*

| Three phonation types | | Mean Difference | Sig. |
|---|---|---|---|
| Normal | Breathy | -13.151* | .000* |
| | Pressed | -1.419* | .018* |
| Breathy | Normal | 13.151* | .000* |
| | Pressed | 11.731* | .000* |
| Pressed | Normal | 1.419* | .018* |
| | Breathy | -11.731* | .000* |

(* indicates statistical significance at 0.05 level)

Results of repeated measures of ANOVA for SPI comparison across different phonation types is given in table 6. From table 6, the three phonation types like normal, breathy & pressed are significantly different from one another. The SPI value was significantly higher for breathy phonation compared to normal & pressed phonation. Further, the SPI value was significantly lower for normal phonation compared to breathy and pressed phonation.

### c) Gender-wise phonation difference on SPI across three phonation types

Table 7:

*Results of pair-wise comparison of phonation types for SPI in males*

| Three phonation types | | Mean Difference | Sig. |
|---|---|---|---|
| Normal | Breathy | -10.945* | 0.000* |
| | Pressed | -0.294 | 1.000 |
| Breathy | Normal | 10.945* | 0.000* |
| | Pressed | 10.651* | 0.000* |
| Pressed | Normal | 0.294 | 1.000 |
| | Breathy | -10.651* | 0.000* |

(* denotes statistical significance at 0.05 level)

From table 7, it is very clear that there is significant difference obtained between normal and breathy phonation and breathy versus pressed phonation on SPI in males. There is no significant difference between normal & pressed phonation on SPI value in males.

Table 8:

*Results of pair wise comparison of three phonation types for SPI in females*

| Phonation types | | Mean Difference | Sig. |
|---|---|---|---|
| Normal | Breathy | -15.35* | 0.000* |
| | Pressed | -2.545* | 0.007* |
| Breathy | Normal | 15.35* | 0.000* |
| | Pressed | 12.81* | 0.000* |
| Pressed | Normal | 2.545* | 0.007* |
| | Breathy | -12.81* | 0.000* |

(* denotes statistical significance at 0.05 level)

From table 8, it is seen that the 3 phonation types are significantly different from each other on SPI value. SPI being significantly higher for breathy phonation and it was significantly lower for normal phonation in females. The order of arrangement of SPI value from the significantly highest to lowest value are as follows;

Breathy phonation > pressed phonation > normal phonation.

**2. Contact Quotient (CQ)**

The results are discussed under three sub headings

a) Results of descriptive statistics on CQ

b) Between group comparison

c) Group wise comparison of CQ in males & females

**a) Results of descriptive statistics on CQ**

Table 9:

*Mean and standard deviation of CQ values across three groups, phonation types and between genders*

| | | CQ (%) | | | |
|---|---|---|---|---|---|
| Age Groups | Phonation Types | Males | | Females | |
| | | Mean | SD | Mean | SD |
| Young (Group I) | Normal | 43.50 | 3.50 | 42.38 | 3.99 |
| | Breathy | 44.82 | 4.73 | 47.31 | 6.12 |
| | Pressed | 47.58 | 5.17 | 44.62 | 4.31 |
| Middle (Group II) | Normal | 41.38 | 3.03 | 45.82 | 2.40 |
| | Breathy | 45.13 | 8.08 | 40.11 | 2.99 |
| | Pressed | 44.28 | 5.60 | 46.38 | 2.81 |
| Elderly (Group III) | Normal | 47.86 | 2.66 | 44.65 | 2.78 |
| | Breathy | 38.83 | 3.46 | 42.09 | 4.17 |
| | Pressed | 46.47 | 3.73 | 45.78 | 4.09 |

Table 10:

*Mean and Standard deviation of Contact Quotient (CQ) of three phonation types across three groups*

| Age Groups | Phonation Types | CQ (%) | |
|---|---|---|---|
| | | Mean | SD |
| Young | Normal | 42.79 | 3.71 |
| | Breathy | 46.06 | 5.52 |
| | Pressed | 46.10 | 4.91 |
| Middle | Normal | 44.86 | 2.66 |
| | Breathy | 38.83 | 3.46 |
| | Pressed | 46.47 | 3.73 |
| Elderly | Normal | 44.75 | 2.68 |
| | Breathy | 40.46 | 4.11 |
| | Pressed | 46.12 | 3.86 |

It is clear from the table 10 that the mean CQ value of normal phonation was highest in group II (44.86%) followed by group III (44.75%) and group I (42.79%). Similarly, higher mean CQ value is found for breathy phonation in group I (46.06%) than group III (40.46%) and group II (38.83%). When comparing the pressed phonation type, the mean CQ value was higher in group II (46.47%) than the group III (46.12%) and group I (46.10%)

**b) Between group differences**

A non parametric Kruskal Wallis H test was done to see the significant difference in the phonation types across three age groups. Table 11 shows the results of Chi- square test for age group comparison on CQ.

Table 11:
*Results of Chi square and significance values of three phonation types across three groups*

| Phonation types | $\chi^2$ | df | P value |
|---|---|---|---|
| Normal | 4.170 | 2 | 0.124 |
| Breathy | 13.92 | 2 | 0.001* |
| Pressed | 0.354 | 2 | 0.83 |

(*significance at 0.05 level)

From table 11, the result revealed that there was remarkable difference for CQ of breathy phonation type on all three age groups. Also, there was no group difference noticed for normal as well as pressed phonation. Since there was a significance difference noticed for breathy phonation, Mann Whitney U test was done to check the pair-wise differences across the three age groups for breathy phonation. It was found that a statistical significance for breathy phonation among young and elderly aged groups (/z/ = 3.859; $p<0.05$) (table 12) and the mean rank was found higher in the group I (39.20) than group III (21.80) as well as significant difference was seen for breathy phonation among group I and group II (/z/ = 2.122; $p<0.05$) (table13) mean rank score was higher in group I (35.28) than group II (25.72). higher mean rank score indicate significant higher value of CQ in group I compared to group II and group III. But, there was no such significance difference observed for breathy phonation when comparing group II and group III (/z/ = 1.2; $p>0.05$) (table14).

Table 12:

*Results of Mann Whitney U test for breathy phonation on CQ between group I and groups III*

| | Age groups | N | Mean Rank | Z | p- value |
|---|---|---|---|---|---|
| Breathy | Young | 30 | 39.20 | | |
| Phonation | Elderly | 30 | 21.80 | -3.859 | 0.00* |

(* indicates significance at the 0.05 level)

Table 13:

*Results of Mann Whitney U test for breathy phonation on CQ between group I and group II*

| | Age groups | N | Mean Rank | Z | p- value |
|---|---|---|---|---|---|
| Breathy | Young | 30 | 35.28 | | |
| Phonation | Middle | 30 | 25.72 | -2.122 | 0.03* |

(*indicates significance at the 0.05 level)

Table 14:

*Results of Mann whitney U test for breathy phonation on CQ between group II and group III*

| | Age groups | N | Mean Rank | Z | p- value |
|---|---|---|---|---|---|
| Breathy Phonation | Middle | 30 | 33.23 | -1.212 | 0.22 |
| | Elderly | 30 | 27.77 | | |

(* indicates significance at the 0.05 level)

Table 15:

*Results of Friedmann test for comparison of three phonation types.*

| Phonation types | *Mean rank* | *N* | $\chi^2$ | df | p-value |
|---|---|---|---|---|---|
| Normal | 1.91 | | | | |
| Breathy | 1.73 | 90 | 18.48 | 2 | 0.000** |
| Pressed | 2.36 | | | | |

(* indicates significance at the 0.05 level)

Friedmann test was carried out to compare CQ value of the three phonation types including 3 groups & gender on CQ. From the above table, a statistically significant difference was seen for CQ values of all the phonation types ($\chi^2$ = 18.48; p<0.05). Hence, gender wise group differences n CQ needs to be evaluated further.

**c) Group wise comparison of CQ in males & females**

i) Group I

Table 16:
*Results of Friedmann test for three phonation types in group I males on CQ*

| Phonation types | Mean rank | N | $\chi^2$ | df | p- value |
|---|---|---|---|---|---|
| Normal | 1.60 | | | | |
| Breathy | 1.93 | 15 | 5.733 | 2 | 0.057* |
| Pressed | 2.47 | | | | |

(* indicates significance at the 0.05 level)

Statistical difference across three phonation types was found from the result of Friedmann test for CQ comparison in group I males.

Table 17:
*Results of Friedmann test for three phonation types in group I females on CQ*

| Phonation types | Mean rank | N | $\chi^2$ | df | p-value |
|---|---|---|---|---|---|
| Normal | 1.53 | | | | |
| Breathy | 2.60 | 15 | 8.933 | 2 | 0.011** |
| Pressed | 1.87 | | | | |

(* indicates significance at the 0.05 level

From the above table 16 & 17, for young aged males ($\chi^2$=5.733; $p<0.05$) and females ($\chi^2$ = 8.933; $p<0.05$) there was an evident difference for CQ of all phonation types.

ii) Group II

Table 18:

*Results of Friedmann test of three phonation types in group II males on CQ*

| Phonation types | Mean rank | N | $\chi^2$ | df | p- value |
|---|---|---|---|---|---|
| Normal | 1.60 | | | | |
| Breathy | 2.20 | 15 | 3.603 | 2 | 0.165* |
| Pressed | 2.20 | | | | |

(* indicates significance at the 0.05 level)

No statistical difference across three phonation types was noticed from the result of Friedmann test for CQ comparison in group II males.

Table 19:

*Results of Friedmann test for three phonation types of in group II females on CQ*

| Phonation types | Mean rank | N | $\chi^2$ | df | p- value |
|---|---|---|---|---|---|
| Normal | 2.27 | 15 | 20.80 | 2 | 0.00** |
| Breathy | 1.07 | | | | |
| Pressed | 2.67 | | | | |

(* indicates significance at the 0.05 level)

Statistical significance was found for CQ of three phonation types in middle aged females ($\chi^2$= 20.80; p<0.05) which is displayed in the table 19.

iii) Group III

Table 20:

*Results of Friedmann test for three phonation types in group III males on CQ*.

| Phonation types | Mean rank | *N* | $X^2$ | df | p value |
|---|---|---|---|---|---|
| Normal | 2.33 | | | | |
| Breathy | 1.07 | 15 | 20.13 | 2 | 0.00 * |
| Pressed | 2.60 | | | | |

(* indicates significance at the 0.05 level)

Table 21:

*Results of Friedmann test of three phonation types in group III females on CQ*.

| Phonation types | Mean rank | *N* | $X^2$ | df | p value |
|---|---|---|---|---|---|
| Normal | 2.13 | | | | |
| Breathy | 1.53 | 15 | 5.200 | 2 | 0.074 |
| Pressed | 2.33 | | | | |

(* indicates significance at the 0.05 level)

From table 20 & 21, statistical difference was found for CQ of all phonation types for elderly aged males ($X^2$ =5.733; $p<0.05$) and no significance was noticed for elderly females ($X^2$ = 5.200; $p>0.05$).

Followed by this test, Wilcoxon Signed Ranks Test was performed to compare the phonation types across the age and gender which had showed significant difference in the Friedmann test.

Table 22:

*Results of wilcoxon Signed Ranks test results for pair wise comparison of all three types of phonation in group I males on CQ*

| Phonation types | Z | p value |
|---|---|---|
| Normal - Breathy | -1.250 | 0.211 |
| Normal - Pressed | -2.272 | 0.023* |
| Breathy - Pressed | -1.079 | 0.280 |

(* indicates significance at the 0.05 level)

Wilcoxon Signed Ranks test results revealed a significant difference found only in comparison of pressed and normal phonation in group I males (/z/ = 2.272; $p<0.05$). On CQ and other phonation types it was found no siginificant difference on CQ.

Table 23:

*Results of Wilcoxon Signed Ranks test for pair-wise comparison of phonation types in group I females on CQ*

| Phonation types | Z | p value |
|---|---|---|
| Normal – Breathy | -2.215 | 0.02* |
| Normal – Pressed | -1.307 | 0.191 |
| Breathy – Pressed | -0.909 | 0.363 |

(* indicates significance at the 0.05 level)

A significant difference was found when comparing between breathy and normal phonation in young females (/z/ = 2.215; $p<0.05$). On CQ and other phonation pairs, on significant difference found.

Table 24:

*Results of wilcoxon Signed Ranks test for pair-wise comparison of phonation types in group II females on CQ*

| Phonation types | Z | p value |
|---|---|---|
| Normal - Breathy | -3.351 | 0.001* |
| Normal - Pressed | -.909 | 0.363 |
| Breathy - Pressed | -3.408 | 0.001* |

(* indicates significance at the 0.05 level)

A noticeable difference was seen in comparison of breathy & normal phonation and pressed & breathy phonation on CQ in young females (/z/= 3.351; p<0.05 and /z/=3.408; p<0.05), respectively. No significant difference noticed between normal and pressed phonation on CQ in middle aged females.

Table 25:

*Results of Wilcoxon Signed Ranks test for pair-wise comparison of phonation types in group III males on CQ*

| Phonation types | Z | p value |
|---|---|---|
| Normal - Breathy | -3.067 | 0.02* |
| Normal - Pressed | -1.420 | 0.156 |
| Breathy - Pressed | -3.408 | 0.001* |

(* indicates significance at the 0.05 level)

The results showed a significant difference between breathy & normal phonation (/z/ = 3.067; p<0.05) and pressed & breathy phonation (/z/ = 3.408; p<0.05) in older males. Also, no significant difference noticed between normal and pressed phonation on CQ in elderly males.

**III. Correlation between SPI and CQ**

To check if there is any correlation between two important parameters, soft phonation index (SPI) and closed quotient (CQ) on vocal fold adduction mechanism for 3 different phonation tasks across age groups Spearman's Rank Correlation test was performed. The result of spearman's correlation coefficient of three phonation types comparison were depicted in the table.

Table 26:

*Results of Spearman's Rank correlation coefficient for SPI & CQ of three* phonation types

| | | CQ | | |
|---|---|---|---|---|
| | Conditions | Normal | Breathy | Pressed |
| SPI | Normal | 0.036 | | |
| | Breathy | | 0.002 | |
| | Pressed | | | -0.024 |

From the above table 26, the study found low positive correlation between SPI & CQ at normal phonation and breathy phonation. However, the correlation is not significant. There is no correlation found between SPI & CQ at pressed phonation. When the correlation is performed by considering all the age groups (N=90). Further, group wise correlation between SPI and CQ was performed and the results are described further.

Table 27:

*Results of Spearman's Rank correlation coefficient for SPI & CQ in young age (group I).*

| | | CQ | | |
|---|---|---|---|---|
| | Conditions | Normal | Breathy | Pressed |
| SPI | Normal | 0.263 | | |
| | Breathy | | -0.087 | |
| | Pressed | | | -0.152 |

From the above table 27, it was observed that low positive correlation was found between SPI & CQ at normal phonation whereas low negative correlation was observed between SPI & CQ at breathy phonation and pressed. This correlation was found to have no statistical significance.

Table 28:

*Results of Spearman's Rank correlation coefficient for SPI & CQ in middle age (group II).*

| | | CQ | | |
|---|---|---|---|---|
| | Conditions | Normal | Breathy | Pressed |
| SPI | Normal | -0.298 | | |
| | Breathy | | -0.039 | |
| | Pressed | | | -0.078 |

With respect to group II, a low negative correlation was found between SPI & CQ at normal, breathy and pressed phonation. This correlation was found to have no statistical significance.

Table 29

*Results of Spearman's Rank correlation coefficient for SPI & CQ in elderly age (group III)*

| | | CQ | | |
|---|---|---|---|---|
| | Conditions | Normal | Breathy | Pressed |
| SPI | Normal | 0.098 | | |
| | Breathy | | -0.020 | |
| | Pressed | | | -0.103 |

It was noticeable from the table 29, that there was low positive correlation found between SPI and CQ at normal phonation and a low negative correlation was observed for SPI & CQ at breathy phonation and pressed phonation. The correlation was found to have no statistical significance in all three correlations.

## Chapter V

## DISCUSSION

The present study is intended to investigate the effect of three phonation types on vocal fold adduction mechanism. The parameters considered to measure this effect are Soft Phonation index from MDVP and Contact quotient from EGG in which these two parameters are viewed as measure that reflects the degree and relative vocal fold adduction. Few objectives of the current study include exploring the above mentioned effect with respect to different age (young, middle & elder age individuals) groups and genders (male & female). Also, checking the correlation between the two measures (i.e. SPI and CQ) taken.

The results of the present study reveal several points of interest:

**First**, the present study did not find significant group (age) difference on soft phonation index.

Results revealed that middle age (group II) obtained higher SPI of normal phonation than young (group I) and elderly age (group III), but this was not statistically significant. This could be because discrete age groups were not taken. Also, the subjects were lesser in each group, which may not have been enough to reveal age-related trends. Thus SPI might not be a sensitive tool to measure the vocal fold adduction. This could be because of the general occurrence of glottal aperture in both young and elderly aged individuals, which may be seen as a normal developmental and aging process. From the literature it was seen that SPI was able to track changes between normal and dysphonic individuals (Mathew & Bhat, 2009), but not the subtle changes that takes place due to aging process.

**Second**, the study did not find any significant gender difference (between males and females) on soft phonation index. With respect to gender, SPI was found to be higher in females than males on all phonation tasks except normal phonation, but it was not found to be statistically significant, which could be because of the larger variability in framework or the configuration of structures itself in males and females. SPI might not be a sensitive parameter to bring about the gender difference as explicitly as fundamental frequency. Males in group I had mean SPI value of 12.36 which was higher than the Western normative mean of 6.77, and mean SPI value of females in group I was 12.60, whereas Western normative provided in the MDVP database was 7.53. So, the present study found increased mean SPI values compared to Western normative data in both the genders. This finding was in agreement with a study done by Hema, Mahesh, and Pushpavathi (2009) in which they attributed this difference to the manner of vowel production in Western and the Indian context which is contrasting. It was said that Western subjects would phonate louder and with an open mouth, but in Indian context, the subjects tend to produce vowels with less opening of mouth and reduced loudness.

**Third**, the soft phonation index was significantly higher for breathy phonation and least for normal phonation while it was in between for pressed phonation. That is, the study found significant difference between each of the phonation types based on SPI value. The order was as follows; breathy > pressed > normal. From the obtained results, it was very apparent that among all the phonation tasks, breathy phonation had the highest SPI value in both the genders, as anticipated. This implies that SPI does reflect lesser firmness of the vocal fold closure. Similar trend of increased SPI for breathy phonation was found by Roussel and Lobdell (2004) in which they said that SPI can predict changes when comparing the different types of phonations. With respect to pressed phonation, relatively higher SPI value was obtained than normal phonation task which was not in the predicted fashion, wherein the SPI is supposed to be lesser when the closure of the vocal folds are firmer (during pressed phonation). A similar kind of result was reported in the above mentioned study as well. The investigators of this study explained this as; the participants would have not produced the pressed voice with tighter vocal fold closure even though they tried to phonate with greater effort. Since the pressed condition was imitated by the subjects with more extrinsic stress, there might have been an occurrence of supraglottic compression. Koreman and Putzer (1997) had observed higher SPI value of 209 in patients with unilateral vocal fold paralysis with supraglottic constriction and lesser SPI value (109) was found in patients with vocal fold paralysis without any constriction. One can infer that the SPI value would get increased if there is supraglottic constriction. This increased SPI value for pressed phonation noticed in the present study would probably be due to more supraglottic constriction rather than at glottis level. Hence the results of the present study support the findings of Koreman and Putzer (1997) and Roussel and Lobdell (2004).

**Fourth**, the study found significant difference on SPI value between breathy and normal phonation and between breathy and pressed phonation conditions in males, whereas, in females all phonation types are significantly different from each other. The phonation related minor differences of SPI in males and females would be unexplained in the present study due to lesser number of subjects in each gender to confirm the above findings. The study needs to be carried out in a larger number of samples in each gender in order to attempt justification for the same.

**Fifth**, the study did not find any age/group difference in CQ for normal and pressed phonation. This finding could have been due to participants not differentiating their mode of production of pressed versus normal phonation sufficiently. Also, the pressed phonation that the participants elicited in the study would probably be constricting the supra-glottic structures rather than at the level of stressing the glottis region which suggested to include visualization techniques to confirm the stress during pressed phonation at the laryngeal region in future studies. However, in order to confirm these findings, the study needs to be carried out in a larger number of samples in age group.

**Sixth**, the CQ was significantly higher for younger (group I) compared to group III (elder) and middle aged (group III) individuals on breathy voice. For breathy phonation, smaller CQ was seen in elderly groups when compared to young group. This could be because in elderly individuals their vocal folds tend to get atrophied which in turn lead to bowing of the vocal folds (Linville, 1992) causing lesser contact quotient than young and middle aged groups.

**Seventh**, the contact quotient was the highest for pressed phonation followed by normal phonation, and it was least for breathy phonation. That is, the order of CQ values for three phonations followed in this way; Pressed phonation > Normal phonation > Breathy phonation. This trend was found in both the genders with statistical significance. The result of the present study was in consonance with studies done by Ma and Love

(2010) and Paul et al (2011), who attributed the increased contact quotient for pressed phonation to the increased surface bulging of the vocal folds than phonation at normal and breathy voice.

**Eighth**, the contact quotient was different in middle aged females and elderly males across three phonation types. That is, age related variations were seen differently in males and females on CQ. In middle-aged females, a significant difference in CQ was seen across the three phonation types, but no significant difference was seen across the phonation types in middle-aged males. Similarly, a difference across phonation types was seen in elderly males on CQ, no such difference was seen in females of the same age range. These differential changes in CQ across genders for varying ages could be attributed to the changes in vocal fold biomechanics that take place in both genders across the lifespan. In middle-age, males would have maximum mass in their vocal fold as opposed to females, and this increased bulk may hinder the different modes of phonation required to differentiate between the three types. On the other hand, in elderly individuals, while women would undergo menopause and consequently develop edema in their vocal folds, males of parallel age would undergo age-related thinning of vocal folds leading to lessening of mass and therefore more potential for change in CQ across the three types of phonation. The present finding was in agreement with the results of a study carried out by Gorham-Rowan and Laures (2006), who attributed this outcome to reduced closure of glottis due to atrophy and bowing of the vocal fold in elderly men, resulting in increased breathiness and hoarseness in this group.

**Ninth**, the results of the present study found no significant correlation between SPI and CQ across 3 phonation types and age groups and between genders. Results of

Spearman's rank correlation showed a poorer agreement or weak correlation between SPI and CQ across the three phonation tasks, and no statistical significance was found. When correlation coefficient was compared across age groups, weak negative low correlation was obtained between SPI and CQ across three phonation tasks for all three age groups. There was no significant difference noticed. This result was in predicted manner because one parameter was acoustic and the other was physiological in nature. Though, both the methods utilized automatic measurement tools, in acoustic analysis, the samples were analyzed acoustically in terms of physical parameters of voice and they had specific values assigned. On the contrary, EGG assessed the vibratory pattern of the vocal folds and their contact area through the use of electrical impedance. It is well known that the operational principle underlying the two measurements itself is different. The method of recording also varies between these two measurements; for acoustic analysis where microphone is used to record the signal whereas, in EGG the electrodes are positioned directly on the thyroid cartilage. Both the recordings were carried out one after the other and not simultataneously. Thus, the present study did not find any significant high correlation between soft phonation index and contact quotient parameter.

# Chapter VI

## SUMMARY AND CONCLUSION

In the present context, perceptual assessment is still considered as a subjective assessment in which the clinicians seek objective support to carry out a comprehensive evaluation of the vocal mechanism. Thus, associations have been established between the various assessment instruments and their corresponding parameters to monitor for the conceivable areas where they may coincide in order to provide further support. In this regard, MDVP and EGG have been widely set as useful techniques or methods to examine and quantify the various aspects of laryngeal functions. The current study was taken up with the interest to study one such aspect of vocal functions i.e., vocal fold adduction mechanism. This study explored the effect of different phonations on vocal fold closure mechanism using acoustic and physiological measures. Along with this, age and gender effects were also investigated. To study this, two parameters were chosen which were specifically found to estimate or quantify the relative degree and firmness of vocal fold closure; namely, Soft Phonation Index (SPI) and Contact Quotient (CQ).

Totally 90 phono-normal individuals were taken and they were instructed to phonate vowel /a/ using three different phonation tasks (normal, pressed & breathy). This was done using MDVP, in which phonation was recorded, and in EGG direct recording was carried out by placing electrodes on either side of the thyroid cartilage. The data was extracted and subjected to statistical analysis for further interpretation. From the result of SPI, it was found that out of three phonation tasks, breathy phonation had greater SPI in both the genders as predicted. This suggests that SPI reflects less firmness of the vocal fold closure. Also, higher SPI was obtained for pressed phonation which was predicted to be lower than for normal phonation, hence it suggests that there may have been presence of supraglottal compensation as the task was imitated. Also, the study found significant difference between each of the phonation type on SPI values in the order: breathy > pressed > normal.

SPI values were found to be higher in females than males on all phonation tasks except normal phonation. Males had SPI value with a mean of 13.37 which was higher than the Western normative mean of 6.77. Mean SPI value in females was 12.34 when compared to Western normative (provided in the MDVP database) which was 7.53. So, the current study showed higher SPI values than Western normative data in both the genders. This also emphasizes the importance of developing Indian normative data. On the analysis of CQ, there was no age group difference for normal and pressed phonation. As there were fewer subjects in each group, the obtained findings cannot be generalized. Thus, more number of subjects should be considered in further studies for better understanding of the differences. Elderly males had greater contact quotient than elderly females, which could be due to age-related changes. Across three phonation types, the contact quotient was found to be highest for pressed phonation (i.e. increased vocal fold contact), followed by normal phonation, and it was least for breathy phonation. This trend was found in both the genders with statistical significance.

The result of the study also found difference in CQ in males and females within each age group, especially in elderly males and middle aged females. This may be because of the presence of posterior glottis chink in middle aged females. Also, in the elderly due to the normal aging process, their vocal folds tend to become atrophied earlier, which may result in bowing of the vocal folds.

Poor negative correlation was found between SPI and CQ across all the phonation tasks and even between the three age groups. This suggests that there was no relationship between the two measures i.e. acoustic and physiological. The possible reason for this could be that they differ from each other in various aspects, such as method of recording, operations, etc.

To conclude, there exist changes in the vocal adduction mechanism across different phonations, which were shown evidently by both the measures (SPI and CQ). A significant effect was found between the phonation types. This study highlights the need to generate normative data across age groups and genders in order to supplement clinical judgments of voice. It also suggests the necessity for clinicians to be aware of the aging process and its impacts on vocal production.

**Implications of the study**

1. The results of the present study will throw lights on vocal fold adduction behavior during different phonation types.
2. The results of the present study help the voice clinician to understand the vocal fold adduction mechanism across three age groups on different phonation types.
3. Findings of the present study provide correlation between two measures Soft Phonation Index (acoustic) and Closed Quotient (Physiologic) on vocal fold adduction.

## Limitations of the study

- Test retest reliability measure was not carried out for the obtained data.
- Only phonation task was used in the study. Gender differences in CQ could have been even more prominent in continuous speech contexts, in which continuous phonatory adjustments are essential to meet different speech and intonation targets.
- There can be various factors which can lead to less than ideal EGG signals, including poor placement of electrodes, mucous strands across the vocal folds, or excess fat in the area of the electrodes, which can influence with limited vocal fold contact.
- Even though increased mean contact quotient was seen for pressed phonation, few subjects had lesser CQ values as well which may also imply that the subject doesn't hyper adduct the vocal folds properly which was not monitored by video strobe procedure.

## Future directions

1. The Current study was done only in phono normal individuals, it would be recommended to replicate the study with dysphonic patients to check if homogeneous findings would be generalize to clinical populations.
2. The upcoming study can be taken up by using speech and singing task for measuring the vibratory pattern of the vocal folds.
3. Further study can be done to check the influence of other acoustic variables on these parameters.
4. Further the study could be carried out with increase in the number of participants

5. Future study can be done by employing criterion level method for measuring EGG signals to explore how variations or changes in measurement criteria for EGG effect its sensitivity to changes in the degree of vocal fold adduction i.e., normal versus breathy versus pressed voice or with respect to specific vocal pathologies.

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