A MEASURE OF VOCAL STABILITY IN FEMALE TRAINED SINGERS AND NON SINGERS

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APRIL, 2018

CERTIFICATE

This is to certify that this dissertation entitled ***"A measure of vocal stability in female trained singers and non-singers"*** is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 16SLP027. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
April, 2018.

Dr. S. R. Savithri
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DECLARATION

This is to certify that this dissertation entitled ***"A measure of vocal stability in female trained singers and non-singers"*** is the result of my own study under the guidance of Dr. T. Jayakumar, 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 other Diploma or Degree.

Mysuru, **Registration No. 16SLP027**

April, 2018

A TOKEN OF LOVE

TO

PAPPA & MUMMY

ACKNOWLEDGEMENT

I can do all the things by the grace of god who strengthen me

THANK YOU LORD APPA FOR HELPING ME TO FULLFILL ONE OF MY DREAMS.

BY THY GRACE I AM WHAT I AM….

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CHAPTER 1

INTRODUCTION

The human voice is considered as a tool for communication. Voice has two main dimensions namely speaking and singing. Both singing and speaking are accomplished by the same anatomical and physiological structures but with diverse regulation. The act of speaking is the very specialized way of using vocal mechanism. The act of singing is even more so. Speaking and singing demands a combination and interaction of the mechanism of respiration, phonation, resonance and speech articulation (Boone, 1977).

In principle there is no difference between the sounds of speech and singing. However, in singing the consonants should not break the flow of vocal sound in the same way as in speech. Singing demands considerable resonance and articulation (Butenschn & Grevink, 1982). In singing the vowels are prolonged since they are especially suited to carry melody. It follows that the rhythmical, dynamic and melodic qualities of speaking and singing differ only in regard to quantity and quality. These formal elements are complicated by additional psychological factors and aesthetic requirements (Luchsinger, 1965).

Another major difference between speaking and singing is the rhythmic progression from sound to sound. Also, singing requires isochronism of vibration of vocal fold which is not much stressed in speech. Greater vocal range is used in singing as compared to speech. Vibrato, singer formants are used by singers. Vocal apparatus is under greater stress during singing than speech. Also, the singer should be able to prolong the expiration, i.e. the ability to maintain smooth steady airflow. The appropriate regulation of the vocal system leads to confident, artistic and stable voice production. To achieve these abilities in singing, the singers require skillful control on vocal mechanism and the endurance or stability of the vocal mechanism.

The audible difference in the speech and the voiced segments of the vocal output can be called as the difference in the voice quality. The quantification of quality of voice among singers and non-singers can be done in two major ways. They are named as subjective or perceptual and objective or instrumental methods. Subjective/qualitative evaluations are done perceptually using standardized rating scales such as GRABS and CAPE- V.

The quantitative or instrumental evaluations can be invasive or non- invasive. An invasive method are usually carried out by medical professionals or under their supervision which includes Video Laryngoscopy and Stroboscopy and it provides visual information about the vibratory characteristics and the structure of the vocal folds. Non-invasive methods include recording and subsequent analysis of the quantified values by the examiner or by the instrument itself. The most common objective approach is the acoustic analysis. This give information about the intensity, frequency, noise and tremor related measures about the voice sample. Acoustic analysis gives more reliable and useful measures than in a non-invasive method. Many studies have been done on the acoustic analysis of voice in singers and non-singers. Majority of the acoustic study showed the singer’s voice is superior to non-singer’s voice.

Mendes et. al (2003) found that, vocal training has a significant effect on the Maximum Phonational Frequency Range (MPFR), F0 and SPL in singers. Singing power ratio (SPR) of sung /a/ in singers is significantly greater than non-singers (Omori et.al, 1996). The most consistent difference in the acoustic parameters of singers when compared to non-singers is the presence of vibrato, singer’s formant and the percentage of jitter (Brown, Rothman & Sapienza, 2000). Acoustic characteristics of trained and untrained Carnatic female singer's voice differ in terms of the temporal parameters such as burst duration, F2 transition duration and vowel steady state duration (Ghosh, 2007). Perceptual studies indicate that there is nothing evident to differentiate the speaking utterance of professional singers and non-singers (Brown, Rothman & Sapienza, 2000). Beyond acoustic analysis, the direct measure of physiological activity of vocal folds is electroglottography (EGG).

Phonatory stability refers to the steadiness and periodicity of vocal fold vibration, which is dependent on the laryngeal system maintaining relatively constant levels of muscular force during a sustained phonation (Ferrand, 2006). The production of vocal sounds through properly coordinated movement of muscles of larynx, the vocal tract and the respiratory system. The precision with which this coordination is achieved determines the quality of vocal function (Schultz- Coulon, 1977). There are many studies have been done on the vocal stability measurement in different population.

Jayakumar (2006) investigated the effect of binaural auditory masking levels (0dB ML, 50 dB ML &80dB ML) on phonatory stability on 10 normal children. Results shows that, 40% had decreased jitter, 20% had no change in jitter from 0db ML to 80dB ML. 70% of the subjects had decreased shimmer and 60%of the subjects increased HNR level and SNR level from 0dB ML to 80 dB ml. The results of intensity, F0, jitter, shimmer, HNR and SNR points to the variability in strategies that children use to compensate for disruption in auditory feedback. The variability evident in subjects indicates auditory feedback is not the sole contributor to vocal motor control and phonatory stability. Kinesthetic feedback may also play an important role to maintain phonatory stability which is supported by the study of Ferrand (2006).

Stephen and Bier (2017) had studied the vocal stability in young and old adults using EGG and multiple type of elicitation of speech sample. The F0, Contact quotient (CQ) and their standard deviations were the measured parameters and found that contact quotient (CQ) is significantly lower for all elicitation type in old speakers. The authors reported that EGG is the effective measure to estimate vocal stability.

EGG is a non- invasive procedure which is used to measure the laryngeal behavior and the vocal fold vibratory behavior activity indirectly by measuring the electrical impedance changes across the throat during speaking. The method was first developed by Fabre (1957) and Frokjaer-Jensen (1968). EGG is a valid means of representing the relative area of contact of the vocal folds during the glottal cycle (Baken, 1992).

The basic principle of EGG is Ohms law. In the course of phonation the vocal folds are periodically separated by an air filled space, the glottis. The tissue is a moderately good electric conductor and air is an extremely poor conductor. Hence, during the glottal cycle, the electrical impedance across the larynx rises as the glottis opens and falls as the vocal folds comes in to contact. Thus impedance probing will be ideally suited to show the details of laryngeal function.

Using EGG, the vibratory behavior is commonly described in terms of Open Quotient (OQ) (Winkler & Sendlmeier, 2006) or Contact Quotient (CQ) (Orlikoff, 1991). The contact quotient (CQ) is a measure of the duration of vocal fold contact in each vibratory cycle relative to the cycle period.

Singers are usually capable of modulating the pitch and intensity of voice rapidly without causing exorbitant stress to their voice. Evidence confirms the presence of broader pitch profile in singers than non-singers (Nora Siupsinskiene et al, 2011; Shaheen et al, 2010; Mendes et al, 2004). A singer is expected to sustain the mean fundamental frequency at a constant value over the time interval of a particular note. Vocal training can clearly have a prophylactic effect on voice (Lawrence, 1979). Singers are not physiologically gifted, rather they are benefited from the technical training (Hunt & Williams, 1988).

To examine the voice quality & stability it is better to measure the short term (cycle-to- cycle) variation of the voice. Typical measurements of vocal stability take the form of standard deviations or perturbation measures. Separating short-term variation in voice features from longer term variation due to prosodic and phonetic variation is difficult. A common way to avoid this problem is to examine sustained vowels where the speaker has to produce a target pitch and target loudness (Bier, Catherine& Mc Cann, 2017).

Examination of standard deviation of (F0) and perturbation of F0 (Jitter) will provide an indication of the person's ability to hold a stable FO in a sustained phonation. Similar measurement can be made the vibratory characteristics of the vocal fold behavior with measures of contact quotient (CQ) and its perturbation ((Bier, Catherine & McCann, 2017). The vocal stability measures work well in the context of sustained vowel works well where the features of interest are held relatively constant for the duration of phonation.

Need for the study:

Singers are considered as elite category of professional voice users. Ever since, the comparison of voice quality of singers and non-singers using different subjective or objective measures has got greater interest in the field of research. Among them acoustic analysis holds an upper hand. Many studies had done on comparison of acoustic properties of voice between singers and non-singers or untrained singers in Western as well as in Indian context.

The steadiness and periodicity of vocal fold vibration decides the vocal stability which will be reflected in the perceived vocal quality. Even though there is no anatomical difference in the vocal tract structure of singers and non-singers, the training which the singer receives makes a significant difference in the quality of voice. Vocal stability can be measured more effectively, when the vocal system are drived to its maximum dynamic range (variation of pitch and intensity) (Bier, Catherine& Mc Cann, 2017).

Many studies had done to measure the vocal stability of different population such as children, young adults, old adults, females and even in dysarthric population using acoustic measures. Till date, EGG has been only considered as a tool for measuring the vibratory behavior of vocal folds. Recently studies proved that EGG is an effective tool for measuring vocal stability (Bier, Catherine & Mc Cann, 2017). However, there is dearth of studies on vocal stability using EGG in Indian context. Singers are one among the population, where the vocal stability measure has worth clinical investigation. Hence, the current study attempts to provide an understanding of vocal stability of trained singers and non-singers using EGG in the Indian context.

Aim of the study:

To measure the vocal stability of young female trained singers and non-singers using Electroglottogram (EGG) and to compare both the groups.

Objectives of the study:

1) To find the vocal stability of sustained phonation in female trained singers by measuring the F0 (mean and standard deviation, periodicity), Jitter, Contact Quotient (CQ) (mean and standard deviation), Open Quotient (OQ) (mean and standard deviation) using EGG.
2) To find the vocal stability of sustained phonation in female non- singers by measuring the F0 (mean and standard deviation, periodicity), Jitter, Contact Quotient (CQ) (mean and standard deviation), Open Quotient (OQ) (mean and standard deviation) using EGG.
3) To make a comparison of the vocal stability of sustained phonation between female trained singers and non-singers.

CHAPTER 2

REVIEW OF LITERATURE

Phonatory stability refers to the steadiness and periodicity of vocal fold vibration, which is dependent on the laryngeal system maintaining relatively constant levels of muscular force during a sustained phonation (Ferrand, 2006). The production of vocal sounds through properly coordinated movement of muscles of larynx, the vocal tract and the respiratory system. The precision with which this coordination is achieved determines the quality of vocal function (Schultz- Coulon, 1977).

Ackermann and Ziegler (1994) acoustically analysed the vocal stability in 20 patients with cerebellar cortical dysfunction during the production of isolated vowels /i/, /u/ and /a/. Mean fundamental frequency (FO), period-to-period variability (jitter), pitch fluctuations, and between-trial variation of FO were the measured parameters. Eleven subjects suffered from purely cerebellar atrophy (CA), the remaining 9 patients had olivoponto cerebellar atrophy (OPCA). Both the CA and OPCA subjects presented with enlarged pitch fluctuations and/or increased jitter values. Asymmetrically distributed motor deficits at the laryngeal level and altered gain settings of laryngeal and/or respiratory reflexes account for the observed phonatory instability. Moreover, 5 of the 20 cerebellar patients had a pitch level exceeding the upper limit of the normal range. This deviation reflects increased vocal effort. This must be assumed there for, apart from proprioceptive loops, the cerebellum also has its own function in maintaining phonatory stability.

Wilcox and Horii (1980) noted jitter and shimmer differences among different vowel. They found that /u/ was associated with significantly smaller jitter (0.55%) than /a/ or /i/ (0.68% and 0.69%, respectively). Studying older subjects, Horii (1980) also found both jitter and shimmer to be smallest for /u/, intermediate for /i/ and greatest for /a/. On the other hand, a trend toward greater jitter for high vowels than low vowels was reported by Johnson and Michel (1969), when examined 12 English vowels. Zemlin (1962) reported a significantly greater jitter for /a/ than /i/. Horii (1982) investigated jitter and shimmer differences in sustained phonation of eight English vowels, recorded through a miniature accelerometer placed on the throat of 20 adult males. Statistical tests indicated no significant differences in either jitter or shimmer among the eight vowels. These studies indicates that there is a difference among vowels for the jitter and shimmer values.

Phonational profiles of female professional singers and nonsingers were compared by Brown et al (1991). 39 professional singers and nonsingers of young, middle and older age groups were participated as subjects for this study. The reading and speaking samples were tape recorded. Rainbow passage had given for reading and the same was used to measure the speaking fundamental frequency (SFF) whereas the second sentence of the same passage was used to calculate vocal intensity. No statistically significant differences were found in SFF values and vocal intensity for the reading and speaking task. The SFF and intensity levels were significantly higher for the professionals in comparison to the nonsingers, but only for certain age groups. Moreover, the non-singer SFF levels varied significantly as a function of age, those for the professional singers did not. Although trends occurred, no significant differences were found for the mean phonational range or habitual pitch levels between the professionals and nonsingers.

Ferrand (1995) studied the effect of practice with and without the knowledge of the result on jitter and shimmer in two groups of 30 normally speaking women ages 22-43 years. Subjects in both the groups sustained trials of /a/ as steadily as possible during a baseline session, two practice sessions, and a transfer session. Subjects in one group received visual and verbal feedback during the practice sessions and the other group received no feedback. Shimmer means remained essentially stable over the four sessions for both the groups and no differences were apparent between the groups. Jitter values were significantly different between sessions for both groups, and between the two groups for the practice sessions. The result of the study shows that frequency perturbations in the normal voice may be decreased through modification of neurologic input to the laryngeal musculature.

Ferrand (2006) investigated changes in intensity, F0, jitter, and HNR in 22 normally speaking college aged women by disrupting the auditory feedback through masking. Subjects produced the vowel /*a*/ under three conditions: no masking level (0-dB ML), 50-dB ML, and 80-dB ML. Significant differences between conditions emerged for intensity; means for the other measures were not significantly different. The author concluded that well-established patterns of kinesthetic feedback allowed the subjects to maintain normal levels of vocal motor control even in the presence of disruptive noise.

Jayakumar (2006) investigated the effect of binaural auditory masking levels (0dB ML, 50 dB ML &80dB ML) on phonatory stability on 10 normal children. Results shows that, 40% had decreased jitter, 20% had no change in jitter from 0db ML to 80dB ML. 70% of the subjects had decreased shimmer and 60%of the subjects increased HNR level and SNR level from 0dB ML to 80 dB ml. The results of intensity, F0, jitter, shimmer, HNR and SNR points to the variability in strategies that children use to compensate for disruption in auditory feedback. The variability evident in subjects indicates auditory feedback is not the sole contributor to vocal motor control and phonatory stability. Kinesthetic feedback may also play an important role to maintain phonatory stability which is supported by the study of Ferrand (2006).

Pebbili and Soonan (2014) acoustically analysed the vocal stability of 11 female trained Carnatic singers and non- singers. The singers were received a minimum of 10 years of training in Carnatic singing. Participants were asked to phonate at their comfortable pitch and loudness and at their possible lowest and highest pitch. The phonation samples were analysed using MDVP. Jitter % (jitt %), smoothed pitch perturbation quotient (sPPQ), shimmer % (shim %), smoothed amplitude perturbation quotient (sAPQ), coefficient of fundamental frequency variation (vFo), and coefficient of amplitude variation (vAm) were the parameters obtained. The frequency pertuberation measures were significantly higher for non-singers at lowest and highest pitch level compared to singers. The amplitude pertuberation measures were not significantly different for both the groups across different pitch level and they concluded that, trained singers have a superior vocal stability over non-singers. Singing training among the singers leads to better vocal stability compared to their counterparts. Much superior vocal stability present at the extremes of their pitch range

EGG and Vocal Stability.

Huang, Minifie, Kasuya and Lin (1995) measured the vocal function during changes in vocal effort level for vowels /ae/ and /a/ produced at three vocal efforts (low, normal, high), five times a day over 3 days at each vocal effort level in 3 healthy men. Three acoustic parameters (jitter, shimmer, and normalized noise energy), and two electroglottographic parameters (contact quotient and contact quotient perturbation) were measured. The jitter, shimmer, and normalized noise energy values from acoustic measures and contact quotient and contact quotient perturbation values varied significantly among the three vocal effort levels. The results indicated that vocal effort must be controlled in order to obtain consistent clinical measures from phonation samples.

Joy (2009) inquired the vocal registers in trained and untrained 40 female Carnatic singers of the age range of 18- 50 years using EGG. The subjects were asked to sing the vowel /a/ in ascending scale in a single breath reaching the three registers. Open quotient (OQ), Contact Quotient (CQ) and F0 were the extracted parameters. The mean value of EGG parameters except F0 doesn't vary across registers for both singers and non-singers. CQ values were higher in head register compared to the falsetto register in singers. OQ values were higher in head register for singers when compared to other two registers. And for non-singers OQ scores were higher in falsetto register. SQ values were significantly different for falsetto register in singers and mean SQ values are higher in non-singers in head and falsetto register. In summary, EGG parameters were significant by different measures especially at chest and falsetto register. These differences contributed by the training received by the singers.

Thomas, (2015) investigated vocal economy of female trained singers and non-singers using EGG. The task was to phonate the vowels /a, I, u/ thrice at soft, moderate and loud level for 5 seconds. F0, SPL, Quasi Output Cost Ratio (QOCR) were the parameters considered. The results revealed that all the parameters except SPL in soft phonation did not show significant difference across the task. The findings suggest the contribution of vocal training to tissue endurance and susceptibility than vocal economy.

CHAPTER 3

METHOD

Participants

A total of 40 female participants were enrolled for the study and one subject from the singers group got eliminated due to extreme values found during the analysis. Participants were grouped in to two based on their singing abilities. One group of participants consisted of 19 trained singers. The second group consisted of 20 non singers. All the participants in both the groups were within the age range of 20-40 years.

Inclusionary criteria:

- All the participants were native speakers of Kannada.
- The participants comprising the group I received not less than five years of training in Carnatic form of singing.
- Participants in group II didn't receive any formal training for singing.
- Participants in both the groups had a normal quality of voice as assessed by a speech language pathologist.

Exclusionary criteria

- Participants, who had signs and symptoms of upper respiratory tract infection or allergic diseases at the time of recording, were excluded from the study.
- Also participants with the history of neurological, speech or language disorders were excluded from both the groups.
- Participants with history of alcohol consumption or smoking and tobacco usage were excluded from the group of individuals with normal voice quality.

Stimuli

Sustained phonations of the vowels /a/ and /i/ in three different pitches (high, mid and low) with comfortable loudness and in three different loudness (loud, normal and soft) with comfortable pitch were collected. The pitch and loudness level were self-determined by the individual. A recorded model for high, model and low pitch level and for loud, normal and quiet loudness level were provided to the non-singers group through headphone. All the stimuli were collected from both the groups of the study.

Procedure

Real-time Electroglottogram (EGG) from the CSL software (Key Pentex, NJ) was used to capture the vibratory behavior of vocal folds. The participants were fitted with two electrode plates at the level of the thyroid cartilage in the larynx. The procedure was explained to the participants and the informed consent was taken before the recording. They were asked to sit straight and relaxed during the recording. Three trials of each sustained phonation were captured. A total of 36 sustained vowels [3(low, mid, high) * 3(quiet, normal, loud) * 2(/a/, /i/)] were elicited from each subject.

Analysis

The second trail of the subject's phonation was considered for analysis. Middle three seconds of the sustained vowels were selected for the analysis to get a stable voiced segment. If the stable voiced segments were not found in the selected sample, third trail or the first trail of the phonation was considered analysis. Voice samples were analysed by considering the fundamental frequency (F0), standard deviation of F0, Periodicity, Jitter, contact Quotient (CQ), standard deviation of CQ, Open Quotient (OQ) and standard deviation of OQ.

Statistical Analysis

The obtained values for each parameter were subjected to statistical analysis using SPSS (Version 20), in order to derive:

- Normality of the sample selected for the study using Shapiro-Wilk test for normality.
- The reference measures for each parameter for trained singers and non-singers using descriptive statistics.
- The differences across the groups with respect to the values for each parameter using Friedman’s test and Mann- Witney U test.

CHAPTER 4

RESULTS

This particular study was focused to measure the vocal stability at different pitch level and loudness level in trained female Carnatic singers and non-singers. The EGG parameters used in the current study were fundamental frequency (F0), standard deviation of F0, Periodicity, Jitter, Contact Quotient (CQ), standard deviation of CQ (CQ- SD), Open Quotient (OQ) and standard deviation of OQ (OQ-SD). The results of this study will be discussed under the following headings:

- ✓ Normality check for the data.
- ✓ Mean and standard deviation of EGG parameters across different pitch level and loudness level for the vowels /a/ and /i/.
- ✓ Comparison of Carnatic singers across different pitch level and loudness level for the vowels /a/ and /i/.
- ✓ Comparison of non-singers across different pitch level and loudness level for the vowels /a/ and /i/.
- ✓ Comparison of Carnatic singers and non- singers across different pitch level and loudness level for the vowels /a/ and /i/.

Normality check for the data

In order to determine the normality of the samples selected for the study Shapiro Wilk's test was carried out with respect to the independent variables different pitch (low, model and high) and loudness (quiet, normal and loud) . It revealed that most of the parameters did not follow normal distribution with $p<0.05$. Hence, non- parameteric statistics was done.

Mean and standard deviation of EGG parameters across different pitch level and loudness level for the vowels /a/ and /i/

The descriptive statistics of EGG parameters across different levels of pitch and loudness for the Carnatic singers are given Table 4.1 and 4.3. The mean values for EGG parameters across pitch showed noticeable difference in fundamental frequency (F0) and F0-SD, Periodicity, CQ-SD and OQ-SD. The mean value for F0, F0-SD, CQ-SD, OQ-SD and Periodicity were higher for high pitch compared to model and low pitch.

Similarly, mean and standard deviations are tabulated for non- singers in three different pitch levels in Table 4.2.and Table 4.4. The mean values for EGG parameters across different pitch levels showed difference in F0-SD, Periodicity, CQ-SD and OQ-SD. The mean value for F0-SD, Periodicity CQ-SD and OQ-SD were higher for high pitch compared to model and low pitch.

Comparison of Table 4.1and 4.2 shows that non-singers had low value for F0 in high pitch compared to singers. The overall standard deviation values were higher for non- singers compared to Carnatic singers. The periodicity values were higher for singers compared to non- singers across different pitch level and the jitter, CQ values were lower for Carnatic singers compared to non- singers at each pitch level

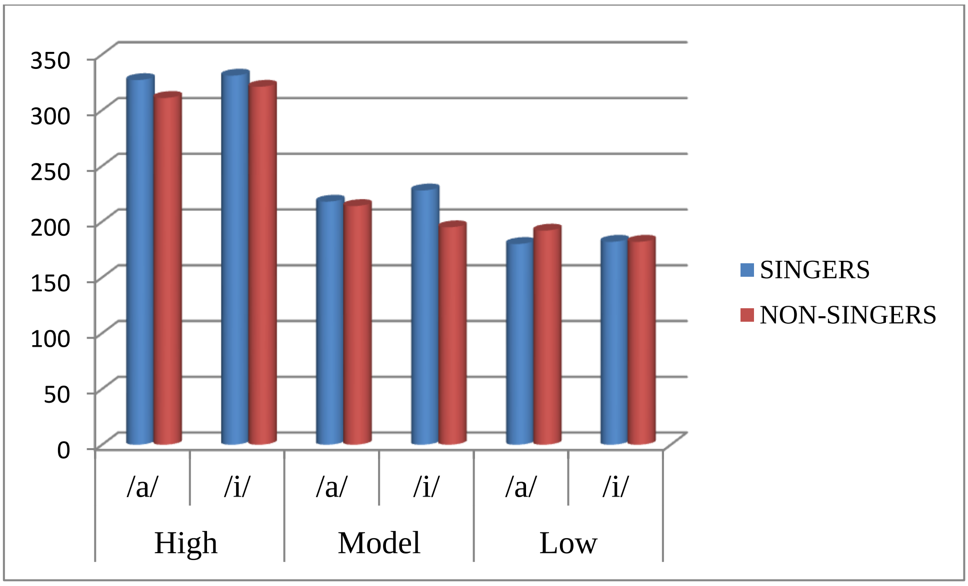
Table 4.1: Mean and standard deviation of EGG parameters across different pitch for Carnatic singers.

Parameters	High		Model		Low	
	/a/ Mean(SD)	/i/ Mean(SD)	/a/ Mean(SD)	/i/ Mean(SD)	/a/ Mean(SD)	/i/ Mean(SD)
F0	327(31.3)	331(29.7)	218(13.4)	228(13.2)	180(9.15)	182(11.0)
F0-SD	2.98(1.32)	2.97(1.28)	2.25(2.20)	1.61(0.41)	1.55(0.49)	1.48(0.35)
Periodicity	29.9(17.1)	34.5(19.3)	23.0(13.0)	22.3(13.4)	17.4(12.6)	13.5(10.3)
Jitter	0.57(0.26)	0.53(0.18)	0.41 (0.17)	0.33(0.12)	0.41(0.18)	0.36(0.14)
CQ	46.3(5.18)	46.3(5.19)	42.2(4.48)	45.6(3.89)	42.2(4.11)	43.4(5.21)
CQ SD	2.74(1.71)	2.52(1.34)	1.76(0.86)	1.45(0.62)	1.39(0.54)	1.5(0.86)
OQ	53.4(5.05)	53.7(4.77)	55.7(4.49)	54.3(3.89)	57.5(4.28)	56.5(5.21)
OQ SD	2.74(1.71)	2.52(1.34)	1.76(0.86)	1.45(0.62)	1.39(0.54)	1.58(0.86)

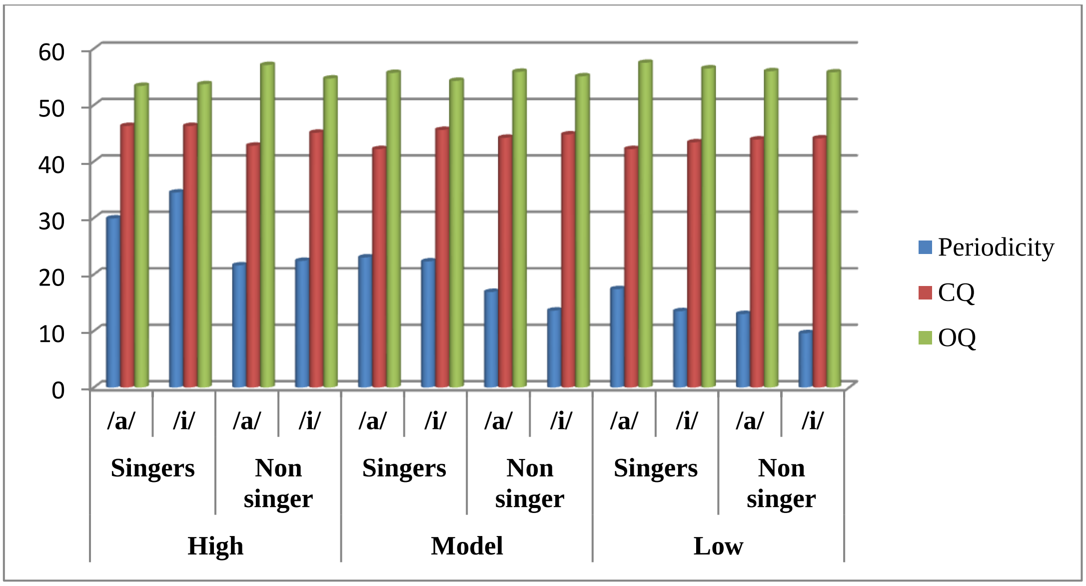
Table 4.2: Mean and standard deviation of EGG parameters across different pitch for non- Singers.

Parameters	**High**		**Model**		**Low**	
	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)
F0	311 (33.1)	321 (18.5)	214 (16.0)	195(14.5)	192 (19.3)	182(16.9)
F0 SD	3.37(2.05)	3.20(1.76)	2.09(1.23)	1.87(0.51)	2.64(2.51)	2.14(0.92)
Periodicity	21.6(12.3)	22.4(11.7)	16.9(8.79)	13.6(8.78)	13.0(6.69)	9.60(6.23)
Jitter	0.67(0.63)	0.57(0.39)	0.42 (0.16	0.51(0.71)	0.67(0.90)	0.44(0.25)
CQ	42.8(4.31)	45.1(5.59)	44.2(3.34)	44.8(3.48)	43.9(4.22)	44.1(4.04)
CQ SD	2.21(0.92)	2.05(1.04)	1.75(0.62)	1.50(0.58)	1.95(1.70)	1.58(1.22)
OQ	57.1(4.31)	54.7(5.62)	55.9(3.77)	55.1(3.48)	56.0(4.21)	55.8(4.04)
OQ SD	2.21(0.92)	2.06(1.04)	1.75(0.62)	1.50(0.58)	1.95(1.70)	1.58(1.22)

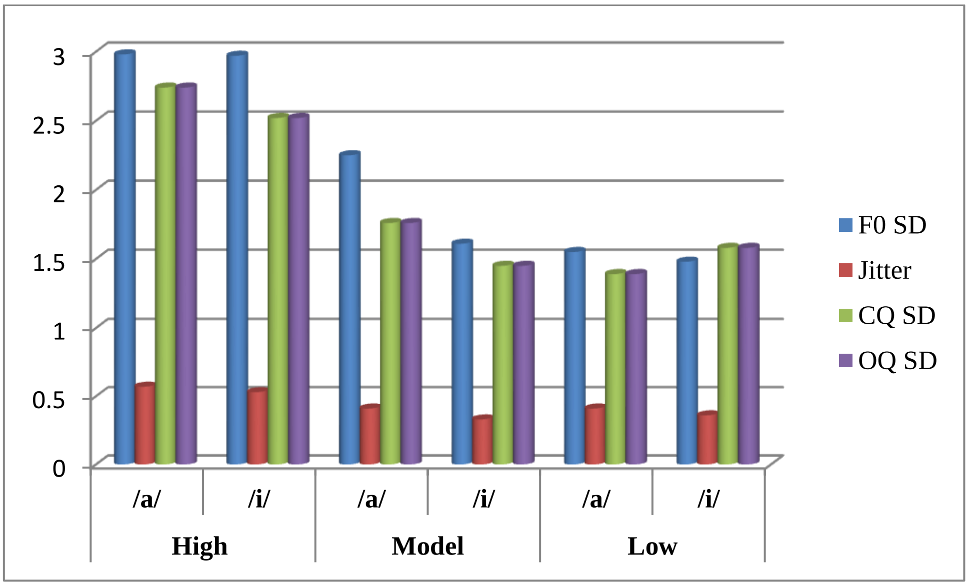
Graph 1: Mean value for F0 for Carnatic singers and non- singers across different pitch level for the vowels /a/ and /i/



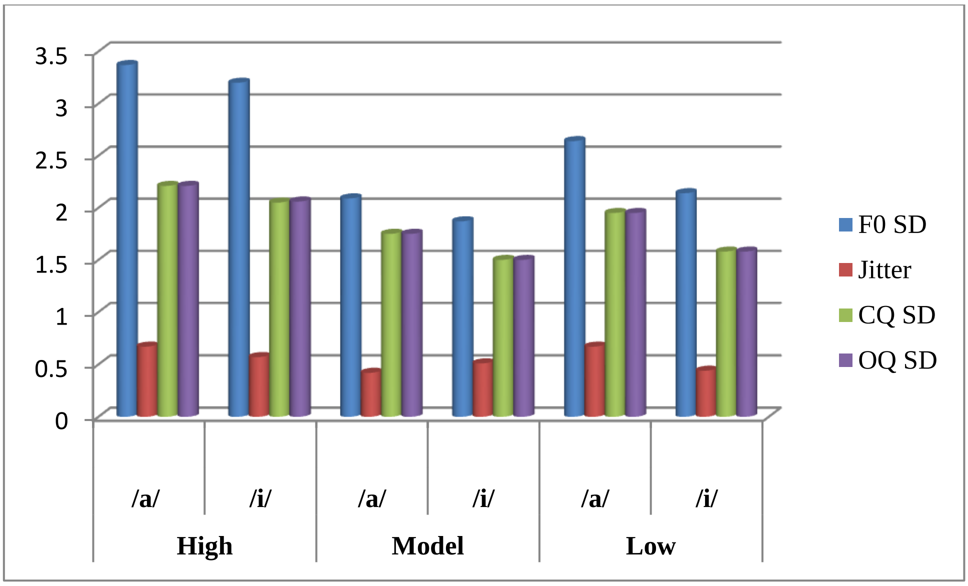
Graph 2: Mean value for Periodicity, CQ and OQ for Carnatic singers and non-singers across different pitch level for the vowels /a/ and /i/



Graph 3: Mean value for Jitter, CQ SD and OQ SD for Carnatic singers across different pitch level for the vowels a/ and /i/



Graph 4: Mean value for Jitter, CQ SD and OQ SD for non- singers across different pitch level for the vowels /a/ and /i/



Mean and standard deviation of all EGG parameters for Carnatic singers at three different loudness levels (loud, normal and quiet) are tabulated in Table 4.3. The mean values for EGG parameters showed noticeable difference across loudness level in F0-SD, CQ-SD and OQ-SD and Periodicity. At quiet phonation level the F0-SD, CQ-SD and Jitter were higher compared to loud and normal loudness level. Periodicity was higher at loud phonation.

Table 4.3: Mean and Standard deviation of EGG parameters across different loudness level for Carnatic Singers.

PARAMETER	Loud		Normal		Quiet	
	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)
F0	224(14.2)	226(15.4)	219(12.7)	221(15.5)	216(15.4)	217(16.4)
F0 SD	1.85(1.59)	1.47(0.31)	1.70(0.83)	1.39(0.22)	2.55(2.54)	2.23(1.71)
Periodicity	36.2(7.82)	31.6(19.2)	30.2(18.1)	23.1(14.6)	19.4(13.5)	11.5(10.1)
Jitter	0.31(0.07)	0.29(0.10)	0.42(0.41)	0.30(0.06)	0.56(0.41)	0.42(0.14)
CQ	44.8(5.15)	43.4(9.48)	44.6(5.56)	44.8(4.71)	43.1(4.35)	43.0(4.40)
CQ SD	1.55(0.60)	1.34(0.72)	1.61(0.98)	1.31(0.45)	2.02(0.98)	1.69(0.77)
OQ	54.7(5.29)	54.0(4.68)	55.3(5.56)	55.6(4.36)	57.0(4.15)	56.9(4.39)
OQ SD	1.55(0.60)	1.34(0.72)	1.61(0.98)	1.33(0.45)	2.02(0.98)	1.69(0.77)

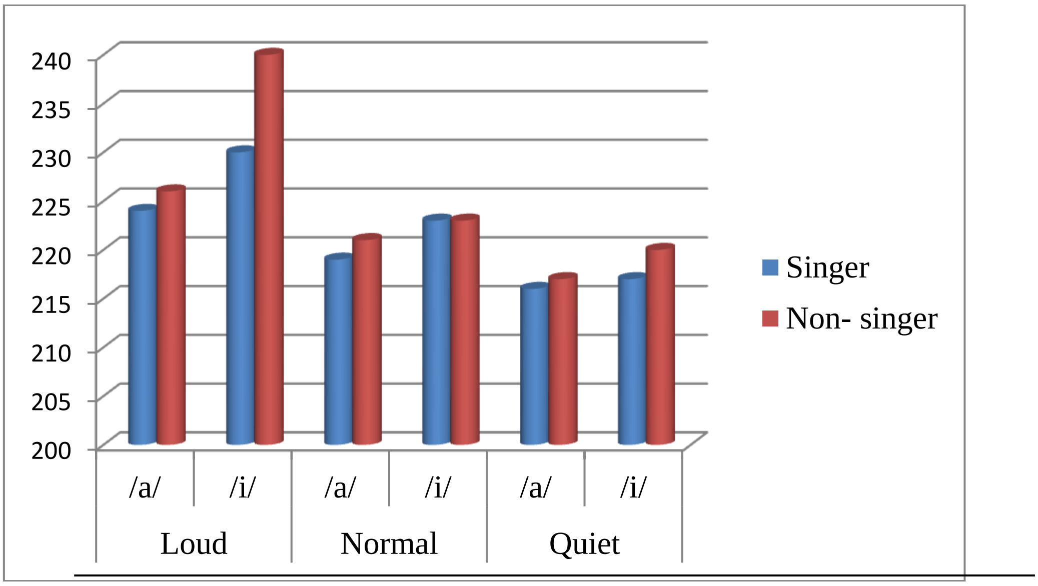
The mean and standard deviation for non- singers in three different loudness levels are tabulated in Table 4.4. The mean values for EGG parameters across different loudness level did not show noticeable difference except for periodicity and CQ- SD.

Table 4.4: Mean and Standard deviation of EGG parameters across different loudness level for non- singers.

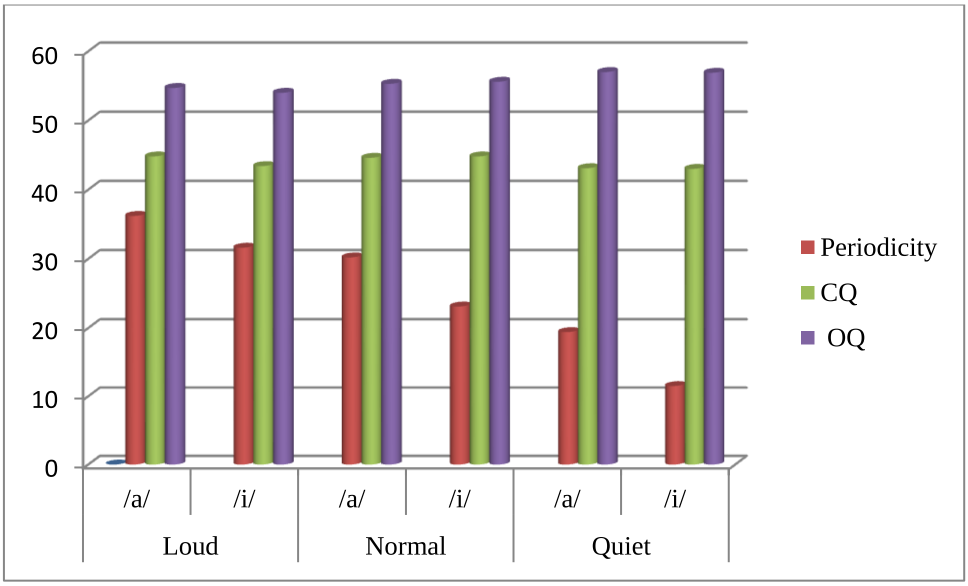
PARAMETER	**Loud**		**Normal**		**Quiet**	
	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)	/a/ Mean (SD)	/i/ Mean (SD)
F0	230(19.5)	240(19.7)	223(29.5)	223(15.4)	217(18.1)	220(16.3)
F0 SD	1.93(0.86)	1.72(0.55)	2.23(0.91)	1.76(0.47)	2.27(0.98)	2.15(0.88)
Periodicity	28.1(2.70)	24.8(13.1)	19.5(7.39)	13.3(6.72)	12.7(5.96)	8.40(3.36)
Jitter	0.33(0.09)	0.30(0.09)	0.40(0.13)	0.34(0.11)	0.51(0.25)	0.43(0.18)
CQ	44.6(4.27)	45.6(4.15)	44.0(3.67)	43.3(3.07)	43.4(3.66)	42.7(3.30)
CQ SD	1.57(0.66)	1.44(0.66)	1.73(0.71)	1.44(0.63)	1.94(0.66)	1.60(0.63)
OQ	55.3(4.27)	57.2(3.30)	55.9(3.67)	56.8(3.07)	56.5(3.66)	57.2(0.30)
OQ SD	1.57(0.66)	1.44(0.66)	1.73(0.71)	1.44(0.64)	1.94(0.66)	1.60(0.63)

Comparison of Table 4.3 and 4.4 shows high F0 for non-singers across different loudness level than that of singers. The mean F0-SD and Jitter values were low for singers compared to non- singers. Mean Periodicity value was higher for singers than non- singers at different loudness level. For both the groups, the mean CQ-SD and OQ-SD values were lower across the loudness level.

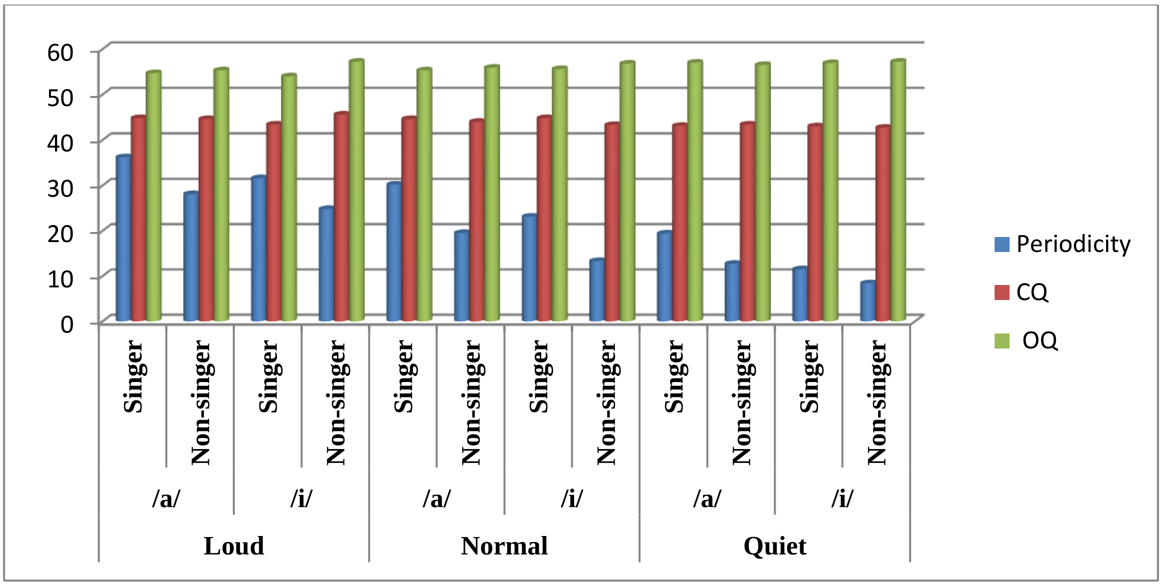
Graph 5: Mean value for F0 for Carnatic singers and non- singers across different loudness level for the vowels /a/ and /i/



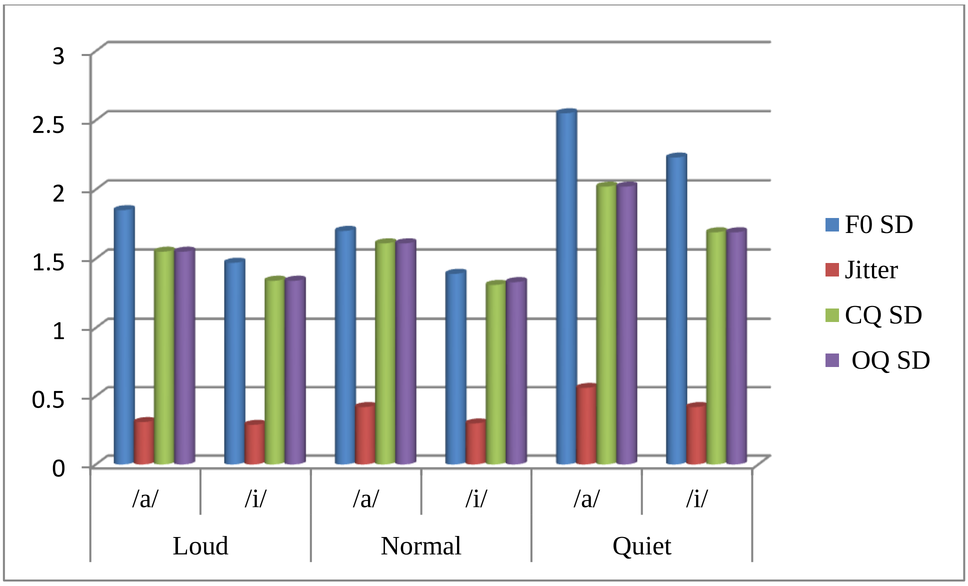
Graph 6: Mean value for periodicity, CQ and OQ for Carnatic singers across different loudness level for the vowels /a/ and /i/.



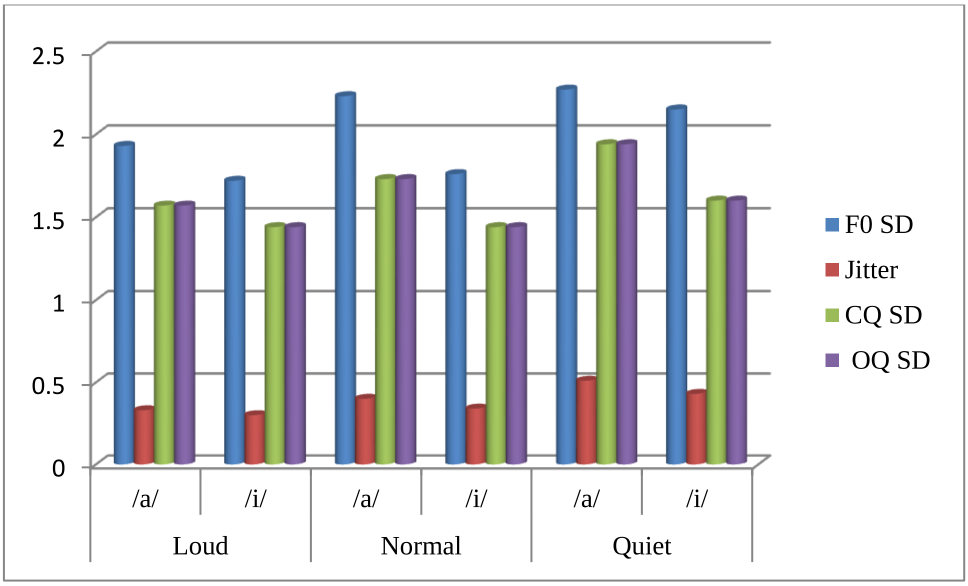
Graph 7: Mean value for Periodicity, CQ and OQ for Carnatic singers and non-singers across different loudness level for the vowels /a/ and /i/.



Graph 8: Mean value for jitter, CQ SD and OQ SD for Carnatic singers across different loudness level for the vowels a/ and /i/



Graph 9: Mean value for F0 SD, jitter, CQ SD and OQ SD for non- singers across different loudness level for the vowels a/ and /i/.



Comparison of Carnatic singers across different pitch level and loudness level for the vowels /a/ and /i/.

For the comparison of different EGG parameters across different pitch level and loudness level Friedman's test and Wilcoxon signed rank test were performed. The result shows that there is a significant difference present for many EGG parameters across different pitch level *($p<0.05$)* for both the vowels /a/ and /i/. CQ and OQ values at high pitch didn't show significant difference on comparison to model pitch. Also, jitter values didn't vary significantly for model and low pitch phonation. Table 4.5 shows the Wilcoxon signed rank test results for different pitch level for singers.

On the flipside, the EGG parameters also varied significantly for each loudness level *($p<0.05$)* except CQ and CQ-SD. The jitter values did not differ significantly at loud and normal loudness level. Table 4.6 shows the Wilcoxon signed rank test results for the comparison of different loudness level for Carnatic singers.

Table 4.5: z value of Carnatic singers across different pitch level for the vowels /a/ and /i/.

PARAMETER	High Vs Model (z/p)		Model Vs Low (z/p)		High Vs Low (z/p)	
	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)
F0	3.92/0.00*	3.92/0.00*	3.92/0.00*	3.92/0.00*	3.92/0.00*	3.92/0.00*
F0 SD	2.46/0.14	3.88/0.00*	1.27/0.20	1.24/0.21	3.88/0.00*	3.92/0.00*
Periodicity	3.09/0.00*	3.47/0.00*	2.20/0.02*	3.58/0.00*	3.21/0.00*	3.84/0.00*
Jitter	2.27/0.02*	3.88/0.00*	0.44/0.65	0.97/0.33	1.96/0.04	2.99/0.00*
CQ	1.86/0.06	0.67/0.50	2.50/0.01*	2.42/0.01*	2.72/0.00*	2.05/0.04*
OQ	2.21/0.02*	0.56/0.57	2.09/0.03*	2.42/0.01*	2.72/0.00*	2.01/0.04*
CQ SD	2.52/0.01*	2.76/0.00*	2.01/0.04*	0.11/0.91	3.21/0.00*	2.97/0.00*
OQ SD	2.52/0.01*	2.76/0.00*	2.01/0.04*	0.11/0.91	3.21/0.00*	2.97/0.00*

**p< 0.05*

Table 4.6: z value of Carnatic singers across different loudness level for the vowels /a/ and /i/

PARAMETER	Loud Vs Normal (z/p)		Normal Vs Quiet (z/p)		Quiet Vs Loud (z/p)	
	/a/	/i/	/a/	/i/	/a/	/i/
F0	1.68/0.09	2.16/0.03*	2.20/0.02*	1.86/0.06	3.09/0.00*	2.68/0.00*
F0 SD	0.48/0.62	0.70/0.47	3.37/0.00*	3.41/0.00*	2.01/0.04*	2.59/0.00*
Periodicity	2.53/0.01*	2.87/0.00*	3.62/0.00*	3.84/0.00*	3.80/0.00*	3.69/0.00*
Jitter	1.02/0.30	1.35/0.17	3.10/0.00*	3.66/0.00*	3.64/0.00*	3.41/0.00*
CQ	0.24/0.80	0.41/0.68	1.56/0.11	1.79/0.07	1.79/0.09	1.60/0.10
OQ	0.70/0.47	2.16/0.03*	1.82/0.06	1.60/0.10	2.31/0.02*	2.53/0.01*
CQ SD	0.09/0.92	0.18/0.85	2.16/0.03*	2.59/0.00*	1.68/0.09	1.90/0.05*
OQ SD	0.09/0.92	0.18/0.85	2.16/0.03*	2.59/0.00*	1.68/0.09	1.90/0.05*

**p< 0.05*

Comparison of non-singers across different pitch level and loudness level for the vowels /a/ and /i/

For the comparison of different EGG parameters across different pitch level and loudness level Friedman's test and Wilcoxon signed rank test were performed. The results are tabulated in Table 4.7 and 4.8.

The results tabulated in Table 4.7 shows difference in the EGG parameters including F0, F0 SD, Jitter, CQ SD and OQ SD across different pitch level (*p<0.05)* especially for high Vs model pitch level.

Similarly, many EGG parameters across different loudness level for non - singers were not different significantly (*p<0.05)* except for F0 and periodicity. Jitter and CQ values were significantly different on high Vs low loudness comparison.

Table 4.7: z value for non- singers across different pitch level for the vowels /a/ and /i/

PARAMETER	High Vs Model (z/p)		Model Vs Low (z/p)		High Vs Low (z/p)	
	/a/	/i/	/a/	/i/	/a	/i/
F0	3.82/0.00*	3.82/0.00*	3.82/0.00*	3.82/0.00*	3.82/0.00*	3.82/0.00*
F0 SD	3.01/0.00*	3.66/0.00*	0.20/0.84	0.28/0.77	2.33/0.02*	2.33/0.02*
Periodicity	1.69/0.09	3.54/0.00*	2.85/0.00*	2.69/0.00*	2.97/0.00*	3.66/0.00*
Jitter	3.05/0.00*	2.75/0.00*	1.81/0.07	1.41/0.15	0.98/0.32	1.75/0.08
CQ	1.12/0.26	0.54/0.58	0.12/0.90	0.80/0.42	1.08/0.27	1.04/0.29
OQ	1.32/0.18	0.54/0.587	0.40/0.68	0.80/0.42	1.08/0.27	1.04/0.29
CQ SD	2.25/0.02*	2.33/0.02*	0.76/0.44	0.88/0.37	1.85/0.64	2.27/0.02*
OQ SD	2.25/0.02*	2.33/0.02*	0.76/0.44	0.88/0.37	1.85/0.64	2.27/0.02*

**p<0.05*

Table 4.8: z value for non- singers across different loudness level for the vowels /a/ and /i/

PARAMETER	Loud Vs Normal (z/p)		Normal Vs Quiet (z/p)		Quiet Vs Loud (z/p)	
	/a/	/i/	/a/	/i/	/a/	/i/
F0	2.77/0.00*	3.54/0.00*	0.88/0.37	1.40/0.15	3.58/0.00*	3.62/0.00*
F0 SD	1.40/0.15	0.44/0.65	0.06/0.95	2.17/0.03*	1.38/0.16	1.77/0.07
Periodicity	3.13/0.00*	3.70/0.00*	3.26/0.00*	2.73/0.00*	3.54/0.00*	3.78/0.00*
Jitter	2.33/0.01*	2.42/0.01*	2.02/0.04	2.57/0.01*	3.58/0.00*	3.22/0.00*
CQ	0.68/0.49	2.31/0.02*	0.40/0.68	1.08/0.27	1.93/0.05*	2.73/0.00*
OQ	0.64/0.52	2.31/0.02	0.40/0.68	1.08/0.27	1.93/0.05*	2.57/0.01*
CQ SD	0.74/0.45	0.14/0.88	1.81/0.07	1.04/0.29	2.19/0.02*	0.88/0.37
OQ SD	0.74/0.45	0.14/0.88	1.81/0.07	1.04/0.29	2.19/0.02*	0.88/0.37

**p<0.05*

Comparison of Carnatic singers and non- singers across different pitch level and loudness level for the vowels /a/ and /i/

The comparison of EGG parameters for singers and non-singers across different pitch level are tabulated in Table 4.9 and the values are graphically represented in graph 9. The values for different EGG parameters did not show significant difference across different pitch level for both the groups (p< 0.05) except F0 (at low pitch and high pitch) and Periodicity.

Table 4.10 shows the EGG parameters across different loudness level when compared for both the groups. The parameters did not show significant difference across different loudness level when compared for both the groups (p<0.05) except F0-SD (at loud and normal phonation) and Periodicity (at normal loudness).

Table 4.9: z value of EGG parameters for Carnatic singers Vs non- singers across different pitch level

PARAMETER	HIGH		MODEL		LOW	
	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)
F0	1.57/0.11	2.07/0.03*	0.84/0.39	0.18/0.85	2.36/0.01*	2.75/0.00*
F0 SD	0.77/0.44	0.12/0.89	1.25/0.21	1.63/0.10	1.56/0.11	2.41/0.01*
Periodicity	1.32/0.18	2.19/0.02*	1.68/0.09	2.13/0.03*	1.02/0.30	0.73/0.46
Jitter	0.01/0.98	0.59/0.55	0.42/0.67	0.81/0.41	1.50/0.13	0.84/0.39
CQ	1.85/0.06	0.70/0.48	0.30/0.75	0.02/0.97	1.79/0.07	0.39/0.69
CQ SD	0.95/0.33	0.98/0.32	0.47/0.63	0.40/0.68	1.18/0.23	0.19/0.84
OQ	1.96/0.04*	0.70/0.48	0.28/0.79	0.02/0.97	1.60/0.10	0.39/0.69
OQ SD	0.95/0.33	0.95/0.33	0.47/0.63	0.40/0.68	1.18/0.23	0.19/0.84

**P<0.05*

Graph 10: Comparison of Carnatic singers Vs non-singers across different pitch level for the vowels /a/ and /i/.

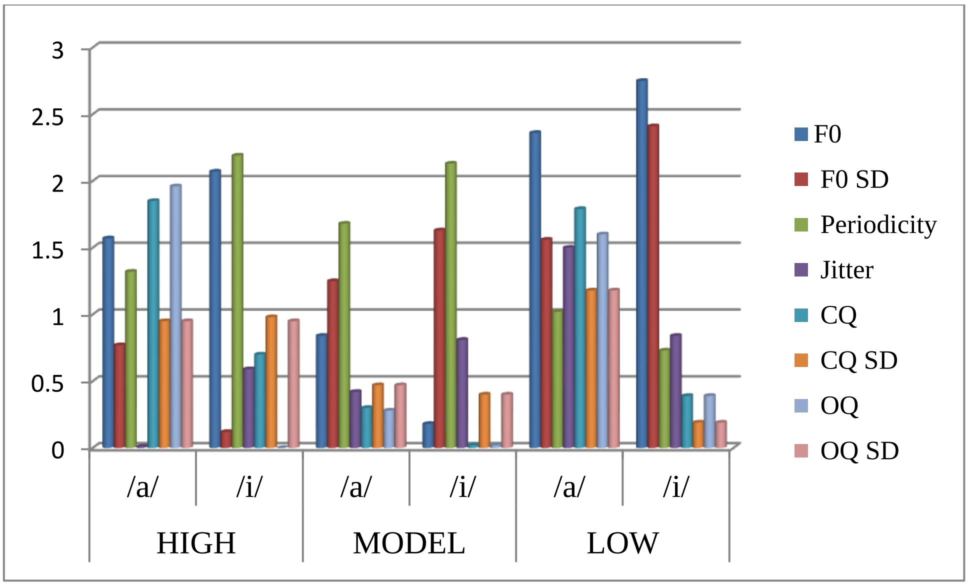
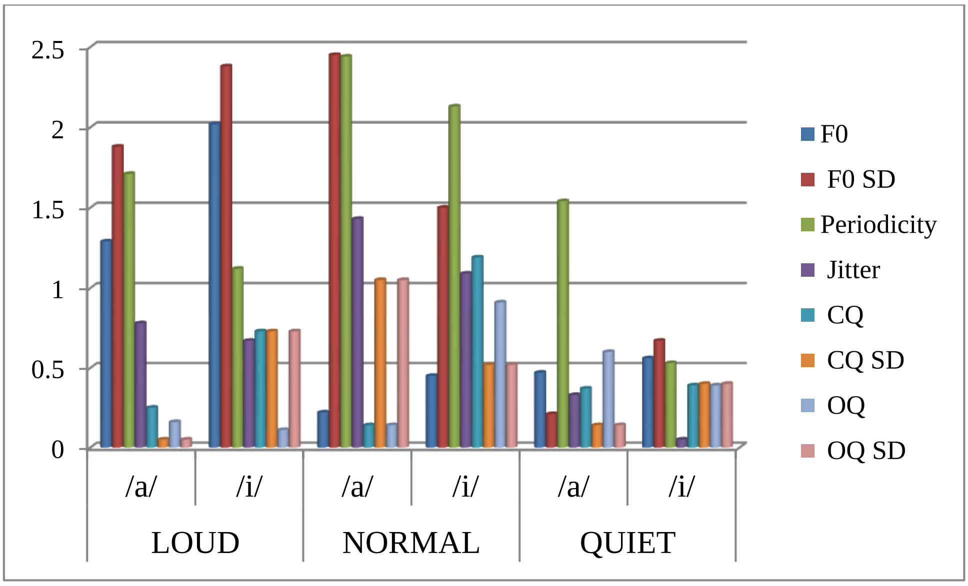


Table 4.10: comparison of Carnatic singers Vs non- singers across different loudness level for the vowels /a/ and /i/

PARAMETER	LOUD		NORMAL		QUIET	
	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)	/a/ (z/p)	/i/ (z/p)
F0	1.29/ 0.19	2.02/ 0.04	0.22/ 0.82	0.45/ 0.65	0.47/ 0.63	0.56/ 0.57
F0 SD	1.88/ 0.06	2.38/ 0.01*	2.45/ 0.01*	1.50/0.13	0.21/ 0.83	0.67/ 0.50
Periodicity	1.71/ 0.08	1.12/ 0.26	2.44/ 0.01*	2.13/ 0.03*	1.54/ 0.12	0.53/ 0.59
Jitter	0.78/ 0.43	0.67/ 0.49	1.43/ 0.15	1.09/ 0.27	0.33/ 0.73	0.05/ 0.95
CQ	0.25/ 0.80	0.73/ 0.46	0.14/ 0.88	1.19/ 0.23	0.37/ 0.70	0.39/ 0.69
CQ SD	0.05/ 0.95	0.73/ 0.46	1.05/ 0.29	0.52/ 0.60	0.14/ 0.88	0.40/ 0.68
OQ	0.16/ 0.86	0.11/ 0.91	0.14/ 0.88	0.91/ 0.36	0.60/ 0.54	0.39/ 0.69
OQ SD	0.05/ 0.95	0.73/ 0.46	1.05/ 0.29	0.52/ 0.60	0.14/ 0.88	0.40/ 0.68

**P<0.05*

Graph11: Comparison of Carnatic singers Vs non-singers across different loudness level for the vowels /a/ and /i/.



Summary of the results:

1) *Descriptive Statistics*

- *Pitch*

✓ In Carnatic singers and non- singers the mean values for EGG parameters for F0-SD, Periodicity, CQ-SD and OQ-SD were higher for high pitch compared to model and low pitch.

✓ Non-singers had low F0 in high pitch compared to singers.

✓ In non- singers the overall standard deviation values were higher compared to Carnatic singers.

✓ The periodicity values were higher for singers compared to non- singers across different pitch level and the jitter and CQ values were lower for Carnatic singers compared to non- singers at each pitch level.

- *Loudness*

✓ In Carnatic singers, the mean values for EGG parameters showed noticeable difference in F0-SD, CQ-SD and OQ-SD and Periodicity.

✓ In Carnatic singers, at quiet phonation level the F0-SD, CQ-SD and Jitter values were higher compared to loud and normal loudness level. Also, Periodicity was higher at loud phonation.

✓ In non-singers the mean values for EGG parameters did not show much difference except for periodicity and CQ- SD.

✓ In non- singers, high F0 values noted across different loudness level than that of singers.

✓ In singers, the mean F0-SD and Jitter were lower compared to non- singers across different loudness level.

✓ In Carnatic singers the mean periodicity values were higher than non- singers at different loudness level. For both the groups, the mean CQ-SD and OQ-SD values were lower across the loudness level.

2) Within group comparison:

- *Carnatic singers*

✓ In Carnatic singers there is a significant difference present for many EGG parameters across different pitch level and loudness level ($p<0.05$) for both the vowels /a/ and /i/.

✓ F0 and Periodicity were significantly different across different pitch.

✓ CQ and OQ values at high pitch did not show significant difference when compared to model pitch. Also, jitter values did not vary significantly for model and low pitch phonation for Carnatic singers.

- ✓ The EGG parameters varied significantly for each loudness level except CQ and CQ-SD.
- ✓ The jitter values did not differ significantly at loud and normal loudness level.

- *Non- singers*

- ✓ EGG parameters including F0, F0 SD, Jitter, CQ SD and OQ SD varied significantly across different pitch level ($p<0.05$) especially at high Vs model pitch.
- ✓ EGG parameters such as F0 and Periodicity were significantly different ($p<0.05$) across different loudness level.
- ✓ Jitter and CQ values were significantly different at high Vs low loudness.

3) Between group comparison:

- *Pitch*
  - ✓ The values for different EGG parameters did not show significant difference across different pitch level for both the groups ($p< 0.05$) except F0 (at low pitch and high pitch) and Periodicity.
  - *Loudness*
- ✓ The parameters did not show significant difference across different loudness level when compared for both the groups ($p< 0.05$) except F0-SD (at loud and normal phonation) and Periodicity (at normal phonation).

CHAPTER 5

DISCUSSION

The current study aimed to find the vocal stability of young female Carnatic singers and non- singers using EGG by eliciting sustained phonations of the vowels /a/ and /i/ at different pitch level and intensity level. The current study investigated vocal stability in 39 female native Kannada speakers (19 Carnatic singers and 20 non-singers) within the age range of 20-40 years.

Comparison of Carnatic singers and non- singers across different pitch level and loudness level across vowels

Singers has reached highest and lowest F0 at high pitch and low pitch than non- singers. This is due to the wide singing range of singing achieved by the singers from training. This is in concurrence with the previous study done by Mendes et al (2013) which revealed that singers had large maximum phonational frequency range (MPFR) than non- singers as an impact of training. Jayaram (1975) and Ragini (1986) also found that trained female singers had a fundamental frequency ranging from 160Hz to 520 Hz and the same for non- singers ranged from 190Hz to 320 Hz.

Also, Carnatic singers had higher periodicity values across different pitch level and loudness level. This indicates that singers can maintain the vocal fold vibration without variability across different pitch and loudness than non- singers.

Non- singers had high F0-SD values at loud phonation compared to singers. This indicates that singers are able to maintain the stability of voice even at loud phonation.

Comparison of Carnatic singers across different pitch level and loudness level across vowels

F0 and Periodicity were significantly different across different pitch level, which indicates that singers are able to produce different pitch without any overlap of frequencies. CQ values are not significantly different for high and model pitch. This suggests that singers can phonate, high pitch with the vocal fold contact similar to model pitch phonation. This finding contradicting the findings of Joy (2009) study where she inquired the vocal registers in 40 female Carnatic singers and non- singers. The study concluded that in singers the EGG parameters such as CQ, OQ and SQ were higher in head and falsetto register than in chest register. These differences are contributed by the training received by the singers.

Comparison of non-singers across different pitch level and loudness level across vowels

Significantly different F0, F0 SD, Jitter, CQ SD and OQ SD across different pitch level suggests that though non- singers can produce different pitch same as singers, but, the stability of phonation is poor. This is in concordance with the findings of Pebbili and Soonan (2014). They found that the frequency perturbation measures were significantly higher for non- singers compared to singers.

The difference in F0 across different loudness indicates that in order to change the loudness, non- singers are trying to change the F0 as well.

Poor stability at extreme loudness levels (high and low) was indicated by significantly different jitter values at quiet and loud phonation. Huang, Minifie and Lin (1995) reported that as the vocal effort level increases, the perturbation values also increases and they concluded that vocal effort must be controlled to get a stable phonation sample. This suggests that non- singers might be making more effort at quiet and loud phonation level which can lead to poor vocal stability

Mean and standard deviation of EGG parameters across different pitch level and loudness level across vowels

The mean value for F0, F0-SD, CQ-SD, OQ-SD and Periodicity were higher for high pitch compared to model and low pitch for both the groups. This may be because, individuals are strongly adducting their vocal folds at higher pitch and stretches the vocal folds to its maximum to maintain the pitch. These findings are in accord with the earlier studies by Pebbili and Soonan (2014). The same way at loud phonation in order to maintain the sub glottal pressure, individuals might be hyper adducting the vocal folds which leads to high SD values.

Also, non-singers had low value for F0 in high pitch compared to singers. Periodicity values are higher for singers compared to non- singers across different loudness level and pitch level. This is because of the effect of training in Singing and the findings supports the studies of Ragini (1986) and Jayaram (1975).

Though the mean value for EGG parameters across different pitch and loudness level were different for both Carnatic singers and non- singers those values were not statistically significant.

Since the EGG is capturing the voice characteristics only at the source level and not considering the effect of tract, the outcomes of this study suggests that the training in singing has does not have an impact on the glottal source. This assumption is supported by the study of White (2009), where he investigated the effect of vocal intensity variation on voice in 10 year old children singing in soft, loud and mid voice using LTAS. The results indicated that the frequency dependent gain increased at higher frequencies than in lower frequencies with increase in loudness. Mendoza, Nieves and Naranjo (1996) used Long-term Average Spectrum (LTAS), to measure the parameters of the voice that remain stable during a two week period of time using consecutive reading task with a reading rate of five times, in 17 young adults with a twofold procedure: (i) analysis of the absolute energy values at different frequency points throughout the length of the spectrum, and (ii) analysis of the relative values obtained by subtraction of each of two consecutive frequency values. The analysis of the absolute energy values at different frequencies showed the differences that exist between various sessions are cantered mainly in the frequencies below 0.6 kHz and the area of 4 kHz, which indicates the signal of the voice is modified over the course of investigation. The relative values indicated the signal remained stable that period of time.

CHAPTER 6

SUMMARY AND CONCLUSION

Phonatory stability refers to the steadiness and periodicity of vocal fold vibration, which is dependent on the laryngeal system maintaining relatively constant levels of muscular force during a sustained phonation (Ferrand, 2006). The stability of the voice reflects the quality of the voice and different objective measures are available to measure the vocal stability.

Many authors have used instrumental methods such as binaural auditory masking (Jayakumar, 2006) and acoustic analysis (Pebbili, 2014) to measure the vocal stability in different population including singers. Stephen and Bier (2017) measured the vocal stability of younger and older adults and opined that EGG is the effective measure to estimate vocal stability. The vocal stability measures work well in the context of sustained where the features of interest are held relatively constant for the duration of phonation. Therefore, the present study was taken up to find out the vocal stability of female Carnatic singers and non- singers.

The study considered native female Kannada speakers within the age range of 20-40 years. A total of 40 individuals participated in the study of whom 20 individuals received a minimum of five years training in Carnatic singing and one singer was eliminated from the study due to extreme values found during analysis. Sustained phonations of the vowels /a/ and /i/ were collected using EGG and corresponding EGG parameters obtained. The obtained EGG parameters were further subjected to appropriate statistical analysis using SPSS 20.

The results revealed that, the mean value for EGG parameters across different pitch and loudness level are different for both Carnatic and non- singers. Though the mean values were significantly different, there is no statistically significant difference found in the EGG parameters across different pitch and loudness level across vowels between Carnatic singers and non- singers. This is contradicting the findings of Pebbili and Soonan (2014), where the acoustic analysis of the voice sample revealed that non-singers had high pertuberation measures at highest and lowest pitch level than singers.

Since the EGG is capturing the voice characteristics only at the source level and not considering the effect of tract, the outcomes of this study suggests that the training in singing has an impact on the resonators than on glottal source. This finding is supported by Mendoza, Nieves and Naranjo (1996) and White (2009) using Long- term Average Spectrum (LTAS).

Implications of the study

- Results of the study will be helpful to understand the singer's voice in terms of voice stability
- EGG can be used as a method to study the vocal stability.

Limitations of the study

- The current study limited number of participants (20 singers & non-singers).
- This study has included only females and Carnatic singers.
- Singers who got minimum five years of training are included for the study. Not all singers were professional singers.
- The loudness was monitored only qualitatively.

Future directions

- The present study made use of only phonation sample. In future studies, reading paragraphs and words can be included to dynamically measure the vocal stability.
- SLM can be used to monitor the loudness level of phonation.
- The present study included only female subjects. In future a comparison of vocal stability can be done between male and female singers. Also, a comparison can be done between Carnatic singers and Hindustani singers.
- To maintain the homogeneity of the groups, only professional singers with more experience in singing can be considered in future.

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