“EFFECT OF HUMMING ON VOCAL FOLD CONTACT DURING PHONATION USING EGG PARAMETERS IN YOUNG PHONONORMIC ADULTS”

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CERTIFICATE

This is to certify that this dissertation entitled "**Effects of Humming on Vocal Fold Contact during Phonation using EGG Parameters in Young Phononormic Adults**" is a bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student with Registration Number 20SLP004. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled "**Effects of Humming on Vocal Fold Contact during Phonation using EGG Parameters in Young Phononormic Adults**" has been prepared 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.

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DECLARATION

This is to certify that this dissertation entitled "**Effects of Humming on Vocal Fold Contact during Phonation using EGG Parameters in Young Phononormic Adults**" is the result of my own study under the guidance of Dr. K. Yeshoda, Associate Professor in Speech Science, 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.

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CHAPTER 1

INTRODUCTION

The larynx and its capabilities are significant in two main areas: biological function and speech. The voice is a crucial component of that distinctively human quality known as speech. The main sound generator used during speech is located in the larynx. The vocal produces each of the distinct speech sounds (Colton & Casper, 2006). There are multiple procedures for studying vocal fold movement through non-invasive study. Electroglottography (EGG) is the most commonly used method of indirect visual examination of vocal fold contact. The method was first described by Fabre (1957) as high frequency glottography.

Electroglottography, a non-invasive technology, is widely used to measure the variation in the contact area between the two vocal folds as a function of time (Fabre, 1957). The EGG works on the premise of passing a low-amplitude high-frequency current between two disc electrodes placed on either side of the thyroid cartilage laminae at the level of the vocal folds. The electrodes measure the change in resistance as the vocal folds close and open (vibrate). Because tissue (i.e. when the vocal folds are in contact) conducts electric current better than air, i.e. when the air gap between the folds (glottis) or when the vocal folds are apart. When the vocal folds open or open phase occurs, there will be an increase in resistance, and when the vocal folds close or close phase occurs, there will be a decrease in resistance (Stemple, Glaze & Klaben, 2009).

The edges of the vocal folds are not moving together and separating as monolithic masses, which adds to the complexity. The lower and upper segments of the glottal margin exhibit considerable independence, and their closing and opening motions are not synchronized, despite being regular, correlated, and quasi-periodic. As a result, the glottal closure at the top and bottom of the vocal fold does not occur at the same moment, nor does the opening through the depth of the vocal fold. Rather, phase disparities in the inferior–superior (Titze et al., 1993; Baer 1981). Equally significant is that the opening and closing do not always occur at the same time in the horizontal plane. Instead, the vocal folds may act like a zipper, closing and opening from one end to the other. These phase variances cause the vocal folds to touch and de-contact at different times along their respective axes. As a result, there is no specific moment when the glottis closes and opens, but rather an interval during which the shutting and opening take place (Herbst et al., 2014; Childers et al., 1986).

The ideal EGG waveform depicts the effects of laryngeal impedance fluctuations as well as vocal fold contacting behaviors in terms of glottal closure and opening duration and rate. The landmarks on the waveform are related to the vocal folds' relative movement and position during phonation. The 'contact quotient,' or CQ, was established by Rothenberg as a measure of relative vocal fold adduction (Rothenberg, 1988). It is utilized to compare the contact phase's duration to the vibratory cycle's period. The fraction of the cycle during which the vocal folds are in contact is calculated using the formula,

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

Titze (1989 & 1990) studied the physiological significance of the EGG signal theoretically, with the latter focusing on 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 choice of algorithms used to calculate contact and de contact instants has an impact on the CQEGG (Contact Quotient EGG) computation, so it should be utilized with caution (Herbst & Ternström, 2006; Kania et al., 2004). To calculate the CQEGG, one of two methods is used: (1) applying a threshold criterion to the locally standardized EGG signal (Rothenberg & Mahshie, 1988) or (2) estimating positive and negative maximums in the first mathematical derivative of the EGG signal (dEGG), which reflects the EGG signal's maximum rate of change over time.

Humming is considered to be a voice facilitating technique administered to increase resonant voice. Previously authors (Cooper, 1973; Colton & Casper, 1996) have given importance of resonance on nose, checks, or lips during humming to properly incorporate a hum (Ogawa et al., 2014).

A well-known vocal exercise for developing a resonant voice is humming. According to Yiu and Ho (2002), Speaking while humming, Yiu and Ho (2002) suggested that speakers make the sound /m:/ before sliding the pitch to the most comfortable and natural level to seem sincere in their opinion. In fact, voice therapy sessions involving humming have been shown to enhance the perceptual vocal quality in patients with vocal nodules or laryngitis as well as those who have been diagnosed with muscular tension dysphonia (MTD) with supraglottic compression. Additionally, they have been shown to reduce the computed perturbation parameters of acoustic and electroglottographic signals in MTD patients (Shalini, 2019).

In recent studies it is shown that in both groups of dysphonic patients and nondysphonic speakers, humming produced a noticeable improvement in the EGG perturbation parameters. The EGG perturbation parameters in more than half of the Organic Dysphonia patients were at the same level as during normal phonation (Vlot et al., 2017).

In individuals with MTD (muscle tension dysphonia), Ogawa et al. (2014) investigated the impact of humming on computed electroglotto-graphic parameters. The results demonstrated that the CQ values in both groups were higher when humming and um-hum phonation were combined than when normal phonation was used.

Need of the study

Humming has been used in voice treatment to help patients with laryngitis, vocal nodules, and muscular tension dysphonia (MTD) with supraglottic compression enhance their perception of their vocal quality. In MTD patients, humming is also employed to reduce the perturbation parameters estimated for the acoustic and electroglottographic (EGG) signals. Researchers have used objective approaches to evaluate the laryngeal alterations that take place during persistent humming phonation in order to clarify the mechanisms underlying the vocal improvement caused by humming (Vlot et al., 2014). The present study is planned to examine the effect of humming on vocal fold contact during phonation (humming, normal, and loud) using EGG parameters in young phononormic adults.

Aim of the study

To investigate the effect of humming on vocal fold contact during phonation using EGG parameters in young phononormic adults.

Objectives

1. To compare the EGG parameters in normal phonation, loud phonation and humming in young phononormic adults aged 18-25 years.

2. To check for the presence of glottal chink, if any, in the participants across 3 tasks.

3. To check for gender specific similarities/differences if any, in the participants across the 3 tasks.

CHAPTER 2

REVIEW OF LITERATURE

The inappropriate use of vocal folds can nevertheless lead to voice production even in the absence of pathologic defects in the vocal folds. Different terms (including functional dysphonia, muscle tension dysphonia (MTD), and muscle misuse vocal disorders) have been used to describe these problems (Koufman & Blalock, 1991; Morrison & Rammage, 1993 and Belafsky et al., 2002,) and voice training is typically an effective treatment. An improvement in perceptual vocal quality, a reduction in supraglottic compression, a reduction in perturbation parameters of both acoustic and electroglottographic signals, and a decrease in the standard deviation of the contact quotient have all been observed in MTD patients who receive voice therapy primarily using humming, according to earlier research (Ogawa et al., 2005; Hosokawa et al., 2012). It is not yet known, however, if these post-therapy alterations are genuinely brought about by the humming itself because the therapeutic and nontherapeutic groups were not compared (Ogawa el al., 2014).

A study by Ogawa et al. (2014) looked into how nondysphonic speakers and MTD patients' estimated electroglottographic (EGG) signal characteristics were changed by humming and the subsequent um-hum phonation. The criteria for exclusion were as such: (1) the prevalence of chronic diseases of the upper aerodigestive tract, (2) the involvement of neurological disease,; and (3) training in music or theatre. The study involved 21 participants (16 males and 5 females; median age: 67 years; range: 35–84 years). Twenty healthy volunteers (15 males and five females; median age: 42 years; range: 24–72 years) were chosen as controls since they had neither functional nor organic laryngeal abnormalities. The study used acoustic characteristics (F0), EGG parameters (perturbation and standard deviation of

CQ), and GRBAS. Both the acoustic and the EGG signals were captured concurrently throughout the phonatory tasks. The patients had to complete the following phonatory exercises: (1) Normal phonation requires more than three seconds of continuous /e:/ phonation at a familiar pitch and volume. (2) Humming phonation, which required closing of lips and producing hum sound /m:/ for 3 seconds in a calm manner while feeling vibration in the nose or lips. (3) Um-hum phonation was a requirement, which involved humming while raising your pitch. According to the findings, humming and um-hum alone reduced significantly EGG perturbation parameters and CQSD in the MTD group (standard deviation of the contact quotient), as well as in vocal roughness and acoustic values. Significant reduction was seen in electroglottography perturbation measures in control group in humming and um-hum phonation, whereas the changes were minimal. The results demonstrated that combining humming and um-hum phonation raised CQ (contact quotients) values in both groups when compared to natural phonation. The increase in CQ brought on by humming may be the results of longer contact length rather than higher contact pressure because of alter in the vocal fold’s physical properties brought on by the relaxed laryngeal muscles.

Vlot et al. (2017) in their study examined to see if humming helped individuals with organic dysphonia improve the regularity of their vocal fold vibrations on electroglottography (EGG) and laryngeal high-speed digital imaging (HSDI). Individuals with cysts, reinke's edema, polyps, or nodules in their vocal folds met the fundamental requirements for inclusion. 49 organic dysphonia patients with vocal fold mass lesions (16 males and 33 females; median age: 54 years; range: 20-82 years) and an equivalent number of nondysphonic participants (controls) were used for the evaluation of the acoustic and electroglottography signals. The control group consisted of 29 males and 20 females; the median age was 37 years; the range was 24-

71 years. The subject was advised to peacefully hum "/m:/" for more than three seconds while experiencing harmonic resonance in the lips and cheeks or nose, but without changing the pitch, after the natural and normal phonation exercise. During the phonatory tasks, acoustic and EGG signals were simultaneously recorded. The Praat software tool was used to determine the 5-point period perturbation quotient (PPQ) and 11-point amplitude perturbation quotient (APQ) for the acoustic and EGG signals of the two jobs. On average, 11 individuals with organic dysphonia and the same number of non-dysphonic subjects had their laryngeal high-speed digital imaging (HSDI) and electroglottography signals recorded during both tests. A single laryngologist recorded phonatory activities in real time.

Both EGG perturbation measures decreased dramatically in the dysphonia and control group studies. While the control group showed no change in any acoustic perturbation measures, the dysphonia group showed enhancement in AcPPQ (acoustic period perturbation quotients). The electroglottography period perturbation quotients (EGG-PPQ) and amplitude perturbation quotients (EGG-APQ) values had shown considerable variation in nodule and polypoid subgroup, but similar results were not obtained for polyp subgroup. Regardless of that the sample population was sizable, this is still the case. These findings indicate that humming had different effects depending on the type of vocal fold lesions found, and that the vocal disturbances' dependence on difficulties and the biomechanical consequences of the lesions varied based on the types of lesions.

De Hoop et al. (2021) sought to determine whether humming could aid in progressively raising voice intensity while only slightly increasing glottal contact and supraglottic compression. The electroglottographic (EGG) signals, high-speed laryngeal movies, and sound pressure levels (SPL) were all recorded at the same time as seventeen healthy nondysphonic speakers performed two phonatory tasks in succession: gradually increasing vocal loudness (crescendo) during sustained phonation of a vowel or production of a hum (the vowel- or humming-crescendo task, respectively). The duration of prephonatory transient glottal closure on the laryngeal movies, the glottal contact parameter of the EGG signals, the glottal opening and laryngeal outlet parameters, and more were all calculated. This study sought to determine whether humming could help in gradually raising vocal intensity with only a slight increase in glottal contact and supraglottic compression. The findings showed that humming reduces the augmentation in both glottal contact and supraglottic compression during a progressive increase in vocal strength, preventing an abrupt increase in vocal intensity in favour of acceptable vocal production.

Ning (2019) examined if prolonged vowel phonation is influenced by age and pitch level using electroglottography (EGG). Thirty female speakers, without vocal problems or prior singing experience, (10 young, 10 middle-aged, and 10 older), participated in the study. During prolonged vowel phonation with a high, middle, or lower pitch, the fundamental frequency, contact quotient, contacting-time quotient, decontacting-time quotient, speed quotient with a midslope criteria (SQ-mid), jitter, shimmer, and the harmonics-to-noise ratio were all measured. The fundamental frequency, contact quotient, contacting-time quotient, decontacting-time quotient, and SQ-mid were all discovered to be significantly influenced by age.

The mean fundamental frequency fell as people became older, while the contact quotient increased. Compared to the younger speakers, the vibratory patterns of the middle-aged and older speakers were more asymmetrical. In terms of pitch level, high pitches were superior than low and mid pitches in terms of SQ-mid and decontacting-time quotient. Due to the lack of discernible interaction between age and pitch level, the consequences may be cumulative. Finally, discriminant analyses showed that a crucial factor in estimating the age of a voice is the contact quotient.

Using electroglottography, Ma and Love (2010) examined the effects of age and gender on specific vocal fold vibratory features during vowel extension and related speech (EGG). There were 46 participants, 23 males and 23 females, all of normal voice. During prolonged vowel prolongation and related speech activities, EGG characteristics such as fundamental frequency and contact quotient were examined.

In both the sustained vowel prolongation and passage tasks, there was a significant age-by-gender interaction for mean contact quotient. This was characterised by older men having a lower contact quotient (i.e., less degree of vocal fold contact) than young males, and older females having a higher contact quotient (i.e., enhanced vocal fold contact). Females had a considerably higher mean fundamental frequency than males. In the female group, there was likewise a significant decline in mean fundamental frequency as they became older.

While taking into account the sociolinguistic context of India, Paul et al. (2011) sought to ascertain the precise nature of vocal fold vibrations in males and females during phonation of various vowels in various vocal registers as well as how these would be reflected in standard EGG parameters like Contact Quotient (CQ) and Contact Index (CI).

Both males and females had significantly higher CQ values in vocal fry than modal phonation, indicating a somewhat hyperconstricted vocal system during vocal fry. Males had considerably higher CQ values than females for both modal and vocal fry phonations, suggesting that males are more likely to tighten their vocal folds. In the vocal fry state, females showed no significant increase in CI values, and in some cases, a drop in CI values, implying a physiological adjustment of the vocal folds that is essentially different from that of males. There were no vowel impacts in any of the circumstances. The contact quotient perturbation (CQP) and contact index perturbation (CIP) values are significantly higher in the vocal fry register than in the modal register, and the increase was bigger in females than in males. The results support certain earlier beliefs about how vowels, gender, and phonatory register affect vocal fold vibratory patterns.

The aim of the study by Awan and Awan (2013), was to re-evaluate the potential impact of gender on measurements of electroglottographic contact quotient (CQ). In addition to criteria threshold approaches, which are routinely employed for electroglottography (EGG) CQ computation, derivative-based methods that have not yet been tested for their ability to distinguish between male and female EGG waveforms were also looked at. Men and women with normal voice (total N = 50) produced prolonged vowels while their EGG waveforms were being recorded. Eight criterion thresholds were used to calculate the EGG CQ (electroglottography contact quotient) measurements (25–60% in 5% increments). The findings of this study demonstrated that gender differences were related to considerably different CQs (as evaluated by the DEGG- EGG derivative) and various wave shapes, particularly distinct profiles to the opening phase. The assumption that the closing and opening points occur at the same percentage of the P-to-P (peak-to-peak) EGG amplitude limits threshold methods, even though the 25% criterion method comes close to the expected adult male versus female CQ difference and coincides with the knee-shaped EGG opening phases typical of men.

The study by Sreedevi et al., (2019) aimed, to establish a qualitative association between EGG patterns for various types of glottis chinks as shown on stroboscopy. These subjects had nearly intact mucosal waves during the stroboscopic test, with a small chink located close to the anterior commissure of the vocal folds. This might have led to the appearance of the typical waveform morphology. Prolonged opening time (46.7%) and a normal EGG pattern are the main EGG findings in anterior glottic chink (33.3 percent). The EGG waveform's prolonged opening time and prolonged open time (6.7 percent) could once more be attributed to the anterior glottic chink, which causes inadequate glottal closure in the adductory phase and consequently results in prolonged open phase lengths. 5% of the normal EGG waveform was observed in cases of anterior glottic chink provided additional evidence in favour of this conclusion. The results of this study is of help for SLPs who cannot afford to have a stroboscopy in their working environment. It has been discovered that EGG recordings and waveform analyses can rather accurately predict the frequently observed glottic chink patterns. Glottal gap patterns can be determined through careful EGG waveform morphology analysis, and management of the condition is made easier. The benefits of employing EGG in vocal testing are highlighted in the current study.

Chen et al. (2002) examined the hypothesis that there are substantial differences in glottal cycle symmetry between men and women during modal phonation but not during vocal fry phonation in the current study. It was also predicted that there would be a vowel effect during vocal fry phonation, in line with earlier research on modal phonation. In four settings with the vowel sounds /a, œ, u, and /i/, five women and five men sustained modal and vocal fry phonations. Electroglottographic (EGG) waveforms were used to derive the vocal F0, duration of the opening and closure phases, and contact symmetry (speed quotient). In their vocal fry range, both male and female speakers had noticeably higher SQ (speed quotients) values than in their modal register, indicating a longer opening-phase length per glottal cycle. During vocal fry phonations, women showed a considerably higher increase in SQ than did males, indicating a stronger imbalance between opening and closing durations. The results showed that vocal fold contact behaviour varies between the sexes during both vocal fry register and modal register. Vowel effects on vocal fold contact behaviour were not observed for either the modal or vocal fry registers, as indicated from the SQ measure and it was assumed that repeated opening and closing phases happening throughout a vibratory cycle could lead to such observations.

Electroglottography is a beneficial technique to understand vocal folds contact. Its application as a clinically valuable tool is proved by studies in literature. Phonation is an uncommon task for an individual and majority of communication is through words, phrases and sentences. Phonation task highlights the symmetry of vocal fold vibrations and loud phonation involves complete closure of the vocal folds. Humming is a technique of initiate smooth and soft and complete contact vocal folds during their productions. Hence, here an attempt was made to understand the vocal fold contact in 3 different modes of sustained voice production, namely, Hum, normal phonation and loud phonation using the electroglottography and compare the parameters across these three modes of sustained voice production.

CHAPTER 3

METHOD

3.1 Participants

The study followed a standard group comparison research design, with a total of 30 healthy participants divided into two groups. Group 1 consisted of 15 male young phononormic adults in the age range of 18-25 years (Mean age= 21.73, SD=1.83). Group 2 consisted of 15 female young phononormic adults in the age range of 18-25 years (Mean age = 23.47, SD = 0.743). All the participants were chosen from the population of students at All India Institute of Speech & Hearing (AIISH), based on the convenient sampling method.

The study followed inclusion and exclusion criteria on selection of the participants as shown below,

3.1.1 Inclusion criteria

- Phono-normonic participants age range between 18-25 years
- No history of any vocal complaints.
- No history of smoking and alcohol consumption.
- No history of dysphonia or other laryngeal pathology.
- No history of previous vocal training.
- Participants who have under gone double dose COVID-19 vaccination

3.1.2. Exclusion Criteria

- History any vocal misuse or over use or loading before the study.
- History of any physical or health related issues

Participants were also screened for their voice quality before starting the testing procedure using Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V). Only, the participants whose voice quality fell under normal category were considered for the further study tasks. The objective of the study was explained to each of the participant and consent was obtained from them individually for agreeing to participate in the present study.

3.2 Stimulus (Task)

- Phonation of vowel /a/ for duration of 5 seconds at comfortable pitch and loudness.
- Loud phonation of vowel /a/ for duration of 5 seconds.
- Humming of nasal consonants /m:/ for a duration of 5 seconds at comfortable pitch and loudness.

3.2.1 Instructions for the participants

i. Normal phonation: "This task involves taking deep breath and phonating /a/ at comfortable pitch and loudness for 5 seconds".

ii. Loud phonation: "this task involves taking deep breath and phonating /a/ at a louder voice than your comfortable loudness level for 5 seconds".

iii. Humming phonation: "This task involved taking deep breath and phonating "hum" with lips sealed for 5 seconds".

3.3 Instrumentation and parameters extracted

Computerised Speech Lab 4500 (Kay-Elemetrics, USA) software was used to measure the Electroglottographic (EGG) and extract the parameters, Contact Quotient (CQ), Open Quotient and Speed Quotient (SQ), waveform morphology pattern, Mean Fundamental frequency (AvF0), Minimum Fundamental frequency (MinF0), Maximum Fundamental frequency (MaxF0), Standard Deviation of Fundamental frequency (SDF0).

3.4 Procedure

The participants were asked to sit comfortably on the chair maintaining appropriate 90 degree upright posture with stable neck placement. Participants were instructed about the procedure of placement EGG electrodes on to the surface of larynx (thyroid lamina) and asked to indicate if any discomfort was felt during the examination. Then the participants were asked to perform the tasks, which are considered as stimulus in the present study. A small instruction with a demo was also provided by the researcher for the participants and was asked to follow the same.

During data collection the COVID-19 preventive protocol was followed. All the voice samples were recorded individually and in a quiet laboratory and the recorded signals were saved in the respective software in .wav format. The saved data of each participant were recalled for extraction of the parameters and tabulated. Further statistical analysis was carried out.

3.5 Statistical analysis

The extracted EGG data were subjected to statistical analysed using Statistical Package for Social Science (SPSS) software version 21. Shapiro-Wilks test of normality was done to check whether the data followed normal distribution. The results of this test revealed that EGG parameters data did not follow normal distribution. Hence, non parametric test (Mann Whitney U test) was carried out as further analysis on SPSS.

Descriptive analysis was done to find the mean and standard deviation of the measured parameters Open Quotient (OQ), Speed Quotient (SQ), Contact Quotient (CQ), Mean F0 (AvF0), Minimum F0 (MinF0), maximum F0 (MaxF0), Standard

Deviation of F0 (SDF0) in the study. Mann Whitney U test was carried out to find similarity/difference between genders across all EGG parameters. Friedman test was performed to compare all the phonation tasks (normal phonation, loud phonation, and humming phonation) across groups. Further, Wilcoxon Signed Rank test was done to compare the tasks which had got significant differences within the group.

CHAPTER 4

RESULTS

The current study attempted to investigate the effect of vocal fold contact during hum, normal and loud phonation in young phononormic adults. 30 participants were included in two different groups of 15 males and 15 females. The EGG parameters were examined; open quotient (OQ), speed quotient (SQ), contact quotient (CQ), Mean F0 (AvF0), Minimum F0 (MinF0), maximum F0 (MaxF0), Standard Deviation of F0 (SDF0) across each phonation tasks and groups and subject for statistical analysis.

The statistical tests that were performed to interpret the data comprises of;

1. Shapiro-Wilks test of normality
2. Mann Whitney U test
3. Friedman test
4. Wilcoxon Signed rank test

4.1. Objective 1 – To compare the EGG parameters in normal and loud phonation versus humming in young phononormic adults.

The mean, median and standard deviation of EGG parameters across all the 3 tasks (humming, normal & loud phonation) for phononormic males (Group 1) and results of the Friedman test are tabulated in Table 1.

Table 1

Mean, SD & median of the EGG measures and χ^2 for males across three phonation tasks.

Para-meters	*Humming*			*Normal Phonation*			*Loud Phonation*			χ^2
	Mean	*SD*	*Median*	*Mean*	*SD*	*Median*	*Mean*	*SD*	*Median*	
CQ	47.36	4.26	48.49	46.63	3.86	46.92	49.33	3.78	49.90	10.53*
OQ	52.63	4.26	51.51	53.36	3.86	53.08	50.66	3.78	50.10	10.53*
SQ	434.69	170.08	443.54	466.83	180.37	447.23	510.60	180.04	478.81	5.73
AvF0	139.37	22.09	129.56	134.58	19.32	135.61	144.53	19.03	144.10	16.13*
MinF0	115.20	33.21	117.91	98.20	26.68	87.85	111.90	32.66	125.64	3.73
MaxF0	194	84.94	174.31	196.59	54.64	179.27	195.73	75.28	159.78	0.53
SDF0	3.50	4	3.50	4.31	2.96	3.52	4.50	5.12	2.65	1.93

*(Abbreviations: CQ-Contact Quotient; OQ-Open Quotient; SQ- Speed Quotients; AvF0- Mean F0; MinF0- Minimum F0; MaxF0- Maximum F0; SDF0- Standard Deviation F0 *significance $p < 0.05$ level)*

Among the phononormic males (Group 1) the median value of CQ has highest contact value at loud phonation (M=49.90) than in humming (M=48.49) and normal phonation (M=46.92). The median of OQ is highest at normal phonation (M=53.08) than in humming (M=51.51) and loud phonation (50.10). The median of SQ is highest at loud phonation (M=478.81) than in normal (M=447.23) and humming (M=443.54) tasks.

Following to the frequency parameters of EGG, median of AvF0 is highest at loud phonation (M=144.10Hz) than in normal (M=135.61Hz) and humming (M=129.56Hz). Similarly, the median of MinF0 is highest at loud phonation (M=125.64Hz) than in humming (M=117.91Hz) and normal (M=87.85Hz) phonation. Whereas, the median of MaxF0 is highest at normal phonation (M=179.27Hz) than in humming (M=174.31Hz) and loud (M=159.78Hz) phonation. Similarly, the median of SDF0 is highest at normal phonation (M=2.96) than in humming (M=3.50) and loud (M=2.65) phonation.

A non-parametric Friedman test was carried out to see is there any significant difference between the three phonation tasks in phononormic males across all the EGG parameters. Result revealed that, there was a significant difference seen between humming, normal & loud phonation only in 3 EGG parameters CQ [$\chi^2(2)=10.53, p<0.05$], OQ [$\chi^2(2)=10.53$, $p<0.05$)] and AvF0 [$\chi^2(2)=16.13$, $p<0.05$)]. So in order to understand the significance the post-hoc analysis with Wilcoxon singed-rank tests was carried out within the group of phononormic males (Group 1).

Table 2

|z| values for the three phonation tasks in males

Parameters	**Humming & Normal phonation**	**Humming & Loud phonation**	**Loud & Normal phonation**
	|z|	|z|	|z|
CQ	1.07	2.95*	2.84*
OQ	1.07	2.95*	2.84*
SQ	1.30	2.04*	1.30
AvF0	2.10*	2.55*	2.89*
MinF0	1.64	0.90	1.96
MaxF0	0.62	0.73	0.34
SDF0	1.02	0.91	0.73

*(Abbreviations: CQ-Contact Quotient; OQ-Open Quotient; SQ- Speed Quotients; AvF0- Mean F0; MinF0- Minimum F0; MaxF0- Maximum F0; SDF0- Standard Deviation F0 *significance p< 0.05 level)*

Wilcoxon signed-rank test was performed to compare male participants across the three phonation type (Table 2). No statistical significant difference was observed for EGG parameters when humming and normal phonation were compared expect AvF0, which showed increase in frequency ($|z|=2.10$, $p<0.05$). Despite there is a discrepancies in median values of EGG frequency related parameters, no significant difference in case of MinF0, MaxF0, SDF0 expect the AvF0 showed significant increase in frequency ($|z|=2.55$, $p<0.05$) but significant increase in EGG vocal movement parameters of SQ, OQ & CQ ($|z|=2.04$, $p<0.05$; $|z|=2.95$, $p<0.05$; & $|z|=2.95$, $p<0.05$) was observed when comparison made between humming and loud phonation respectively. Also significant increase seen in AvF0, OQ & CQ when comparison was made between loud and normal phonation ($|z|=2.89$, $p<0.05$; $Z=2.84$, $p<0.05$; & $|z|=2.84$, $p<0.05$) respectively, even though there are reduction in SQ &

MinF0 and increase in MaxF0 & SDF0 in median values, but absences of significant difference in other EGG parameters.

The mean, median and standard deviation of EGG parameters across all the 3 tasks (humming, normal & loud phonation) for phononormic females (Group 2) and results of the Friedman test are tabulated in Table 3.

Table 3

Mean, Median, and SD of the EGG measures and χ^2 for the three phonation tasks in females

Parameters	**Humming**			**Normal Phonation**			**Loud Phonation**			χ^2
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	
CQ	43.11	4.17	44.08	43.97	4.02	44.63	45.61	2.86	45.13	9.79*
OQ	56.89	4.17	55.92	56.02	4.02	55.37	54.39	2.86	54.87	9.79*
SQ	250.70	43.06	256.58	266.30	42.90	268.12	281.23	77.83	285.89	4.13
AvF0	225.25	21.12	221.29	220.30	26.53	216.49	237.49	23.03	227.79	17.73*
MinF0	122.17	63.66	86.64	90.22	32.36	78.05	90.24	37.87	76.43	0.93
MaxF0	270.77	41.90	259.41	300.15	60.54	306.25	270.81	52.58	253.45	2.67
SDF0	6.79	3.69	6.13	9.64	3.99	9.73	8.56	2.89	9.04	6.40*

*(Abbreviations: CQ-Contact Quotient; OQ-Open Quotient; SQ- Speed Quotients; AvF0- Mean F0; MinF0- Minimum F0; MaxF0- Maximum F0; SDF0- Standard Deviation F0 *significance $p< 0.05$ level).*

Among the phononormic females the median value of CQ was highest at loud phonation (M=45.13) than in humming (M=44.08) and normal phonation (M=44.63). The median of OQ is highest at humming (M=55.92) than in normal phonation (M=55.37) and loud phonation (54.87). The median of SQ is highest at loud phonation (M=285.89) than in normal (M=268.12) and humming (M=256.58) tasks.

The median AvF0 is highest at loud phonation (M=227.79Hz) than in normal (M=216.49Hz) and humming (M=221.29Hz). Similarly, the median of MinF0 is highest at humming (M=86.64Hz) than in loud phonation (M=76.43Hz) and normal (M=78.05Hz) phonation. Whereas, the median of MaxF0 is highest at normal phonation (M=306.25Hz) than in humming (M=259.41Hz) and loud (M=253.45Hz) phonation. Similarly, the median of SDF0 is highest at normal phonation (M=9.73) than in humming (M=3.50) and loud (M=2.65) phonation.

A non-parametric Friedman test was carried out to see is there any significant difference between the three phonation tasks in phononormic females across all the EGG parameters. Significant difference was seen between humming, normal & loud phonation only in 4 EGG parameters CQ [$\chi^2(2)=9.79, p<0.05$], OQ [$\chi^2(2)=9.79, p<0.05$), AvF0 ($\chi^2(2)=17.73, p<0.05$) and SDF0 ($\chi^2(2)=6.40, p<0.05$). So in order to understand the significance the post-hoc analysis with Wilcoxon singed-rank tests was carried out within the group of phononormic females.

Table 4

|z| *values for the three phonation tasks in females*

Parameters	**Humming & Normal phonation**	**Humming & Loud phonation**	**Loud & Normal phonation**
	/z/	/z/	/z/
CQ	1.47	2.79*	1.84
OQ	1.47	2.79*	1.84
SQ	1.64	1.64	1.02
AvF0	1.42	3.23*	3.40*
MinF0	1.76	1.07	0.39
MaxF0	1.70	0.22	1.47
SDF0	2.49*	0.96	1.07

*(Abbreviations: CQ-Contact Quotient; OQ-Open Quotient; SQ- Speed Quotients; AvF0- Mean F0; MinF0- Minimum F0; MaxF0- Maximum F0; SDF0- Standard Deviation F0 *significance p< 0.05 level).*

Wilcoxon signed-rank test was performed to compare the phonation type across participants (Table 4) who had showed significant difference in the Friedman test. No statistical significant difference was observed across all EGG parameters when compared between humming and normal phonation expect SDF0 showed increase in frequency ($|z|=2.49$, $p<0.05$). Despite there is a discrepancies in median values of EGG frequency related parameters, no significant difference in case of MinF0 and MaxF0, AvF0 showed significant difference in humming versus loud phonation ($|z|=3.23$, $p<0.05$) and the SDF0 showed no significant increase in frequency in humming versus loud phonation and loud versus normal phonation, but significant increase in EGG vocal movement parameters of CQ & OQ ($|z|=2.79$, $p<0.05$; & $|z|=2.79$, $p<0.05$) was observed when comparison made between humming and loud phonation respectively. Also significant increase seen in AvF0 when comparison was made between loud and normal phonation ($|z|=3.40$, $p<0.05$), and between humming and loud phonation ($|z|=3.23$, $p<0.05$)

4.2. Objective 2 - To check for the presence of glottal chink, if any, in the participants across three tasks.

Descriptive analysis of the median scores of the OQ & SQ were compared between the two groups (males vs females), to examine the amount glottal opening during each three tasks (Table 5).

Table 5

Median values for EGG measures for males and females across the three phonation tasks.

Parameters	Male (Median)			Female (Median)		
	Humming	Normal phonation	Loud phonation	Humming	Normal phonation	Loud Phonation
OQ	51.51	53.08	50.10	55.92	55.37	54.87
SQ	443.54	447.23	478.81	256.58	268.12	285.89

(Abbreviations: OQ- Open Quotient; SD- Speed Quotients).

Results showed that the median scores of OQ are higher for females than in males across three tasks of humming, normal & loud phonation, but the median SQ scores are lower for females compared to males across three phonation tasks. In females the OQ is highest at humming (M=55.92) compared to normal & loud phonation, whereas the SQ is lower in humming task (M=256.58) compared to other tasks.

This increase in OQ & reduction in SQ measures in humming task of female participants indicates that the glottal opening is reduced at humming tasks than in any other tasks (Table 5).

Also the results of Mann Whitney test between the two groups across the EGG parameters of all the tasks (Table 6), showed that the OQ measures are higher in females (Group 2) than in males (Group 1) and significant different observed in humming ($|z|=2.75$, $p<0.05$) & loud phonation ($|z|=3.11$, $p<0.05$) expect in normal phonation ($|z|=1.80$, $p<0.05$). Similarly the SQ measures were higher in males (Group 1) than in females (Group 2) and significant difference were observed in all the tasks; humming ($|z|=2.96$, $p<0.05$), normal phonation ($|z|=3.13$, $p<0.05$) & loud phonation ($|z|=3.87$, $p<0.05$)

4.3. Objective 3 - To check for gender specific similarities/differences if any, in the participants across the three task.

A non-parametric Mann Whitney U test was done to check any significance difference between two groups of genders (Males vs Females) in all the tasks.

Table 6

Median and |z| *values for both the genders across all the three phonation tasks*

	Humming			Normal Phonation			Loud Phonation		
Parameters	**Males**	**Females**	**/z/**	**Males**	**Females**	**/z/**	**Males**	**Females**	**/z/**
CQ	48.49	44.08	2.75*	46.92	44.63	1.80	49.33	45.13	3.11*
OQ	51.51	55.92	2.75*	53.08	55.37	1.80	50.66	54.87	3.11*
SQ	443.54	256.58	2.96*	447.23	268.12	3.13*	510.60	285.89	3.87*
AvF0	129.56	221.29	4.66*	135.61	216.49	4.66*	144.53	227.79	4.66*
MinF0	117.91	86.64	0.43	87.85	78.05	1.20	111.90	76.43	1.68
MaxF0	174.31	259.41	3.25*	179.27	306.25	3.58*	195.73	253.45	3.05*
SDF0	3.50	6.13	2.84*	3.52	9.73	3.38*	4.50	9.04	3.21*

*(Abbreviations: CQ-Contact Quotient; OQ-Open Quotient; SQ- Speed Quotients; AvF0- Mean F0; MinF0- Minimum F0; MaxF0- Maximum F0; SDF0- Standard Deviation F0 *significance $p < 0.05$ level).*

4.3.1 Comparison of EGG parameters between the groups in humming task

In the humming task, results showed that the median scores of OQ, AvF0, MaxF0 & SDF0 have increased in increase in females (Group 2) compared to males (Group 1) and also a statistical significant difference was observed across these parameters; OQ ($|z|=2.75$, $p<0.05$); AvF0 ($|z|=4.66$, $p<0.05$); MaxF0 ($|z|=3.25$, $p<0.05$) and SDF0 ($|z|=2.84$, $p<0.05$). Similarly the CQ, SQ & MinF0 median scores are higher in males (Group 1) than females (Group 2) and a statistical significance was observed in CQ ($|z|=2.75$, $p<0.05$) & SQ ($|z|=2.96$, $p<0.05$), but not in MinF0 ($|z|=0.43$, $p>0.05$) parameters (Table 6).

4.3.2 Comparison of EGG parameters between the groups in normal phonation task.

In the normal phonation task, results showed that the median scores of OQ, AvF0, MaxF0 & SDF0 have increased in increase in females (Group 2) compared to males (Group 1) and statistical significant difference was observed only in AvF0 ($|z|=4.66$, $p<0.05$); MaxF0 ($|z|=3.58$, $p<0.05$) and SDF0 ($|z|=3.38$, $p<0.05$) parameters, but not in OQ ($|z|=1.80$, $p>0.05$). Similarly the CQ, SQ & MinF0 median scores are higher in males (Group 1) than females (Group 2) and a statistical significance was observed only in SQ ($|z|=3.13$, $p<0.05$), but not in CQ ($|z|=1.80$, $p>0.05$) & MinF0 ($|z|=1.20$, $p>0.05$) parameters (Table 6).

4.3.3 Comparison of EGG parameters between the groups in loud phonation task

In the loud phonation task, results showed that the median scores of OQ, AvF0, MaxF0 & SDF0 have increased in increase in females (Group 2) compared to males (Group 1) and also a statistical significant difference was observed across these parameters; OQ ($|z|=3.11$, $p<0.05$); AvF0 ($|z|=4.66$, $p<0.05$); MaxF0 ($|z|=3.05$, $p<0.05$) and SDF0 ($|z|=3.21$, $p<0.05$). Similarly the CQ, SQ & MinF0 median scores are higher in males (Group 1) than females (Group 2) and a statistical significance was observed in CQ ($|z|=3.11$, $p<0.05$) & SQ ($|z|=3.87$, $p<0.05$), but not in MinF0 ($|z|=1.68$, $p>0.05$) parameters (Table 6).

CHAPTER 5

DISCUSSION

The goal of the current study is to look into how humming affects different EGG parameters depending on gender. Open quotient (OQ), speed quotient (SQ), contact quotient (CQ), mean F0, minimum F0, maximum F0, and SD F0 are the factors taken into account to measure this effect. Examining the aforementioned dimensions across gender (male and female) and work are only a few of the study's objectives (normal phonation, loud phonation, and humming).

First objective was to compare the EGG parameters in normal phonation versus humming in young phononormic adults aged 18-25 years.

According to results there was no significant difference between humming and normal phonation task across six of the seven parameters assessed in males. Significance was seen in mean F0 measure only. Similar results supporting the present finding was obtained by De Hoop et al. (2021) wherein, they concluded that the mean values of EGG-CQ (contact quotient of EGG signal) and GAW-OQ (open quotient of glottal area waveforms) did not significantly differ between the VCT (vowel-crescendo task) and HCT (humming-crescendo task). Even in the present study no significance was found between humming and normal phonation. One more supporting study was done by Ogawa et al. (2014) demonstrated, at a comfortable constant volume, the EGG-CQ value did not significantly change between phonations of regular vowels and humming. In females the results showed no significance in six of seven parameters assessed. Significant difference was obtained in SD F0. Standard deviation F0 has shown significance which suggests that number of participants was inadequate.

Second objective was to check for the presence of glottal chink, if any, in the participants across 3 tasks.

According to results obtained, it is shown that median OQ value is greater for females than males across all 3 tasks. Similar results were reported by Sreedevi et al. (2019) stating further that the presence of a glottic chink in the anterior region may be responsible for the prolonged opening time and open time in the EGG waveform, leading to inadequate glottal closure during the adductory phase and prolonged open phase durations also seen in videostoboscopy.

Third objective was to check for gender specific similarities/differences if any, in the participants across the 3 task.

Normal phonation tasks

Results revealed that CQ of normal phonation task for male is greater than female. Similar result was observed in Paul et al. (2011) who stated that males have significant higher CQ values than females both at modal and vocal fry phonation. This also indicates that males had longer closed phase than females. Awan, and Awan (2013) reported of results that showed only CQs measured using the DEGG indicated significant differences in the direction anticipated by prior research (i.e., men > women), despite the fact that mean CQs tended to be higher in males compared to women.

In the current study, results have shown that mean F0 value for female is more compared with males. According to Ma and Love (2010), in comparison to males, girls had a mean fundamental frequency that was substantially greater.

Accordingly males have greater SQ value than females. As per Chen et al. (2002), women speakers demonstrated significantly higher SQ values than men in the modal and vocal fry modes. Because vocal folds closed more quickly at modal register phonation than they opened. Compared to men, women in the current study generated each vowel with a greater opening-phase duration (compared to the closure phase). This finding was consistent with a small number of studies that found female speakers to have glottal chinks, or inadequate posterior closure of the vocal folds, for women as compared to men. The glottal cycle's opening phase is longer due to the partial closure. This finding also supports our second objective, which was to note the presence of glottis chink in female participants and finding proved that female participants demonstrated glottis chink compared to male participants.

Humming phonation task

According to results all EGG parameters have shown significant difference across gender except minimum F0. Humming phonation has shown that there is higher contact quotients for male as compared to female which indicates that females has lesser contact area of vocal folds during humming phonation than males. This indicates that there is presence of glottal chink during phonation of humming because similar difference was observed in contact quotients of normal phonation (Titze et al., 1993). Due to the above mentioned reason open quotient and speed quotients also have significant difference. Mean F0 of males and females have shown significant difference because of difference of mass, length, and tension properties of the vocal folds (Titze, 1989). Significance was observed only for standard deviation of F0 and indicated variation in mean frequency values and that may have been due to small sample.

Loud phonation task

According to results all EGG parameters have shown significant difference across gender accept minimum F0. During production of voice, males had more contact quotients than females because male vocal folds make contact throughout the length of the vocal cords. As compared to females there is presence of posterior glottal chink which reduces the contact quotients because the entire length doesn’t involve in vibration therefore, prolonged open phase is observed. Due to presence of glottal chink in females speed quotients is lesser as compared to males and it shows significance difference. There is significant difference in lung volume in males and females which is used for phonation. Lung volume also plays a vital role as it helps in increasing subglottic pressure which decides the contact of the vocal folds during phonation task or speech tasks. Mean F0 was observed and significant difference was obtained because of difference of mass, length, and tension in the vocal folds of males and females (Titze, 1990; Titze et al., 1993).

CHAPTER 6

SUMMARY AND CONCLUSION

The goal of the current study is to noninvasively learn more about the mechanism of the vocal folds contact. This study used physiological measurements to examine how different sustained production affected vocal fold contact. Additionally, gender differences and the existence of the glottal chink in females were looked into. To study this, seven parameters were chosen of EGG; namely, open quotient (OQ), speed quotient (SQ), contact quotient (CQ), Mean F0, Minimum F0, maximum F0 and SD F0.

A total of 30 phononormic participants took part in the study, and they were given three separate phonation tasks to complete (normal, loud, and humming). EGG direct recording was used for recording of the signal, and electrodes were positioned on either side of the thyroid cartilage. For further interpretation, the data was extracted and statistical analysis carried out. Results indicated that for humming and normal phonation, it was found that males had no significant difference in contact quotients, open quotients, mean F0, speed quotient, minimum F0, and maximum F0 indicating no significance in vocal folds contact and opening phase. Only significance was obtained in Mean F0 between humming and normal phonation of males. In males humming was observed to have more contact quotients than normal phonation.

In females no significant difference was observed in contact quotients, open quotients, mean F0, minimum F0, maximum F0, and speed quotients across humming and normal phonation tasks. Contact quotients were lesser in humming task as compared to normal phonation. This might be due to presence of posterior glottal chink which restrict from making good glottal contact. In females standard deviation

F0 has only shown significant difference which indicates variation in mean vocal habitual frequency and this could also be because of sample size.

It was also seen that females has found to have greater open quotient across all three phonation tasks (normal, loud, and humming) compared to males. This suggests that contact area of the females is less compared to males and indicates presence of glottal chink in females.

Gender comparison has shown significant difference during humming task between males and females. Contact quotient, open quotient, speed quotient, mean F0, maximum F0, and SD F0 have shown significant difference across male and female. CQ is higher for males than females, OQ is greater for females as compared to males because of prolonged open phase. SQ of males is greater than females. Mean F0 is higher for females than males due to anatomical differences between males and females. For normal phonation, results have shown significant difference between speed quotient, mean F, maximum F, and SD F0. Contact quotient and open quotients showed no significance across gender. Speed quotient was higher for males as compared to females.

To conclude, there exist changes in the vocal adduction mechanism across different phonation, which were shown evidently in some of the EGG parameters. There was no significance observed between humming and normal phonation. But significance was observed for loud phonation and humming task. This study highlights on gender similarities or differences across these three tasks (normal, loud, and humming). Humming and loud phonation showed significant differences across gender but in normal phonation significance was noted only in few parameters, speed quotients, mean F0, maximum F0, and SD F0.

6.1 Implications of the study

- The results indicated EGG contact characteristics differed between Hum and loud phonation tasks. These tasks could be used to investigate vocal folds contact in dysphonic individuals as a post therapeutic outcome measure.
- EGG contact characteristics were significantly different in female and male participants confirming the proven fact of physiological differences across these two groups.

6.2 Limitation of the study

- Only phonation of vowel /a/ was used.
- The sample size used in study was less.

6.3 Future directions

- Future studies may include more number of participants and different age groups.
- Further studies could include invasive procedures along with EGG recordings.

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