VOCAL ECONOMY IN FEMALE PRIMARY SCHOOL TEACHERS AND NON TEACHERS

Salome Mariam Philip

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE-570 006

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CERTIFICATE

This is to certify that this dissertation entitled **"*Vocal Economy in Female Primary School Teachers and Non Teachers*"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 13SLP023. 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.

Mysore
May, 2015

Dr. S.R. Savithri
Director
All India Institute Of Speech and Hearing
Manasagangothri, Mysore-570006

CERTIFICATE

This is to certify that this dissertation entitled **"*Vocal Economy in Female Primary School Teachers and Non Teachers*"** has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
May, 2015

Guide
Dr. K. Yeshoda
HOD, Department of Clinical Services
Reader in Speech Sciences
All India Institute Of Speech and Hearing
Manasagangothri, Mysore-570006

DECLARATION

This is to certify that this dissertation entitled **"*Vocal Economy in Female Primary School Teachers and Non Teachers*"** is the result of my own study under the guidance of Dr. K. Yeshoda, HOD, Department of Clinical Services, Reader in Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore, Registration No. 13SLP023

May, 2015

Dedicated to,

DADDY & MUMMY,

STEFFY

And

Beloved Yeshoda ma'am

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CHAPTER I

INTRODUCTION

"Your voice is the mirror of your soul."- Unknown

Human interaction and culture is greatly influenced by their voices. It is the primary means for verbal communication and even can be used to sing. Human voice is also used by different individuals to express emotions which may include pleasure, happiness, sadness, anger or fear. Professional Voice Users refers to those individuals for whom voice is the primary tool of their occupation. These include teachers, politicians, clergy, salesperson, actors and attorneys (Titze, Lemke, and Montequin, 1997; Wingate, Brown, Shrivastav, Darenport and Sapienza, 2007).

Voice is an auditory perceptual event/function which means that the audible sound produced by the larynx, which embodies such parameters as pitch, loudness, quality and variability. According to Johnson, Brown, Curtis, Edney & Keaster (1965), a normal voice must have a pleasant musical quality, appropriate pitch to the age and gender of the speaker and appropriate loudness in the communication event. It must also have adequate flexibility in terms of pitch and loudness variations to express various meanings, feelings and emotions along with adequate sustainability to meet the social and occupational demands even when extended use of voice is required.

A professional voice user is a person who primarily depends on voice for his/her means of income. These individuals are at a greater disadvantage if they have frequent episodes of voice loss during their job which may require an alternative employment (Titze, Lemke and Montequin, 1997). Literature has identified a few risk factors for these individuals which could be within the workplace including background noise, poor air quality, poor posture and vocal loading (Vilkman, 2000;

Lehto, Alku and Vilkman 2005). Studies have also shown that these risk factors are cumulative and can be prevented (Vilkman, 2000; Williams and Carding, 2005).

Some of these professionals voice users are school teachers, singers, actors, barristers, auctioneers, radio and television announcers who are prone to develop voice problems due to work demands. Few others who also belong to this group are lecturers, tutors, ministers of religion, politicians, soldiers, translators, tour guides, telephone and telegraph operators, sales personnel, secretaries, shop managers and conductors (Berufsstimmstorungen, 1974). Research has proved that teachers frequently approach for medical help and therapy for voice disorders. The effect of voice problems on teachers, their students and communication is quite significant (Calas, Verhuist, Lecoq, Dalleas & Seilhan 1989; Cooper, 1970; Gunderman, 1963; Stemple, 1984).

Professional voice users have been advised to follow preventative measures to reduce the risk of voice disorders among the working population (Williams and Carding, 2005). One of the measures advised was to undergo voice training for professional voice users (Duffy and Hazlett, 2004). Singers and actors are a group of professionals who receive training in voice care and preservation unlike teachers who also belong to the group of professional voice users. Many of the teachers are not aware of how to sustain and maintain their voice which is a primary tool for communication and is the greatest professional weapon. One of the major factors contributing to prevalence of voice problems in teachers is poor voice training programs especially in training courses of teaching (Niebudek-Bogusz et al, 2008).

Teachers are superficially “high-functioning” with no prominent signs of voice disorder. Voice problems in teachers may lead to physical injury to the

laryngeal tissue (Simberg, Sala, Laine, & Rönnemaa, 2001; Sliwinska-Kowalska et al., 2006), a limitation in job satisfaction, job performance, job attendance (Mattiske, Oates & Greenwood, 1998; Thibeault, Merrill, Roy, Gray & Smith, 2004; Yiu, 2002), and a limitation in social, psychological, emotional, physical, and communicative functioning (Yiu, 2002). Teachers with voice problems may not find it life threatening but some impact have found results similar to life threatening events (Smith, Gray, Dove, Kirchner, Heras, 1996; Yiu, 2002).

The consequences of voice problems in teachers can hinder them from not conveying information to students clearly and effectively, and forcing them to be absent from work (Roy, Merrill, Thibeault, Gray & Smith, 2004; Yiu & Ma, 2002). Voice problems in teachers can also influence a teacher's daily communication and emotions, consequently generating feelings of inadequacy and frustration within the individual (Yiu & Ma, 2002). Teachers with voice problems are unable to project their voice in an effective manner and are unable to control the classroom situation (Gunderman, 1963). Voice problems in them can act as a barrier to their teaching career and highly competent and experienced teacher may be forced to leave the classroom (Calas, Verhuist, Lecoq, Dalleas & Seilhan 1989).

According to Sapir, Keidar and Van Velzen (1993) voice problems reported was 93% from kindergarten and primary school teachers and only 7% was from high school teachers. They reported that more than 50% of teachers have multiple symptoms of vocal attrition and it had a negative effect on work. Various factors have been responsible for voice problems in teachers. One of the primary causes is vocal abuse and misuse due to the vocal demands of teaching and poor classroom acoustics (Herrington-Hall, 1988; Ohlsson, Jarvholm & Lofqvist 1987; Calas, Verhuist, Lecoq,

Dalleas & Seilhean 1989; Cooper, 1970; Sapir et al, 1993; Safarti, 1989; Unger & Bastian, 1981), lack of vocal education and training (Cooper, 1973). Other aspects include the individual's emotional state such as stress and anxiety (Gotaas & Syarr, 1993; Marks, 1985; Calas et al, 1989; Cooper, 1970; Gotaas, 1986). Factors such as the duration of teaching service (Pekkarinen, Himberg & Pentti, 1992) and the type of teaching taken up (Safarti, 1989; Unger & Bastian, 1981) also play an important role. The presence of medical and previous history of voice problems also contribute to the development of vocal dysfunction (Berufsstimmstoungen, 1974; Sapir et al, 1993; Safarti, 1989).

Vocal fatigue has been reported in Indian teachers as they speak loudly and continuously in poor acoustical environments like noisy classrooms, high student-teacher ratio and longer duration of teaching hours. Primary school teachers teach a variety of subjects and have to fulfill a minimum criterion of 30 teaching hours per week resulting in prolonged usage of voice for 3 hours. Colton & Casper, 1996 and Fawcus, 1991 have reported that vocal fatigue can lead to vocal hyperfunction and benign lesions such as nodules. Sivasankar M. (2002) conducted a study in which primary school teachers who reported vocal fatigue symptoms had higher fundamental frequencies.

According Welham and Maclagan (2003), vocal fatigue is defined as “negative vocal adaptation that occurs as a consequence of prolonged voice use". They described vocal adaptation as "a perceptual, acoustic, or physiologic concept, indicating undesirable or unexpected changes in the functional status of the laryngeal mechanism. Some of the symptoms associated with vocal fatigue include increased vocal effort and discomfort, reduced pitch range and flexibility, reduced vocal

projection or power, reduced control of voice quality, an increase in symptoms across the speaking day and improvement after resting (Colton, Casper & Leonard, 2006; Gotaas & Starr, 1993; Kitch & Oates, 1994; Stemple, Gaze & Klaben, 2000).

According to Titze (1983), many factors are responsible for vocal fatigue. They may be peripherally or centrally mediated. Peripherally mediated factors may include the neuromuscular aspects such as the peripheral nervous system and the muscles which innervate it. They can be fatigued due to prolonged muscle activity at high levels. During vocal fatigue, there could be excessive force activated on the laryngeal structures which may alter the vertical position of the larynx in the neck. This may cause stiffness of the larynx and lead to muscle tension dysphonia (MTD) and its strained voice quality. This is also called as neuromuscular fatigue. The larynx is covered by pliable, non-muscular tissues which undergo frequent and rapid vibrations, biomechanical fatigue is seen.

According to Solomon (2008), vocal fold mucosa is more prone to mechanical stress during phonation because of the deformation of lamina propria and the shear stress exerted at the endpoints of the tissue. Moreover at higher pitches tensile stress comes into action because of the anterior-posterior lengthening of the vocal folds via action of the cricothyroid muscles. Contact stress can also occur due to approximation of the vocal folds at the vocal processes of the arytenoid cartilages. The contact of the vibratory portion of the vocal folds creates inertial and collision stresses.

Researchers have studied that phonation occurs between 17-40% of the time during a teacher's working day with an average approximately 25% (Masuda, Ikeda, Manako, & Kooijama, 1993; Sala et al., 2002; Södersten, Grandqvist, Hammarberg, & Szabo, 2002). This is equivalent to two hours of voicing in a 8 hour working day.

In female teachers who have a mean fundamental frequency of 200Hz, the vocal folds would be vibrating in the order of 1.4 million times during a teaching day (Titze, Hunter and Svec 2007; Vilkman, 2004). This may create situations for biomechanical stress and strain to occur.

Centrally mediated factors would involve reduced central activation to the lower motor neurons pools of the peripheral nervous system. This may be indicated as an increased sense of effort (Enoka & Stuart, 1992). Therefore external performance may not appear to be affected as the system makes adjustments in order to continue at similar level of accuracy.

In the course of recovery, there may be redistribution of fluids and restoration of blood flow to the laryngeal tissues. It may also involve re-establishing baseline biomechanical and physiological properties of the active muscles. Each of these mechanisms vary in terms of the time course they can occur (Titze, Hunter & Svec, 2007).

There are researches focusing on estimating vocal economy in teachers using acoustic measures. Vocal economy is the means by which maximum vocal output can be obtained by providing minimum stress on the vocal folds. One of the measures for vocal economy is "quasi-output cost ratio" (QOCR) or "economy ratio" which is calculated as follows

$$QOCR = [SPL\ (dB)/CQ_{EGG}] \times [T/T_0]$$

where SPL is the sound pressure level, CQ is contact quotient, T= period length, F_0 is considered for obtaining the value of T_0= period length which is normalized in females and is a constant. The mean F_0 considered is 200 Hz for healthy females and therefore T_0=0.005 secs (Laukkanen et al, 2009).

Need of the study

Impact stress has been one of the causes for vocal fold nodules and vocal fold trauma especially in lamina propia layer of the vocal folds which is a common vocal pathology among professional voice users such as teachers (Jiang and Titze, 1994; Horacek, Laukkanen & Sidlof, 2007). The vocal demands on teachers are high with less attention given to voice conservation in primary school teachers. The amount of vocal effort for a primary school teacher is much more demanding compared to school teachers teaching higher grades. The duration of working hours, number of subjects taught by the teacher, number of students the teacher has to pay attention to, the kind of activities such as reading aloud, giving instructions to students and other activities along with the background noise levels also add to the vocal load and demands for a primary school teacher. Therefore they are more susceptible to voice disorders. Thus economy of voice production in primary school teachers is essential and it might also reduce vocal fatigue symptoms by minimizing the vocal load.

Moreover according to Laukkanen, Mäki and Leppanen (2009) teachers have a higher 'quasi-output cost ratio' (QOCR) than vocally untrained subjects. This indicates that higher QOCR values lead to better economic voice production than lower QOCR. Therefore it also implies that regular vocal use for teaching might be useful in enhancing QOCR values and vocal economy. Majority of these research were done on subjects in Western countries and the practices and vocal demand would be different in consonance with the practices in such set-ups. In addition, the results obtained need to be validated in teachers in India and find out whether cultural and societal set up yield similar results to those reported in Western population.

The present study was planned to check QOCR values in female primary school teachers and compare them with that of the non-teachers.

CHAPTER II

REVIEW OF LITERATURE

An individual whose prime means of income depends on vocal usage is more prone for acquiring voice disorders. Teaching is a profession which has high demands on vocal usage and can be detrimental for their voice due to speaking loudly in poor classroom acoustics, poor working posture, greater distance between teacher and student, lack of quality aids, inadequate treatment for early laryngeal infections (Sivasankar, 2002; Rajasudhakar & Savithri, 2010).

According to Rajasudhakar and Savithri (2009a), studied the vocal acoustic characteristics in a primary school teachers and observed that there was an increase in fundamental frequency of phonation, standard deviation of fundamental frequency of phonation and jitter after one day of work load (teaching performance).

The effects of teaching and voice rest on acoustic voice characteristics of female primary school teachers were studied by Rajasudhakar and Savithri (2010). Results revealed that the frequency related measures, jitter and shimmer values increased after school hours compared to pre teaching (baseline condition). These values came to baseline condition after 17 to 18 hours of voice rest. It was observed that Harmonic to Noise Ratio (HNR) which is one of the noise related measures did not show any significant changes across the conditions.

Many studies have shown that teacher's voice problem is related to vocal loading at work. They speak with higher sound pressure level compared to nurses (Pekkarinen, Himberg & Pentti, 1992; Sala, Laine, Simberg, Pentti & Suonopää, 2001; Sala, Airo, Olkinuora, Simberg, Ström, Pentti & Suonopää, 2002). Fundamental

frequency and sound pressure level (SPL) have been found to be higher and there is lowering of the spectral tilt in females after vocal loading. Few studies have shown that there is relation between voice production type and the amount of voice complaints.

Mäiki, Niemi, Lundén & Laukkanen (2001) have reported that subjects who had greater mean fundamental frequency (F_0) and sound pressure level (SPL) values for the loading test had higher symptoms of vocal fatigue after the test. Similarly Rantala &Vilkman (1999) revealed that the female teachers, who used greater F_0 and SPL in their classroom speech, had more voice complaints than their colleagues.

According to Solomon, (2008); Titze, (1994); Verdolini, Hess, Titze, Bierhals & Gross, (1999) revealed that excessive vocal loading is one of the leading causes for vocal fatigue and development of voice disorders. If voice production is economic in nature, it would minimize vocal loading and thus prevent vocal fatigue. Thus the concept of vocal economy was introduced and various researches have been carried out to calculate vocal economy.

According to Berry, Verdolini, Montequin, Hess, Chan & Titze (2001) vocal economy is defined as the "ratio between voice output (dB) and intraglottal impact stress (kilopascals) under constant subglottic pressure and frequency". It is a means of finding out the maximum vocal output with minimum amount of stress on the vocal folds. This can be useful for vocal training and voice therapy.

An early attempt to quantify vocal economy was by Verdolini, Chan, Titze, Hess & Bierhals (1998), had carried out an experiment in which two larynges were excised and mounted on a micrometer for varying the vocal fold length. Vocal fold vibrations were induced using a humidifier (ConchaTherm III heater-humidifier,

Respiratory Care, Inc). An open-ended manometer (Dwyer No. 1211) was used to measure the subglottic pressure. The impact stress was measured in kPa at the anteroposterior midpoint of the membranous vocal folds. Impact stress was measured using a round, Precision Measurement Type 060 piezo resistive transducer (Ann Arbor, Michigan) with a frequency response from DC to 50 kHz and a dynamic range of 050 psi (approximately 0-345kPa).

Electroglottogram (EGG) was measured using (SynchroVoice Inc.) from the mounted larynges. Tektronik 2212 60-MHz Digital Storage Oscilloscope was used to monitor online the EGG and impact stress signals during the experiment. Results revealed that when threshold and saturation effects were excluded, contact quotient and impact stress had a strong correlation. It was found that there was linear relationship between contact quotient and impact stress i.e. an increase of 0.15 in contact quotient (CQ) leads to an increase of 1kPa in terms of impact stress. Thus when the vocal folds collide strongly during vibration they remain in contact with each other for a longer duration thus leading to a rise in contact quotient and impact stress (Verdolini et al, 1998). The current study tried to throw some light on the importance of contact quotient as an indicator to the extent of impact stress on the vocal folds.

In a study by Verdolini, Duker, Palmer & Samawi (1998), contact quotient for phonation task has been reported to be higher especially in hyperfunctional phonation. Here twelve adult singers and actors were participants for the study wherein six of them had healthy larynges and the remaining six had nodules. Professional voice users were taken as subjects to enhance token validity and stability. Participants were asked to produce repeated tokens of resonant, pressed, normal and breathy voice

during sustained vowels. Videoscopic views of the larynx were used to estimate the laryngeal adduction along with blinded, ordinal, visual-perceptual ratings.

Contact quotient (CQ) from Electroglottogram (EGG) was calculated for each trial separately. Electroglottography (EGG) is a non-invasive means to obtain contact quotient of the vocal folds during phonation. Subjects belonging to both groups produced resonant voice with a barely adducted or abducted laryngeal configuration which correlated with perceptual ratings. This was different from configurations for pressed and breathy (but not normal) voice. Therefore contact quotient (CQ) served as a reliable measure for healthy participants and those participants with vocal nodules.

Berry, Verdolini, Montequin, Hess, Chan & Titze (2001) conducted a study where they defined "Output cost ratio (OCR) as the acoustic output in SPL (dB) in relation to impact stress". A major problem with this concept was that it was difficult to measure in humans directly though some attempts had been made. The 'output-cost ratio' (OCR) was expressed as the acoustic output (in SPL, dB) is expressed relative to impact stress (IS):

$$\mathrm{OCR} = 20 \log_{10}\left(\frac{P_A}{P_0}\right) - 20 \log_{10}\left(\frac{\sigma_P}{\sigma_0}\right)$$

where σ_p is the impact stress and σ_0 is some nominal value of stress. With this definition, OCR can be computed as the SPL (sound pressure level) minus ISL (impact stress level).

In this study, five canine larynges were excised and it was mounted on a micrometer. The experimental set up was similar to the one carried by (Verdolini et al, 1998). Parameters such as fundamental frequency were kept constant at 150 Hz and the sub glottal pressure was varied from 1.0 to 1.6kPa. Glottal width and vocal processes was varied from a pressed condition to a 2-mm gap. The output cost ratio

(OCR) was measured as a function of glottal width. A maximum value in the output cost ratio (OCR) was obtained with no vocal tract, across all pressure conditions, at about 0.6mm. It was suggested that through computer simulations, sharper maxima may be seen when the effect of vocal tract comes into picture. The experimental results correlated with the earlier investigations (Verdolini & Titze, 1995). As a result the output cost ratio (OCR) was considered as a value which was potentially of clinical relevance. This experiment was a key to measure impact stress and its application in clinical utility.

According to Laukkanen, Mäki & Leppanen, (2009), sixty-two Finnish female participants without any laryngeal or auditory pathology were taken. Twenty-three were teachers with a (mean age 43.8 years; mean teaching experience 14.2 years, SD 8.8, all having at least some minor voice training), 21 were university students without any special voice training (mean age 28.2 years, SD 4.1), and 18 were students with voice training (mean age 29.6 years, SD 8.8) being either student actors (n=8) or students of voice and speech (n=10).

The subjects were asked to repeat the word ‘papapa’ 5 times loudly. Here estimation of sub glottis pressure from oral pressure during voiceless plosive was carried out and therefore the word ‘papapa’ was taken. Tascam DA-20 digital recorder and a Brüel & Kjær 4165 microphone was used to record the acoustic signal. Microphone was placed at a distance of 40cm from the subject’s lips and Electroglottogram (EGG) was recorded (dual-channel EGG, Glottal Enterprises). Oral air pressure and flow (using pneumotach mask; MSIF-II,Glottal Enterprises).

Participants were also asked to attend a vocal loading test consisting of shouting numbers for 5 minutes at 90dB once the recording was completed. This was measured at a distance of 1m (Brüel & Kjær frequency analyzer 2120) in a well

damped studio. They were also asked to fill a questionnaire regarding vocal fatigue symptoms. A 10-cm visual analogue scale was used to rate the loading test from (0= not strenuous at all, 10cm- very strenuous) and hoarseness (0= no hoarseness, 10= very much hoarseness). Apart from this, participants were also asked if they felt any other symptoms of vocal fatigue such as respiratory, laryngeal or articulatory on a 3 point rating.

Analysis of the acoustic signals was done for the mean F_0 and SPL using the Intelligent Speech Analyzer (ISA) signal analysis system developed by Raimo Toivonen. Results showed that there was an inverse relation between Quasi-Output Cost Ratio (QOCR) and sound pressure level (SPL), fundamental frequency (F_0) and contact quotient (CQ). Moreover students who had undergone vocal training reported somewhat more strenuousness after the vocal loading test and exhibited greater vocal fatigue symptoms.

After the vocal loading test, teachers stated that there was more hoarseness in their voice which revealed a higher sensitivity to changes in voice and voice production. Teachers had greater quasi-output cost ratio (QOCR) values than students which may be indicative of the effect of vocal training and greater experience of voice usage. However the quasi-output cost ratio (QOCR) values did not correlate with the vocal fatigue symptoms. Therefore this study was an attempt to show how vocal training and experience may serve as important factors which may be sensitive to vocal loading tests.

In a study by Kankare and Laukkanen (2012), phonation samples of 119 female kindergarten teachers from two large cities in Finland were recorded. During the study, 23 subjects were excluded due to noisy EGG signal and therefore it was not

possible to compute contact quotient (CQ). The mean age of 96 subjects was 43.2 years (SD 9, range 25-64), and mean years of working experience was 16.6 years (SD 9.7, range 1-36). Subjects were asked to carry out two tasks. Firstly there were asked to produce the sustained vowel /a: / three times at a comfortable loudness for a minimum of 5 seconds. If subjects had difficulty in phonating at their habitual pitch, then more than three trials were recorded. Next task was to obtain controlled SPL values by asking subjects to produce /a: / at sound pressure level $90dB_{6\ cm}$ at their own habitual and comfortable pitch. Sound level meter (Type 2206, Brüel & Kjaer, Copenhagen) was used to monitor the SPL. A weighting network was used and controlled SPL was primarily used as earlier studies have shown that QOCR values decrease with SPL.

In the latter task, a short mouth to microphone distance (6 cm from the corner of the mouth) was used to prevent room acoustics. The mean background noise in the empty recording room was 35dB (32-41dB) and this was measured using sound level meter. The recordings was carried out using dual channel EGG (Glottal Enterprises) with 20Hz low frequency limit, sampling rate of 44.1Khz and the amplitude range was 16 bits. Later these recordings were calibrated with a sound level meter for each subject's phonation. The recorded samples of both the tasks were given for evaluation to eight experienced voice trainers. They were asked to evaluate for voice quality, suitability of pitch and firmness of phonation. Rating was carried out in two separate sessions due to large number of voice samples. Samples were presented through headphones (Sony Stereo Headphones MDR-CD 480) from a portable PC with external sound card (M- Audio, MobilePreUSB). The perceptual evaluation was done using a bipolar visual analogue scale (VAS) with Judge Program. The scale had a rating from 0-1000 for each of the parameters considered for evaluation-voice quality,

suitability of pitch and firmness of phonation. The kindergarten teachers were administered a questionnaire which is available on the internet regarding vocal fatigue symptoms. This questionnaire was similar to the Voice Activity Participation Profile (VAPP) and it consists of 9 questions which are rated in terms of frequency and severity using a 6-point rating scale. The results of the questionnaire were totaled and calculated using the frequency and severity points.

Mean F0 and SPL was measured using the Intelligent Speech Analyser signal analysis developed by Ramio Toivonen. Period length (T) and contact quotient (CQ) $_{EGG}$ was measured using VoceVista Pro voice analysis software with 25% criteria level. Then the QOCR values were calculated using the formula [SPL(dB)/CQ_{EGG}] X [T/T_0] where T_0 was set to 5ms. Results revealed that there was a low and negative correlation between QOCR values and the perceived firmness of voicing at standard SPL and also at too high pitch for subjects at both SPLs. Moreover the QOCR values did not predict the results of the self report questionnaire on vocal fatigue.

Master, Guzman and Dowdall (2013), carried out an experiment in which 30 vocally trained actresses and 30 untrained non actresses were recruited. Participants were of the age range 20-50 years and they were asked to sustain the vowels /a/,/i/ and /u/ for at least 5 seconds at three loudness levels (habitual, moderate and high). Acoustic variables such as sound pressure level (SPL) was measured using sound level meter (MINIPA MSL 1351C; Pares Electronica, Brazil), contact quotient (CQ) from Kay Pentax electroglottograph (Kay PENTAX, Lincoln Park, NJ) model 6103 connected to a Computerized Speech Lab (CSL), model 4500 (KayPENTAX, Lincoln, NJ). Results revealed that actresses had a higher QOCR, though the difference did not reach statistical significance. Moreover the quasi-output cost ratio

(QOCR), fundamental frequency (F_0), sound pressure level (SPL) showed a significant difference at different loudness levels.

Therefore from this study it was concluded that quasi-output cost ratio (QOCR) did not serve as indicator for the level of vocal training when compared in trained and untrained actresses. Vocal economy was found to be more in moderate and high loudness levels and explained to be due to more voice output without an increase in glottal adduction.

In the Indian context, primary school teachers are faced with a lot of challenges at work place which might have a serious effect on their voice. Primary school teachers often involve in vocal abuse, speaking loudly in presence of poor classroom acoustics, continuous use of voice without breaks etc. This leads to vocal fatigue and hyperfunctional voice disorders. Moreover according to Swapna (2012), the prevalence of voice disorders in primary and secondary school teachers was 9%. It was also found that among the male and female teachers, prevalence of voice disorders was higher for female teachers.

Another study by Rajasudhakar and Savithri (2009b) wherein, in five primary school teachers were studied, the results revealed higher values for fundamental frequency of phonation, standard deviation of fundamental of phonation, jitter and speaking fundamental frequency compared to pre-teaching (baseline) condition, after 6 hours of teaching.

The current study is a preliminary attempt to see whether vocal training really has an effect on vocal economy. If vocal economy improves with vocal training then untrained individuals can be recommended for vocal training. If vocal economy proves to be a good means to measure impact stress, norms can be obtained for

professional voice users as well non-professional voice users. Then these values can be used as a means to counsel patients regarding the vocal use and to what extent they can use their voice effectively without causing trauma to the larynx. If QOCR values serves as a good indicator of vocal economy, it can be included as one of the quantitative measures for voice evaluation in professional voice users. It will also help in voice therapy and would serve as a benchmark for clinicians as well as professional voice users to judge improvement in voice quality and vocal output with minimum stress on the vocal cords.

Aims of the study

- To examine whether regular vocal use (in teaching) entails vocal economy in teachers and non-teachers using QOCR.
- To examine whether there exists a correlation among the acoustic variables such as fundamental frequency (F_0), contact quotient (CQ) and SPL (dB) values in both female primary school teachers and non-teachers.

CHAPTER III

METHOD

Primary school teachers are at a higher risk for voice problems because of the professional work load, poor acoustic environment, exposure to dust, chalk powder, etc. and thereby prone to vocal fatigue due to prolonged speaking hours. Hence this study aims to investigate the effect of regular use of voice during teaching on vocal economy.

Subjects

Fifteen primary school teachers and twenty two non teachers in the age range of 25-40 (teachers mean age- 31.53 years, SD-3.94, non teachers mean age- 31.9 years, SD-4.45) participated in the study. The inclusion criteria for primary school teachers taken for the study were as follows:-

1. No history of any communication disorder.
2. Should be working in private schools located in the city of Mysore.
3. Teaching experience of minimum 4 years.
4. Should teach minimum 2 subjects.
5. Duration of vocal use for at least 6 hours/day.

The inclusion criteria for non teachers were as follows:-

1. No history of any vocal pathology or voice disorder.
2. No experience in any vocal training.

PROCEDURE

Informed consent was taken from the subjects for the study and they were initially briefed about the same. Later the instructions were given to the subjects about the task they have to perform.

The data recordings were carried out in a sound treated room of the institute. The background noise was <50dB as monitored by the Radio Shack Sound Level Meter. The data recordings were done at times convenient to the subjects. All the subjects (teachers and non-teachers) of the study were counseled about vocal hygiene tips and given pamphlets about the same after the conclusion of data recordings.

Instrumentation

EGG recordings were measured using Real Time EGG Analysis (Kay PENTAX, Lincoln Park, NJ), model 6103 which was connected to a Computerized Speech Lab (CSL), model 4500. Sound levels were measured using Radio Shack Sound Level Meter which was placed on a tripod stand.

Tasks

1. ***Phonation of the three vowels /a, i, u/ individually for 5 seconds thrice at soft loudness level***
2. ***Phonation of the three vowels /a, i, u/ individually for 5 seconds thrice at moderate loudness level***
3. ***Phonation of the three vowels /a, i, u/ individually for 5 seconds thrice at loud level***

Instructions

The subjects were instructed to produce sustained vowel /a/, /i/, /u/ for at least a minimum of 5 seconds three times at three different loudness levels- soft, habitual and loud. An audio-video recorded demo of the task was also shown to the subjects when they failed to understand instructions. The subject in the audio-video recorded demo was an age matched female subject who was able to project her voice and carry out the task appropriately.

Subjects were instructed to be seated comfortably in an upright position for EEG recording and two surface electrodes were placed on the thyroid cartilage with an elastic neckband. The electrodes were attached to the Velcro strip and wrapped around the subject's neck comfortably. The electrode placement was adjusted in order to obtain clear visual signals of EGG recordings. The quality and morphology of the waveforms obtained during the EGG recordings was constantly monitored. Sound Level Meter was mounted on a tripod stand and placed in front of the subject at a distance of 30 cms. Then the subjects were asked to perform the tasks in a sequence.

SPL recordings along with EGG recordings were carried out simultaneously using Radio Shack Sound Level Meter and Real Time EGG Analysis connected to Computerized Speech Lab, Model 4500 respectively. Based on the EGG and SPL recordings, stable sections of the signal for each subject was considered for the three vowels ***/a, i, u/*** at three different loudness levels (soft, habitual and loud) to obtain the following parameters,

1. SPL (dB) was noted from the digital display in the Radio Shack Sound Level Meter
2. EGG parameters

- F_0 (Hertz)-number of cycles of vocal folds vibration per second and CQ (contact quotient) was noted from the digital display of Real Time EGG Analysis. T-was manually calculated using inverse of F0 obtained from EGG recordings. The mean F_0 was considered for obtaining the value of T_0= period length which will be normalized in female primary school teachers and was considered as a constant. Here the mean F_0 was considered as 235 Hz for female primary school teachers (Koul & Yeshoda, 2004) and therefore T_0= 0.005 secs for the present study.

3. Quasi Output Cost Ratio-The quasi-output cost ratio (QOCR) values according to Laukkanen et al, (2009) was calculated using the equation:

$$QOCR= [SPL\ (dB)/CQ_{EGG}] \times [T/T_O]$$

From the obtained SPL and EGG parameters the QOCR was calculated manually for all subjects.

Statistical Analysis: The obtained data was subjected to statistical analysis using Statistical Package for the Social Sciences SPSS, version 21.0. All the various variables measured in both the groups were subjected to Mann-Whitney U test, Friedman's test, Wilcoxon Signed Rank test and Karl Pearson Coefficient of Correlation for detailed statistical analysis.

CHAPTER IV

RESULTS

The study aimed to quantify and compare vocal economy (Quasi Output Cost Ratio- QOCR values) in female primary school teachers and non teachers. The data was subjected to statistical analysis using SPSS version 19. Non parametric tests were carried out.

Shapiro-Wilk test of normality was carried out for all the data obtained for both the groups (teachers and non-teachers). It was found that most of the parameters did not follow the normal distribution curve ($p < 0.05$) and therefore non-parametric test was done. Mean, median and standard deviation for all the acoustic parameters and QOCR values was obtained across both the groups as shown in Table 1 and Figures 1, 2, 3 and 4.

Table 1: *Mean, Median and Standard Deviation (SD) of Sound Pressure Level (SPL), Contact Quotient (CQ), Fundamental Frequency (F0) and Quasi-Output Cost Ratio (QOCR) across teachers and non-teachers at three different loudness levels-soft, medium and loud*

		Teachers			**Non Teachers**		
		Mean	Median	SD	Mean	Median	SD
SPL	Soft	55.46	55	2.66	57.15	56.16	4.02
	Medium	65.4	66.33	3.35	67.53	68.33	2.67
	Loud	75.91	74.66	2.98	83.03	83.16	4.34
CQ	Soft	45.15	44.91	3.52	46.13	46.23	4.3
	Medium	46.97	47.69	3.67	45.24	45.65	3.17
	Loud	48.71	50.01	3.01	48.2	49.81	5.21
F0	Soft	204.36	202.18	23.46	197.56	197.97	23
	Medium	218.6	214.59	22.94	231.2	232.83	19.84
	Loud	243.41	248.28	27.05	291.76	282.05	39.25
QOCR	Soft	1.13	1.03	0.24	1.27	1.25	0.17
	Medium	1.2	1.14	0.18	1.3	1.33	0.12
	Loud	3.39	5.29	2.82	1.2	1.16	0.18

In table 1, it was observed that non teachers had greater SPL values than teachers for all the three loudness levels as depicted in Figure 1. It was also seen that non teachers had higher contact quotient (CQ) values for soft phonation, teachers had higher CQ values for medium and loud phonation as shown in Figure 2. Fundamental frequency (F0) was higher for teachers in soft phonation and for non teachers in medium and loud phonation as seen in Figure 3. QOCR values were higher for non teachers in soft and medium phonation. During loud phonation, teachers had higher QOCR values than non teachers as shown in Figure 4.

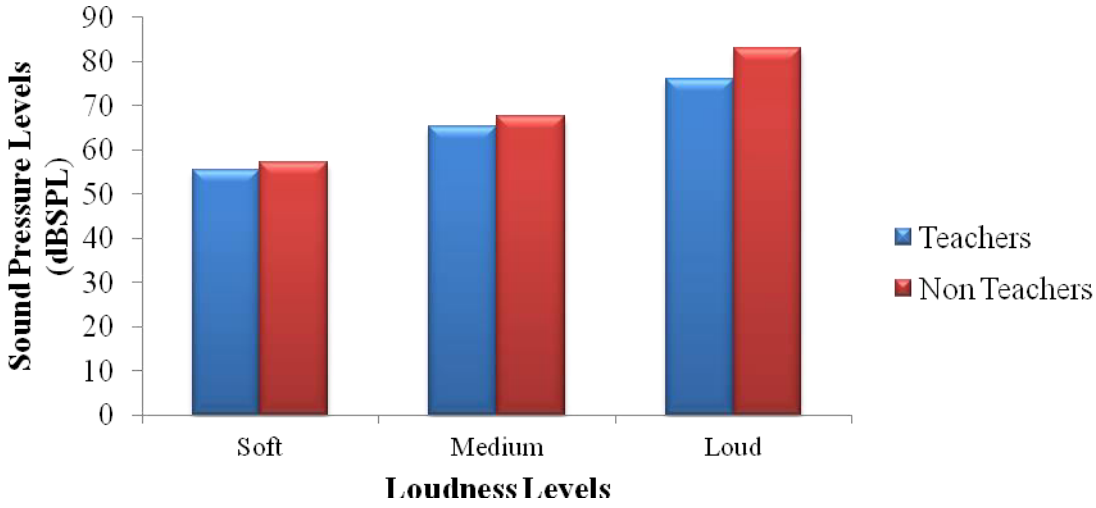

Figure 1: Mean values of Sound Pressure Levels (SPL) for both the groups at three different loudness levels

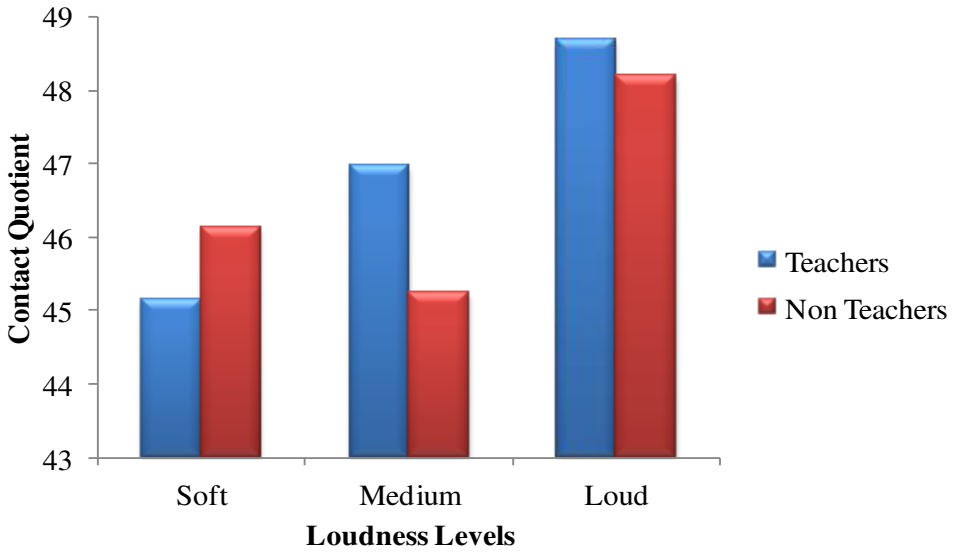

Figure 2: Mean values of contact quotient (CQ) for both the groups at three different loudness levels

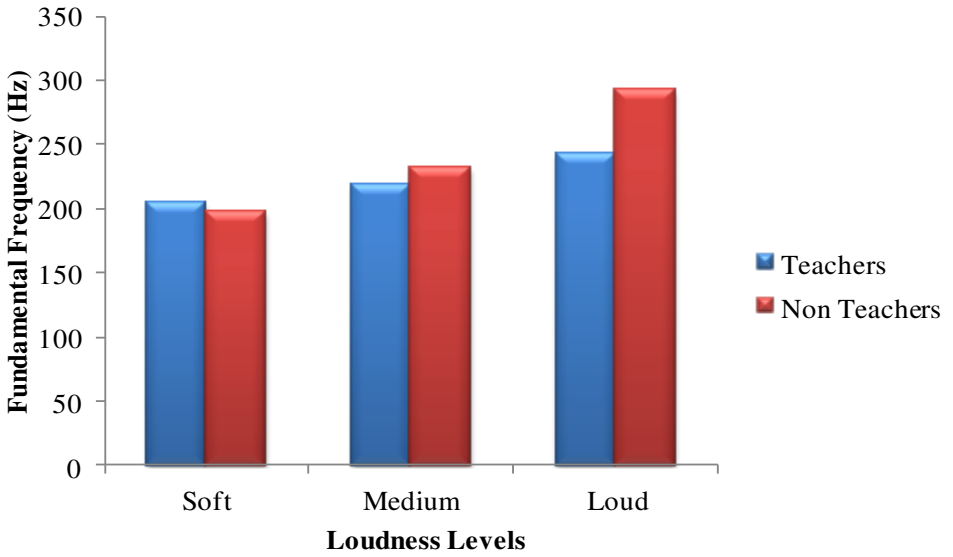

Figure 3: Mean values of fundamental frequency (F0) for both the groups at three different loudness levels

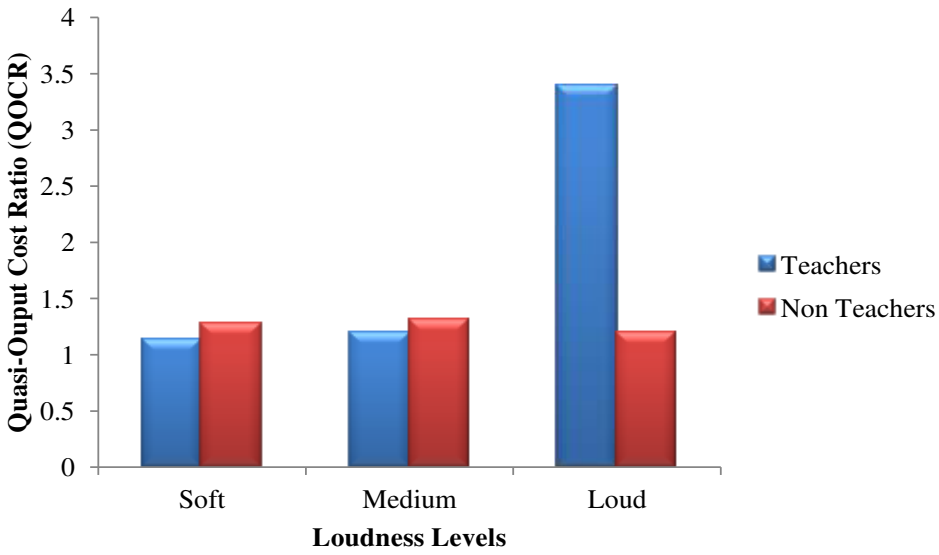

Figure 4: Mean values of Quasi-Output Cost Ratio (QOCR) for both the groups at three different loudness levels

When between groups comparison was done using Mann Whitney–U test, it was found that there was significant difference ($\alpha < 0.05$) for the parameter SPL at medium and loud levels, parameter F0 for loud level and parameter QOCR for loud level as depicted in Table 2.

Table 2: *Results of Mann Whitney-U Test for SPL, CQ, F0 and QOCR values across both the groups*

		Z value	Asymp.sig(2 tailed)
SPL	Soft	- 1.45	0.25
	Medium	- 1.98	0.04
	Loud	- 4.05	0.00
CQ	Soft	- 0.58	0.55
	Medium	- 1.26	0.20
	Loud	- 0.27	0.78
F0	Soft	- 0.83	0.40
	Medium	- 1.76	0.78
	Loud	- 3.68	0.00
QOCR	Soft	- 2.25	0.24
	Medium	- 2.01	0.44
	Loud	- 1.88	0.05

Comparison of QOCR values within the groups (teacher and non teachers) across the three loudness levels (soft, medium and loud) was carried out using Friedman's test and significant difference ($\alpha < 0.05$) was seen in both the groups across all the three loudness levels. In teachers, $\alpha = .01$ and for non teachers, $\alpha = 0.48$ across all the three loudness levels.

Wilcoxon Signed Rank Test was also computed for the pair-wise comparison of QOCR values as within the groups across the three different loudness levels. It was observed that teachers had statistical significance for pair-wise comparison of QOCR values ($\alpha < 0.05$) across all the three loudness levels while in non teachers there was a statistical significance ($\alpha < 0.05$) only between QOCR loud-medium values as shown in Table 3.

Table 3: *Results of Wilcoxon Signed Rank Test for QOCR values at soft, medium and loud within the groups*

		Teachers		Non Teachers	
		Z Value	Asymp. Sig. (2- tailed)	Z Value	Asymp. Sig. (2- tailed)
QOCR Values	Medium-Soft	- 2.04	0.04	- 0.95	0.33
	Loud-Soft	- 3.06	0.002	- 1.18	0.23
	Loud-Medium	- 2.61	0.009	- 2.58	0.01

Karl Pearson Coefficient of Correlation was carried out to see the correlation among the acoustic variables and QOCR values within groups across the three different loudness levels- soft, medium and loud.

Table 4: *Results of Karl Pearson Coefficient of Correlation among the acoustic variables (SPL, CQ and F0) and QOCR values within the groups for soft phonation*

		SPL Soft		CQ Soft		F0 Soft		QOCR Soft	
		Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher
SPL Soft	Pearson Correlation	1	1	- 0.02	-.21	- 0.09	.04	0.41	.60**
	Sig. (2-tailed)			0.26	.33	0.74	.85	0.12	.003
CQ Soft	Pearson Correlation	- 0.02	-.21	1	1	-.17	-.48*	-.50	-.31
	Sig. (2-tailed)	0.93	.33			.53	.02	.05	.15
F0 Soft	Pearson Correlation	-.09	.042	-.17	-.48*	1	1	-.57*	-.54**
	Sig. (2-tailed)	.74	.85	.53	.023			.02	.009

***Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

Table 5: *Results of Karl Pearson Coefficient of Correlation among the acoustic variables (SPL, CQ and F0) and QOCR values within the groups for medium phonation*

		SPL Medium		CQ Medium		F0 Medium		QOCR Medium	
		Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher
SPL Medium	Pearson Correlation	1	1	.26	.10	.24	.30	.26	.07
	Sig. (2-tailed)			.34	.65	.37	.17	.34	.75
CQ Medium	Pearson Correlation	.26	.10	1	1	-.19	-.12	-.38	-.59**
	Sig. (2-tailed)	.34	.65			.48	.57	.15	.003
F0 Medium	Pearson Correlation	.24	.30	-.19	-.12	1	1	-.46	-.62**
	Sig. (2-tailed)	.37	.17	.48	.57			.08	.002

***Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

Table 6: *Results of Karl Pearson Coefficient of Correlation among the acoustic variables (SPL, CQ and F0) and QOCR values within the groups for loud phonation*

		SPL Loud		CQ Loud		F0 Loud		QOCR Loud	
		Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher	Teacher	Non Teacher
SPL Loud	Pearson Correlation	1	1	.05	.30	-.24	.36	.06	-.14
	Sig. (2-tailed)			.85	.17	.38	.09	.82	.52
CQ Loud	Pearson Correlation	.05	.30	1	1	-.18	.02	-.10	-.62**
	Sig. (2-tailed)	.85	.17			.50	.91	.71	.002
F0 Loud	Pearson Correlation	-.24	.36	-.18	.02	1	1	-.17	-.71**
	Sig. (2-tailed)	.38	.09	.50	.91			.526	.00

***Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

In table 4, it was found that for soft phonation in teachers there was a low positive correlation between QOCR values and SPL and moderate negative correlation between QOCR values and CQ, F0. In non teachers, there was moderate positive correlation for QOCR values and SPL, low negative correlation between QOCR values and CQ and moderate negative correlation between QOCR values and F0.

In table 5, it was found that for medium phonation in teachers there was a low positive correlation between QOCR values and SPL and low negative correlation between QOCR values and CQ, F0. In non teachers, there was low positive correlation between QOCR values and SPL, moderate negative correlation between QOCR values and CQ, F0.

In table 6, it was found that for loud phonation in teachers there was low positive correlation between QOCR values and SPL and low negative correlation between QOCR values and CQ, F0. In non teachers, there was low negative correlation between QOCR values and SPL and moderate negative correlation between QOCR values and CQ, F0.

CHAPTER V

DISCUSSION

The present study aimed to measure the vocal economy parameter Quasi-Output Cost Ratio (QOCR) among teachers and non teachers and also to see the correlation among the various acoustic variables such as sound pressure level (SPL), contact quotient (CQ) and fundamental frequency (F0) with QOCR values obtained at three different loudness levels- soft, medium and loud.

Teaching is a profession which requires high vocal demand in terms of duration as well as intensity (Morton & Watson, 1998) and therefore vocal economy for teachers is important. Teachers speak loudly for longer duration in poor acoustic environments such as high levels of background noise and not in a conducive environment (Rajasudhakar & Savithri, 2010) and therefore it is expected that they should have poorer vocal economy. In the present study it was found that there was statistical significance for QOCR values at loud intensity levels for teachers than non teachers. This may be attributed to experience in voice use. Moreover, teachers might have developed better tissue endurance over the years of vocal use which might have contributed to higher vocal economy (Laukkanen, Mäki & Leppänen, 2009).

In the current study, it was also found that there was negative correlation between QOCR values and CQ for teachers as well as non teachers at all three loudness levels. Results of this study are in accordance with the earlier studies reported in the literature (Laukkanen et al, 2009; Kankare & Laukkanen, 2012).

Researchers have reported that impact stress increases with the degree of SPL, F0 and glottal adduction. Therefore, if the values for SPL, F0 and CQ are low, low

degree of impact stress should be observed (Jiang & Titze, 1994). Moreover studies have shown that there is a positive relationship between CQ and impact stress (Verdolini, Chan, Titze, Hess & Bierhals, 1998; Horácek, Laukkanen & Švec, 2006). Modes of phonation also influence glottal impact stress and hence pressed phonation should show high degree of impact stress and breathy phonation should show low degree of impact stress. So a negative relationship should be expected between glottal adduction and vocal economy and this study indicates that there is inverse correlation between QOCR and CQ.

Studies have also reported that QOCR values and F0 have a negative correlation (Laukkanen et al, 2009; Kankare & Laukkanen, 2012). However, literature also reports of positive correlation between QOCR values and F0 (Master, Guzman & Dowdall, 2013). In the present study, it was seen that there is a negative correlation between QOCR values and F0 for both the groups at all the three different loudness levels. Earlier studies have revealed that high F0 values indicate high degree of impact stress. Therefore, an increase in F0 values would imply that voice production is less economic. Horácek, Laukkanen & Sidlof (2007) also reported similar results as high F0 values would indicate greater vocal fold tissue acceleration and deceleration than low F0 values. Tissue acceleration is considered one of the main factors associated for vocal loading and is associated with more impact stress. Hence, it might be inferred that a high F0 might contribute towards a low vocal economy.

The relationship between QOCR values and SPL is reported to be the least consistent in most of the earlier studies. Laukkanen et al, 2009 found that was a negative correlation while Kankare & Laukkanen (2012) observed no correlation between QOCR values and SPL respectively. However, Master et al, 2013 had reported a positive correlation between QOCR values and SPL. Results of the current

study also revealed that there is a positive relationship between QOCR and SPL values for teachers at all the three loudness levels while in non teachers only for soft and medium intensity levels. In the formula for calculating QOCR values, SPL is used which is the numerator; so when it increase, the quotient SPL/CQ also increases and therefore it affects the final QOCR values. In addition, the physiological explanation for the same would reveal that an increase in SPL would indicate more impact stress (Jiang & Titze, 1994; Horácek et al, 2007) and thereby less vocal economy. An increase in SPL can be accounted to an increase in subglottic pressure which would produce an increment in the tissue acceleration and impact stress (Jiang et al, 2001).

Findings of the current study have also shown a low negative correlation between QOCR values and SPL for non teachers at loud intensity levels. This could be accounted due to the fact that at higher SPL's, impact stress would increase due to hyperadduction of the vocal folds (Jiang and Titze, 1994) and thereby leading to poor vocal economy.

CHAPTER VI

SUMMARY AND CONCLUSION

Human interaction and culture is greatly influenced by their voices. It is the primary means for verbal communication and even can be used to sing. Human voice is also used by different individuals to express emotions which may include pleasure, happiness, sadness, anger or fear. Professional Voice Users refers to those individuals for whom voice is the primary tool of their occupation. Some of these professionals voice users are school teachers, singers, actors, barristers, auctioneers, radio and television announcers who are prone to develop voice problems due to work demands. Few others who also belong to this group are lecturers, tutors, ministers of religion, politicians, soldiers, translators, tour guides, telephone and telegraph operators, sales personnel, secretaries, shop managers and conductors.

Vocal economy is the means by which maximum vocal output can be obtained by providing minimum stress on the vocal folds. One of the measures for vocal economy is "quasi-output cost ratio" (QOCR) or "economy ratio" which is calculated as follows

$$QOCR = [SPL\ (dB)/CQ_{EGG}] \times [T/T_0]$$

In this regard, the present study was planned to check QOCR values in female primary school teachers and compare them with that of the non-teachers.

Fifteen primary school teachers and twenty two non teachers in the age range of 25-40 years participated in the study. Subjects were given phonation tasks at three different loudness levels- soft, medium and loud, EGG recordings and SPL recordings were measured for the same. Later QOCR values were calculated using the formula.

Statistical analysis was carried out using Statistical Package for the Social Sciences SPSS, version 21.0. All the various variables measured in both the groups were subjected to Mann-Whitney U test, Friedman's test, Wilcoxon Signed Rank test and Karl Pearson Coefficient of Correlation for detailed statistical analysis.

Results revealed there was statistical significance for QOCR values at loud intensity levels for teachers than non teachers. This may be attributed to experience in voice use. Moreover, teachers might have developed better tissue endurance over the years of vocal use which might have contributed to higher vocal economy.

To conclude, the results of the present study indicate that regular use of voice might entail vocal economy at higher intensities.

Future Directions:

1. Studies can be carried be out to see if vocally trained female teachers also similar results of the present study.
2. Questionnaires related to vocal fatigue symptoms in teachers along with QOCR values can be studied to see if there is any correlation between them.
3. Studies in which pre and post QOCR values can be calculated using vocal loading tasks can also be done.
4. Research can also be done to compare and see if there any difference in vocal economy for primary and high school teachers.
5. New methods to quantify vocal economy can also be carried out in which speaking or reading tasks can be incorporated.

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