EFFECT OF VOCAL LOADING ON SELF-PERCEPTUAL AND ACOUSTIC PARAMETERS IN CARNATIC SINGERS

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Certificate

This is to certify that the dissertation entitled "**Effect of vocal loading on self-perceptual and acoustic parameters in Carnatic singers"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech Language Pathology) of the student Registration Number: 17SLP002. 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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Certificate

This is to certify that the dissertation entitled "**Effect of vocal loading on self-perceptual and acoustic parameters in Carnatic singers"** has been prepared under my supervision and guidance. It is also being 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 the dissertation entitled "**Effect of vocal loading on self-perceptual and acoustic parameters in Carnatic singers"** is the result of my own study under the guidance Dr. Santosh. M, Associate Professor, Department of Speech-Language 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

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TABLE OF CONTENTS

LIST OF TABLES

Acknowledgement

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CHAPTER 1

INTRODUCTION

The voice is considered as one of the most integral part of the unique quality that humans possess, which is called the Speech. The larynx acts as the major source of voice production with its anatomical and physiological coordination and integration. The voice or the tone that is generated at the larynx is modified as it passes through different other structures in the vocal tract such as the pharynx, palate, nasal cavity, tongue and lips. This characteristic makes every individual's voice unique and is also generally recognised that voices are identifiable as belonging to particular people like they are uniquely personal like faces. The voice serves as a reflection of one's inner self and personality. It can also convey a variety of emotions which can have an impact on the communication partner. Voice is dynamic in nature. As an individual grows physically through the development changes of life, there can be long term changes in the voice. The usage of voice at different stages will be based on the demand imposed on it. The reasons for these differences include biological maturation, emotional, social and occupational demands that are placed on the individual's life.

However, prolonged and consistent use of voice for a long time can increase the risk of developing voice disorders. The major group of individuals who are at risk for developing voice disorders includes the occupational or professional voice users. Professional voice users are individuals who use their voice extensively and excessively on a regular basis for their livelihood. The occurrence of voice disorders in these populations would lead to social isolation, reduced performance in their respective occupational fields, and will have a negative impact on communication (Herdon, Sundarrajan, Sivasankar, & Huber, 2017). Boon and McFarlane (1994) reported that excessive use of voice can lead to vocal fold edema or tissue engorgement.

Past researches have been done to look into the anatomical and physiological changes that happen in the larynx after prolonged and consistent usage of voice in professional voice users. One of the approaches used in these studies is challenging the optimal functioning of the larynx called vocal loading. Any conditions that stress or challenge the optimal functioning of the physiological system will lead to diversity in the range of function of the system and physiological limits (Fujiki & Sivasankar, 2017). Just like how a person is made to run on a treadmill to stress his physiological system and asses his cardiac functioning, the larynx can also be made to stress by manipulating the external (faulty room acoustics, increased background noise, varying humidity levels and posture) and internal environment (duration and type of the task, quality of voice, and intensity of voice production) and the response can be studied.

Several researchers in the past have studied the effects of the vocal loading tasks by investigating various measurements like acoustic, aerodynamic, auditory-perceptual, self-perceptual, and laryngeal visualization measures. Under aerodynamic measurements, the most common parameter assessed is the Phonatory Threshold Pressure (PTP). The minimum amount of subglottic pressure necessary to initiate and maintain vocal fold vibration can be estimated using PTP. This parameter is sensitive enough to even subtle changes that happen in the larynx as a result of vocal loading tasks (Erickson-Levendoski & Sivashankar, 2011; Enflo, Sundberg, & McAllister, 2013; Chang & Karnell, 2004). Acoustic measurements in most of the studies have assessed parameters such as jitter, fundamental frequency, shimmer, signal to noise ratio, and cepstral peak prominence (Stemple, Stanley, & Lee, 1995; Gelfer, Andrews, & Schmidt, 1991). Self-perceptual measurements such as perceived phonatory effort have been widely used in some of the studies. (Stemple, Stanley & Lee, 1995; Bodt, Wuyts, Heyning, Lambrechts, & Abeele, 1998; Chang & Karnell, 2004; Sundarrajan, Fujiki, Loerch, Venkatraman, & Sivasankar, 2017). Videostrobosopic studies have also been carried to visualize the changes happening in the larynx following a vocal loading task (Stemple, Stanley & Lee, 1995; Whitling, Ryedll, & Ahlander, 2015; Gelfer, Andrews, & Schmidt, 1991).

Identifying healthy individuals who are at risk for developing voice disorders can be made possible by studying vocal loading by varying extrinsic and intrinsic factors. In past literature, various types of vocal loading tasks have been used. The most commonly used vocal loading task is loud reading with various internal factors such as reading at different intensity levels, using forced mouth breathing while reading (Sivasankar & Erickson-Levendoski, 2012), loud reading using pressed voice quality at range level high and low (Fujiki, Chapleau, Sundarrajan, Mckenna, & Sivasankar, 2016). Other tasks used in the literature were, repetition of sustained vowels (Rowan, Berndt, Carter, & Morris, 2016), phonating vowels (Enflo, Sundberg, & McAllister, 2013) and singing (Yiu & Chan, 2003 ; Yiu et al, 2013). The intrinsic factor such as the duration of the vocal loading task varied across different studies. The duration ranged from 15 minutes (Linville, 1995) to 3.75 hours (Vilkman, Lauri, Alku, Sala, & Sihivo, 1999). It is believed that a vocal loading task with a duration of more than an hour is sufficient enough to stress the normal laryngeal mechanism.

Review of literature based on vocal loading studies have revealed that a few studies were done on professional voice users such as teachers (Bodt, Wuyts, Heyning, Lambrechts, & Abeele, 1998; Laukkenen et al, 2004; Remacle, Morsomme, Berrue & Finck, 2012) and in singers (Yiu & Chan, 2003; Yiu et al., 2013). However, not many empirical studies on professional voice users such as singers are done and are yet to be explored.

Despite being the carrier of words for speech, voice can also be used to produce music. The singer with a good control of the voice brings immense pleasure to the listener. A good singing requires a coordinated anatomical and physiological control of respiratory, phonatory, resonatory and articulatory subsystems. Different styles or genre of singing requires different respiratory or phonatory support.

Indian Carnatic classical music is one of the oldest form of art in the world. This style of singing requires a person to sing with an open throat, powerful and low-pitched voice and loud singing. Mastering this form of music requires rigorous and regular practice. This can impose an enormous amount of stress in the laryngeal apparatus which could further lead to development of voice disorders (Arunachalam, Bhoominathan, & Mahalingam, 2014). Vocal loading studies in professional voice users especially in singers are least explored. Therefore, extensive empirical studies in singers have to be carried out to examine the larynx in response to the stress induced vocal loading task.

Thus, the objectives of the study are:

1) To determine if there are changes in the acoustic measurements after vocal loading task in Carnatic Classical Singers.
2) To determine if there are changes in the self-perceptual measurements after vocal loading task in Carnatic Classical Singers.

Hypothesis

1) There is no significant difference in the acoustic measurements after vocal loading task in Carnatic Classical Singers.

2) There is no significant difference in the self-perceptual measurements after vocal loading task in Carnatic Classical Singers.

CHAPTER II

REVIEW OF LITERATURE

In the recent past years, several studies have been conducted which induce stress or demands on the physiological system which would reveal diversity in the functional range and physiological limits. One such physiological system where the researchers have done extensive studies is the larynx. The response of a healthy larynx to the stress or demands helps in understanding the underlying laryngeal mechanism. In recent years, researchers have carried out studies which used vocal demanding tasks or vocal loading tasks to challenge the laryngeal mechanism (Fujiki & Sivasankar, 2017).

Vocal load refers to the "amount of work accomplished by the laryngeal mechanism over time, which can be mostly determined by the duration, intensity, and frequency of vocalizations" (Morrow & Connor, 2011). Multiple studies on vocal loading tasks in professional voice users have been conducted. A healthy and optimal voice is an important tool of professional voice users which can have an impact on the person's social, emotional, and vocational well-being.

Considering the type of vocal loading tasks used, many studies in the past have used a variety of vocal loading tasks to challenge the underlying laryngeal mechanism, out of which prolonged and loud reading was found to be common. To compromise the laryngeal mechanism, the duration of the vocal loading tasks should ideally be over an hour with increased intensity of production (Fujiki & Sivasankar, 2017). Tasks requiring shorter than this duration would not exhibit considerable changes in the acoustic, aerodynamics or other objective voice measurements (Fujiki & Sivasankar, 2017). In the literature, the effect of vocal loading tasks on the optimal laryngeal mechanism have been studied by various researchers by investigating its effect on the acoustical, aerodynamic, laryngeal recordings, auditory-perceptual and self-perceptual measurements (Fujiki & Sivasankar, 2017)

Fujiki and Sivasankar (2017) reviewed studies on vocal loading tasks. Two out of the 28 studies which were reviewed used singing as a vocal loading task. Yiu and Chan (2003) used karaoke singing as vocal loading task for a duration of 95 minutes in twenty amateur karaoke singers aged between 20-25years. The study was done across two gender groups. The subjects were divided into two groups: one group of singers were provided with hydration and a period of vocal rest at regular intervals during singing and the other group was required to sing continuously without vocal rest and hydration. Acoustic, perceptual and phonetogram analysis were carried out. For the acoustic analysis, the voice measurement sample used were, sustained phonation of /a/ for 5 seconds and reading aloud a Chinese sentence at comfortable pitch and intensity. In the subjects who were given voice rest and hydration during singing, it was found that the quality of the voice which was measured by acoustic and perceptual measurements and phonatogram which was used to measure the function of voice had no significant changes. For the group who was not given break and hydration and sang continuously, it was found that there was a change in the jitter measurements initially after like singing ten songs, but the changes became less significant subsequently when the subjects got used to intensive demand on the vocal function while singing. The initial deterioration in jitter measures could be due to the warm-up effect after singing 10 songs. It was also found that there was a change in the highest sustainable fundamental frequency after singing 10 songs in the female participants. Similarly, in the phonatogram analysis, a reduction in the highest fundamental frequency was found for the female participants. This could be due to changes in the length, size and elasticity of the muscles which could lead to fatigue of laryngeal muscles.

In yet another study done by Yiu, et al., (2013) recruited 10 females and 10 males who were between 18 to 23 years old and who didn't have prior vocal training. The task was to take up karaoke singing for a duration of minimum of 95-minutes. Participants were not given vocal rest or water in between the task to bring about tiredness in the voice. Background music was set up to 60 dB SPL and they were asked to sing at 80 dB SPL. Before and following the vocal loading task, a high-speed laryngoscopic image recording for phonation of the vowel /i/ was taken. Glottal measures such as ratio index of length-to-width of the glottis, speed quotient and open quotient were quantified. A decrement in the ratio index length-to-width of the glottis was found following the vocal loading task (Yiu et al, 2013). This could be due to the adaptation of hypertensive mode by the participants during the vocal loading task which lead to an increase in the medial compression of glottis following the singing task (Yiu et al, 2013)

Gelfer, Andrews and Schmidt (1991) conducted a study on twenty-six trained and twenty-four untrained singers. The two groups were given a vocal loading task of reading anything of their interest for 1 hour at a comfortable intensity range. During the one hour long vocal loading task, after every 15 minutes, the subjects were given a break of 1 minute and authors studied acoustic measures such as jitter ratio, fundamental frequency, signal-to-noise ratio and shimmer. In the trained singers, jitter ratio for the vowel /i/ showed significant change between the pre and post test measurements, which indicates a decrement in the vocal quality. Whereas for untrained singers, for the vowels /i/ and /u/, the fundamental frequency was found to be increased and the signal-to-noise ratio was found to be decreased. This could be due to certain vocal habits such as prolonged period of vocal training which resulted in greater irregularity in the function of vocal fold.

Stemple, Stanley, and Lee (1995) recruited ten normal speakers and studied aerodynamic, acoustic, videostroboscopic findings and subjective observations before and following the prolonged use of voice (2 hours of reading). Under acoustic and aerodynamic measures, jitter, fundamental frequency, maximum phonation time and flow rate were measured for phonation samples of /a/, /u/, and /i/ vowels for each subject. Additionally, fundamental frequency and frequency range for connected speech were also obtained. For sustained vowels, jitter values were found to be low between the pre and post measurements for high pitched vowels. Significant increase in pre and post test was found for fundamental frequency during reading. The reason for increase in fundamental frequency could be that after a prolonged reading task, the subjects would have found it difficult to produce low pitch. In 6 of the 10 subjects who participated, videostroboscopic findings revealed anterior glottal chinks and one of the 10 subjects had incomplete closure during the post test. This could be attributed to the straining of laryngeal muscles during the experimental task.

In a study, Remacle, Moesomme, Berrue and Finck (2012) looked into the impact on voice for a prolonged reading task. 16 female teachers with normal voice and 16 female teachers with disordered voice were studied. The two groups of participants were required to read a French novel for a duration of 2 hours. The study was conducted in 2 sessions of oral reading. In the first session the participants were required to have a voice level of 60-65dB and 70-75dB in the second session. Participants were required to read aloud in a quiet room. After every 30 minutes the participants were ensured that they remain hydrated by providing them with a glass of water. Subjective self-ratings and objective measurements such as voice range, aerodynamic, and acoustic measurements were evaluated. For the acoustic analysis, Multidimensional Voice program (Kay Elemetrics, Lincoln Park, NJ) was used. Parameters like shimmer percent, jitter percent, average fundamental frequency, and noise harmonic ratio were assessed by phonating the vowel /a/ for three times and the samples were analyzed. The results revealed that the jitter percent had no significant difference, whereas a significant and gradual decrease in the shimmer percent through the 2-hour reading task in the dysphonic female teachers was found. The results of the study showed that after the vocal loading task, there was stability in the voice. This could be because of the increase in the tension of larynx leading to increase in the fundamental frequency and more stability in the vocal fold vibration in the dysphonic group.

In recent studies on vocal loading tasks and its effects on the acoustic, aerodynamics and auditory-perceptual measurements, a few studies have been carried out which used cepstral and spectral measures such as Cepstral Peak Prominence (CPP). CPP is considered one of the robust acoustic measures to identify overall severity of dysphonia. It is a measure of the relative cepstral peak amplitude which is measured in decibels of the voice signal. In one such studies by Rowan, Berndt, Carter and Moris (2016), seven adults between 19 and 52 years of age were included which investigated the function of voice with the use of thickened liquid after a vocal loading task. The task used in the study was 3 x 10 repetitions of a sustained vowel at 65dB-75dB. Voice was recorded and subjective ratings were obtained before and after the vocal loading task. Fundamental frequency, loudness and perturbation measures were analysed for the recorded voice samples. Additionally, CPP was analysed using the Analysis of Dysphonia and Speech in voice software. Results showed a decrease in the CPP on soft phonation. This could be because of the sensitivity of soft phonation to the changes that happens in the larynx due to vocal fatigue. Connected speech (rainbow passage) sample was also used to analyse CPP for pre and post experimental conditions. It was found that the vocal loading did not have a significant effect on the CPP measures. Other acoustic measures such as speaking fundamental frequency, speaking relative loudness level and ratio of low spectral energy to high spectral energy were also analysed. The result revealed that there was a significant increase in these parameters which represents that as greater demand was imposed on the vocal fold as a result of vocal loading task, subjects could have used greater adduction of the vocal fold as a compensatory response and this can be considered as a normal response. The subjects also rated increased perceived fatigue in the voice and soreness in the muscle following the loading task. This could be attributed to the demands that are placed on the laryngeal system

In another study by Fujiki, Chapleau, Sundarrajan, Mckenna, and Sivasankar (2016), sixteen healthy adults were recruited and they were subjected to a 30-minute vocal loading task. They investigated this effect of vocal loading on the measurements of voice at two different humidity levels, one in low and other in moderate. The vocal loading task used in this study was to read with elevated pitch and pressed voice quality. A multi-talker speech babble noise was introduced in the background at 65dB. Acoustic and perceptual parameters were measured at the baseline and after the vocal loading task at both humidity levels. Under acoustic analysis, CPP measures on sustained vowels as well as connected speech were analysed to look into the effects of vocal loading. Analysis of Dysphonia in Speech and Voice (Model 5109, Kay PENTAX, Montvale, NJ) was used to analyze CPP. It was found that in moderate humidity, that the effect of vocal loading was more sensitive to the soft sustained phonation when compared to low humidity condition. Laryngeal edema that is caused due to the induced loading in voice could be the reason for this. There was no significant change in the CPP measures on connected speech (rainbow passage) after the vocal loading. This shows that CPP on connected speech has very less sensitivity to effects of vocal loading. Also self-reported measures such as perceived phonatory effort and perceived tiredness significantly increased with increased humidity.

Among the self-perceptual measurements, Perceived Phonatory Effort (PPE) is the most commonly used measurement tool. Chang and Karnell (2004) in their study about effect of prolonged vocal loading task on PPE and Phonation Threshold Pressure (PTP). In this study they used PPE as a self-perceptual rating. To evaluate PPE, at the minimum and maximum comfortable levels, the subjects were asked to sustain the vowel /a/. At each of these levels, they were then asked to allot numbers, which served as anchors. Several subjects in the study used a 1-5-10 scale where 1 indicated minimum effort, 5 indicated most comfortable effort and 10 indicated maximum effort. Fujiki and Sivasankar (2017) found several studies which used this self- perceptual rating tool and have found an increase in the PPE for as short as 20-30 minutes of vocal loading tasks to up to 60 minutes of vocal loading. Sundarrajan, Fujiki, Loerch, Venkatraman, and Sivasankar (2017) used the similar perceived phonatory effort rating scale to study the vocal loading effects in older adults in different humidity levels. But here, the subjects were asked to sing "Happy Birthday" at their comfortable level and rate their effort on a visual analog scale by marking a vertical line on the scale based on their perception of effort produced while singing happy birthday. The anchors used for the scale were - no effort and maximum effort. A similar PPE rating scale was used by Fujiki, Chapleau, Sundarrajan, Mckenna, and Sivasankar (2016) where the participants were asked to draw a vertical line on 9-inch visual analog scale based on their perception of effort.

Another self-perceptual rating tool which has been used in some of the studies is the Perceived Vocal Tiredness. Similar to the measurement of perceived phonatory effort in their study, Fujiki, Chapleau, Sundarrajan, Mckenna, and Sivasankar (2016) used this tool in their study which required the participants to rate their level of tiredness experienced in the voice on a 9-inch visual analog scale by reading first three sentences of the "rainbow passage", which was similarly used in the measurement of perceived phonatory effort. Similarly, Sundarrajan, Fujiki, Loerch, Venkatraman, and Sivasankar (2017) used this tool to rate their participants' vocal tiredness and before and after vocal loading tasks. The anchors used were "not tired" and "tired". Participants were required to mark a line on the visual analog scale to indicate their level of vocal tiredness.

Indian studies on vocal loading

Mathur, Pande, and Sahgal (2016) evaluated and compared the voice characteristics of primary school teachers with and without dysphonia complaints. A pre and post vocal loading test was done. The vocal loading test was performed on all the participants in which they were asked to read a text loudly with 80dB SPL white noise presented for a duration of 30 minutes. A voice sample of sustained phonation /a/ for a duration of 5 seconds was collected and analyzed for shimmer, fundamental frequency, jitter, and harmonic to noise ratio for pre and post vocal loading. The results revealed increase in the fundamental frequency, jitter, and shimmer and a decrease in the HNR from pre to post vocal loading test in both teachers with and without dysphonia.

Several studies have looked into the effect of vocal loading in professional voice users especially teachers since they are more susceptible to voice disorders due to their professional demand of prolonged usage of voice for an extensive time period. Another group of professional voice users who are more susceptible to voice disorders are the singers. However, there are few studies which have shed light into determining the effects of vocal loading in professional singers.

Indian classical music

The Indian classical music can be divided into Hindustani and Carnatic music. The classical music form practiced in the southern states of Kerala, Tamil Nadu, Karnataka, Telangana and Andra Pradesh is called Carnatic classical music. It is considered as one among the oldest forms of music. It requires much thought and technique in order to be expressed effectively. The ragas or the melodic scales and talas or the rhythmic scales form the basis of Carnatic music. The ragas originate from the seventy two fundamental ragas and also there are seven rhythmic cycles. Any classical music is sung by varnam in the beginning and pallavi at the intervening stage, which is the repetition of any kriti or keerthana. The lyrics of Indian classical music especially Carnatic music mainly comprises of devotional, which is written and composed by eminent scholars, saints, and poets. (Krishnaraj, 2010)

The art of Carnatic music should be mastered from eminent gurus (teachers) and though religious and rigorous practice. This form of music requires a dynamic and powerful voice with appropriate breathing pattern and singing on a right shruthi or tonic pitch. The essence of Carnatic singing lies in executing long musical phrases with varying octaves and tempos. Due to their rigorous practice sessions, poor vocal hygiene and sometimes due to the use of poor singing technique, they are more susceptible to vocal pathologies (Arunachalam, Bhoominathan, & Mahalingam, 2014). Therefore, it is essential to study the vocal parameters in these population using various measurements such as acoustic, aerodynamic, perceptual etc., which would help in carrying out comprehensive assessment and would lead to better management.With this preview, the present study will focus on to investigate the effects of vocal loading in Carnatic classical singers.

CHAPTER III

METHOD

Participants

Ten Carnatic classical singers, four males and six females, between the age 20 and 50 years were recruited for the present study. Participants were included based on the following selection criteria: participants who had a formal training in Carnatic classical music for about 10 to 15 years, indulged in regular music practice and had a perceptually normal quality of voice on the day of baseline recording. Participants with a history of any laryngeal pathology, neurological disorders, speech, hearing problems, respiratory distress or who were under medication for any disorders that can have an effect on the laryngeal mechanism were excluded from the study. Table 1 shows the individual participant demographic characteristics. Table 2 shows the individual participant characteristics with respect to their singing. The mean age of the participants was 32.50 (SD=12.04), the mean of the singing experience of the participants was 16.1 (SD=7.56), the mean of the age of beginning of singing practice was 11.50 (SD=10.12), the mean of the number of hours involved in singing practice per day was 4.10 (SD=2.96), the mean of the number of days involved in singing per week was 5.90 (SD=1.79)

Table 1

Demographic details of the participants which includes age, gender and educational qualifications

Subjects	**Age**	**Gender**	**Education**
1	23	Female	M.Sc.
2	45	Male	M.A
3	35	Female	B.Com
4	25	Male	B.Com
5	50	Female	B.Com
6	33	Female	B.Com
7	20	Male	B.A Music
8	24	Female	B.Com
9	50	Male	SSLC
10	20	Female	MBBS

Table 2

Singing details of the participants which includes singing experience, age of beginning of singing practice, number of hours involved in singing in a day and number of days involved in singing per week (Devadas, Kumar & Maruthy, 2018).

Subjects	**Singing Experience (years)**	**Age of beginning of singing practice (years)**	**No of hours involved in singing in a day (Hours)**	**No of days involved in singing per week (Days)**
1	12	4	2	7
2	10	31	4	7
3	15	13	2	3
4	10	3	5	7
5	35	3	12	7
6	20	12	4	7
7	12	6	3	7
8	15	9	4	7
9	20	28	2	4
10	12	6	3	3

The participants were briefed about the present study and an informed consent was taken from all the participants in prior to the commencement of the study.

Procedure

Vocal loading task

The vocal loading task used in the present study is singing in the presence of background noise. The participants were asked to sing for 95-minutes continuously without voice rest and hydration in between. A multi-talker speech babble noise of 60 dBSPL was played in the background through a free field speaker and SPL was measured using a sound level meter 30cm away from the participants' mouth (Yiu et al., 2013). The background noise was played continuously, making it conducive for appropriate vocal loading to happen. The participants were instructed to sing Carnatic songs such as swarajategalu, keerthanas, devaranama or varnams of their choice. The participants were required to complete the singing task for 95-minutes without breaks or hydration in between. However, they could stop singing whenever they felt tired and could not sing any further.

Analysis

Acoustic Analysis

The acoustic parameters considered for the study were, fundamental frequency, jitter, shimmer, cepstral peak prominence and smoothened cepstral peak prominence.

Fundamental frequency is considered the lowest rate or frequency at which the vocal fold vibrates. It is one of the most commonly used acoustic parameter in the studies pertaining to vocal loading. There have been studies which found alterations in the fundamental frequency after a vocal loading task. Therefore, it was of our interest to include this parameter to investigate if there was any significant difference.

"Variations of fundamental frequency and amplitude of successful glottal pulses in particular, are often referred to as jitter and shimmer, respectively" (Heiberger & Horii, 1982). This perturbation measure of the acoustic signal gives information about the physiological phenomenon. It has been studied extensively in normal population as well in pathology population. Increase in the jitter and shimmer can be considered as a sign of developing vocal pathologies (Verstraete, Forrez, Mertens, & Debruyne, 1993). Therefore it was important to consider these parameters in the present study to investigate the physiological response following a vocal loading task.

For extraction of fundamental frequency, jitter and shimmer measures, the subjects were required to phonate the vowel /a/ in their comfortable pitch and loudness. Multi-Dimensional Voice Program (MDVP model 5105; Kay Pentax Corp., NJ, USA) was used for recording. A total of 3 trials were taken. For the analysis, a steady state portion of 3 seconds from each trial was taken and was then averaged.

In the acoustic signal, Cepstrum is a Discrete Fourier Transform of the logarithm power spectrum which is an alternative way of tracking fundamental frequency. Cepstral measures have been considered one of the effective tools to differentiate between normal and dysphonic voices. In the present study, PRAAT (Version 6.0.49) was used to extract the cepstral peak prominence and smoothened cepstral peak prominence.

Self-perceptual Analysis

Perceived Phonatory Effort (PPE) and Perceived Vocal Tiredness (PVT) were the two self-perceptual measurements. These parameters were used subjectively by the subjects to rate the effort and tiredness they feel after a vocal loading task. These parameters were rated using various scales such as visual analog scale and numerical ratings. In the present study, the participants were instructed to rate their perceived phonatory effort by marking a vertical line on a 9- inch visual analog scale with the anchors being “no effort” and “maximum effort”. Similarly, PVT was also rated with the anchors being “not tired” and “tired” (Sundarrajan, Fujiki, Loerch, Venkatraman, & Sivasankar, 2017).

The study was conducted in 2 tasks.

1. *Control task*

Each of the participants was seated in a comfortable position in a quiet room. The control task began by recording their voice first. To record the voice, the researcher first demonstrated the task by instructing to take in a deep breath and phonate /a/ in their comfortable pitch and loudness while exhaling and sustain it for a duration of 4 to 5 seconds. The participants were then made to sit comfortably in a chair. A microphone (CM-903, Electret condenser meeting microphone) was placed 10 cm away from the participants' mouth. The participants were then instructed to carry out the phonation task as demonstrated. The phonation was recorded in Multi-Dimensional Voice Program (MDVP model 5105; Kay Pentax Corp., NJ, USA) and PRAAT (Version 6.0.49) softwares. Acoustic and self-perceptual measurements were analyzed as mentioned above. After this, self-perceptual parameters were analyzed. After the baseline measurement, the participants were seated in a sound treated room and they were required to maintain a silent period for 95-minutes with absolutely no vocal usage. Following which, the participants´ voice was recorded again using the above mentioned procedure and the acoustical and self-perceptual measurements were analyzed.

2. *Experimental task*

Prior to the vocal loading task, the acoustical and self-perceptual measurements were documented for /a/ phonation sample as mentioned above. Following which the vocal loading task was carried out. A sound treated room was used to conduct the task. The participants were instructed to sit upright and sing Carnatic songs like swarajategalu, keerthanas, devaranama or varnams of their choice in the presence of multi-talker speech babble background noise which was set at 60 dBSPL. A sound level meter (TECPEL 331 Sound level meter) was used to measure the output of the background noise. They were instructed to sing continuously for a duration of 95-minutes without break in between and without hydration. However, they were instructed to discontinue the vocal loading task once they felt that they were tired or couldn't sing any further. Following the vocal loading task, the participants underwent the acoustical and self-perceptual measurements for /a/ phonation sample as mentioned above and the values were documented. At least an hour of gap was provided between the control task and the experimental task.

Statistical Analysis

SPSS software (Version 20) was used to run the statistical analysis. As the sample size was small, non-parametric test, Wilcoxon Signed Rank test was carried out to examine if there was any significant difference in the acoustic and self-perceptual parameters between pre and post measures across control and experimental conditions. A descriptive statistics was also run to obtain mean and standard deviation values for the dependent variables.

CHAPTER IV

RESULTS

The aim of the present study was to investigate the effect of vocal loading on acoustic measurements and self-perceptual measurements in Carnatic Classical singers. The vocal loading task used was singing for a duration of 95-minutes in the presence of background noise. The study was conducted considering two tasks. One was the control task and the other was the experimental task. In both the tasks, pre and post acoustic and self-perceptual measurements were carried out. All the participants were able to complete 95-minutes singing task.

Acoustic measurements

As the sample size was small, Wilcoxon Signed Rank Test was done to check the differences in pre and post acoustic and self-perceptual measurements of both the tasks. A descriptive statistics was also done to find the mean and standard deviation of the dependent variables (Table 3). Table 3 also shows the Z value and p value for each of the acoustic parameters for both control and experimental conditions. The results of the Wilcoxon Signed Rank Test revealed statistically no significant difference ($p > 0.05$) between pre test versus post test scores of both control and experimental conditions for all the acoustic measurements.

Table 3

Pre and Post mean values, standard deviation, Z *and p values of acoustic parameters across control and experimental tasks.*

Parameters	**Tasks**	**Mean**		**SD**		**Z Value**	***p* Value**
		Pre	Post	Pre	Post		
Fundamental Frequency (Hz)	Control	172.52	170.84	43.43	40.74	-.357	0.721
	Experiment	173.94	180.12	46.49	47.35	-1.172	0.241
Jitter (%)	Control	0.85	0.86	0.51	0.43	-.178	0.859
	Experiment	0.88	0.95	0.49	0.50	-.153	0.878
Shimmer (%)	Control	2.37	2.65	0.66	0.71	-1.377	0.169
	Experiment	2.49	2.80	0.81	0.80	-1.362	0.173
Cepstral Peak Prominence (dB)	Control	27.10	27.12	3.61	4.05	-.051	0.959
	Experiment	27.53	26.74	4.06	3.45	-1.274	0.203
Smoothened Cepstral Peak Prominence (dB)	Control	16.57	16.22	2.65	3.15	-.969	0.333
	Experiment	16.63	15.87	2.96	2.74	-1.481	0.139

Self-Perceptual Measurements

Under self-perceptual measurements, two parameters were considered. Perceived Phonatory Effort and Perceived Vocal Tiredness. Table 4 shows the mean, standard deviation, Z value, *p* value and effect size of the self-perceptual parameters for both control and experimental conditions. As the sample size was small, Wilcoxon Signed Rank test was used. The results showed a significant difference ($p < 0.05$) between the pre test versus post test scores of the experimental condition for both the parameters. Whereas, there was no significant difference ($p > 0.05$) between the pre test versus post test scores in the control condition for both the parameters.

Table 4

Pre and Post mean values, standard deviation, Z *and p values and effect size of self-perceptual parameters across control and experimental tasks.*

Parameters	**Tasks**	**Mean**		**SD**		**Z Value**	***p* Value**	**Effect Size**
		Pre	Post	Pre	Post			
Perceived Phonatory Effort	Control	1.53	1.02	1.06	0.88	-.889	0.374	
	Experiment	0.59	2.77	0.41	1.65	-2.803	0.005	-0.88
Perceived Vocal Tiredness	Control	0.70	0.81	0.66	1.10	0.000	1.000	
	Experiment	0.47	3.33	0.54	1.96	-2.803	0.005	-0.88

CHAPTER V

DISCUSSION

Past literature on vocal loading has suggested that tasks which involve elevated vocal production for a duration of more than an hour would compromise the normal laryngeal physiology. Duration of less than an hour would generally not produce significant changes in the objective voice measures. The present study used singing for 95-minutes in the presence of background noise as the optimal vocal loading task to investigate its effect on the acoustic and self-perceptual measurements in Carnatic classical singers.

Acoustic measurements

The results of the present study revealed that there is no significant difference in pre and post measurements of control and experimental conditions of any of the acoustic parameters selected. There have been studies which showed varying results in acoustic measures which suggest that the sensitivity of the larynx to the vocal loading tasks varied in different studies.

Neils and Yairi (1987) in their study, used loud reading for 45-minutes with background noise ranging from 50, 70 and 90 dB (A) in six females of 22 years old. Speech samples were recorded after 15, 30 and 45 minutes of loud reading. Fundamental frequency was extracted from the phonation of the vowel /a/ after a period of voice rest for 45-minutes. It was found that fundamental frequency showed no significant difference. They report that this could be because the vocal loading task used was not sufficient and consistent enough to exert vocal fatigue through the reading period. They also reported that the subjects would have used a relatively large respiratory contribution to increase their loudness during loud reading instead of increasing glottis resistance.

Similarly in another study, thirty healthy female professional voice users (teachers, saleswomen and child care taker) between 18 and 21 years old underwent vocal endurance test of loud reading for a duration of 20 minutes under continuous binaural masking of 85dB white noise (Bodt, Wuyts, Heyning, Lambrechts, & Abeele, 1998). The subjects were required to sustain phonation of /a/ at a comfortable pitch and loudness level immediately following the vocal endurance test and fundamental frequency was measured. Fundamental frequency measures showed no significant difference in the pre and post measurements following the reading task. They report that fundamental frequency measurement may not be sensitive enough to show significant changes for this type of endurance test. They also report that the test used may not be strenuous enough for appropriate vocal loading to happen.

Stemple, Stanley and Lee (1995) studied 10 normal female subjects between the age range 22 and 45 years. They examined the acoustic, videostroboscopic, and aerodynamic measures after a prolonged reading task at an intensity of 75-80 dB. The vocal loading task used in the study was a 2-hour reading with a 5-minutes break after 1-hour. Under acoustic measurements, fundamental frequency was measured for reading at comfortable loudness level using Visi-Pitch. The results revealed there was a significant difference in the fundamental frequency for pre and post test measures. The increase in fundamental frequency was attributed to straining of the thyroarytenoid muscle as a result of the vocal fatigue which results in difficulty in maintaining lower pitch.

Similar increase in acoustic measurements was seen in a study conducted by Gelfer, Andrews, and Schmidt (1991). In their study they compared the pre and post acoustic measurements after a prolonged reading task for about 1-hour. The study was done in trained singers who were 26 in number and untrained singers who were 24 in number. Acoustic measurements such as jitter ratio, fundamental frequency, signal-to-noise ratio, and shimmer were compared across the two subject groups. In the results, the pre and post acoustic measures untrained and trained singers were compared. It was found that there were significant changes in the fundamental frequency and jitter ratios in the untrained singers when compared to the trained singers. This showed that the 1-hour duration of loud and consistent reading had a negative effect on the voice of the untrained singers compared to the trained singers.

Verstraete, Forrrez, Mertens, and Debruyne (1993) conducted a study which examined whether there was an increase in jitter and shimmer percentages with vocal fatigue. Nine females (21-23 years old) without voice problems were included for the study. The vocal loading task used in the study was a continuous production of vowels (/a/,/e/,/i/ and /o/) for about 25 minutes, where each of the vowels lasted for 2 seconds. The vowels were produced at 65dB. Jitter and shimmer measurements were measured for the vowel /a/ before the test and then after every 5 minutes of the vocal loading task. It was found that the jitter and shimmer percentages did not increase and remained at the same level through 0 to 25 minutes.

The sensitivity of acoustic measurement such as Cepstral Peak Prominence (CPP) on vocal loading induced changes is yet to be explored more. However, a few studies pertaining to vocal loading have measured CPP for connected speech, soft phonation and sustained phonation. One such study by Rowan, Berndt, Carter and Moris (2016) investigated the function of voice with thickened liquid use after a vocal loading task. Seven healthy adults between the age range of 19 to 52 years were included in the study. Voice recordings and subjective ratings were analysed for the vocal fatigue pre and post experimental conditions. The vocal loading task used in the study was to sustain the vowel /a/ for 3 sets for 10 repetitions at a loudness level 65-75 dB SPL. CPP was analysed using the Analysis of Dysphonia and Speech in voice software.

Connected speech (rainbow passage) sample was used to analyse CPP for pre and post experimental conditions. It was found that there was no significant effect of vocal loading on the CPP measures.

In yet another study, the effect of surface hydration and vocal loading on the measurements of voice was studied (Fujiki, Chapleau, Sundarrajan, Mckenna & Sivasankar, 2016). A 30-minute vocal loading task was used where the subjects had to read aloud using a pressed voice quality in the presence of multi-talker babble background noise (65 dBSPL). Self-perceptual ratings and acoustic measurements were analysed. CPP measures were obtained for soft, sustained phonation of /a/ at 10^{th} percent pitch, soft, sustained /a/ phonation at 80^{th} percent pitch and 2 sentences of the rainbow passage. It was found that vocal loading had an effect on CPP measures for soft phonation. There was a significant difference in CPP measures for soft phonation when compared to CPP measures for connected speech. This could be due to inherent difficulty in producing a stable, sustained high note. Whereas, CPP measure in connected speech did not change after vocal loading. This could be because of the adjustments or compensations made by the speakers in their pitch and rate of speech.

So, from the present study it is found that the acoustic measurements such as fundamental frequency, jitter, shimmer, cepstral peak prominence, and smoothened cepstral peak prominence did not vary significantly in pre test versus post test scores across both control and experimental conditions.

Self-perceptual Measurements

The result of the present study revealed that there is a significant difference between the pre and post measurements of perceived phonatory effort and perceived vocal tiredness in the experimental condition. However, no significant difference was seen in the control condition. This result of the present study is in favour of most of the studies pertaining to vocal loading, where in most of the studies have found an increase in the vocal effort and vocal tiredness following a vocal loading task (Erickson-Levendoski & Sivasankar, 2011; Whitling, Rydell, & Ahlander, 2015; Remacle, Finck, Roche, & Morsomme, 2012). Literature says that several studies showed increase in PPE and PVT after as little as 20-30 minutes to more than 60 minutes of vocal loading. One study by Sivashankar and Erickson-Levendoski (2012) however was an exception because the duration of the vocal loading task was only 15 minutes of reading, which did not have any effect on PPE (Fujiki & Sivashankar, 2017).

Chang and Karnell (2004) in their study used Perceived Phonatory Effort to rate the vocal effort perceived by the subjects after a 2-hour reading task. To rate PPE, subjects were asked to sustain /a/ at their comfortable minimum and maximum effort levels. Numerical rating system was used. The subjects were asked to use their own numerical rating system. Increase in the phonatory effort was found following the reading task. The explanation given for this is that, higher vibrational amplitude and higher fundamental frequency will lead to a more energy loss after a vocal loading task which results in vocal fatigue.

Stemple, Stanley, and Lee (1995), examined the aerodynamic, acoustic, videostroboscopic measures as well as subjective observations after a prolonged use of voice at high intensity in normal subjects. Reading task for a duration of 2-hours was used. In the study, the subjective observations were made by asking the subjects to estimate their level of effort after the first and second hours of reading. A visual analog scale was used to rate the effort with anchors at both the ends being “no extra effort” and “maximum effort”. 8 out of the 10 subjects reported that they experienced 100 % of maximum effort following the prolonged and consistent reading task. The subjects also reported some physical discomfort such as feeling of dryness and tickle in the throat after the vocal loading task.

In the present study, it is found that the PPE and PVT parameters significantly increased after the vocal loading task in the experimental condition, thus rejecting the hypothesis.

CHAPTER VI

SUMMARY AND CONCLUSION

The present study aimed at investigating the effects of vocal loading on the acoustical and self-perceptual measurements in Carnatic Classical singers. 10 Carnatic Classical singers were included in the study. The vocal loading task used in the present study was a 95 minute singing in the presence of background noise. Some of the conditions that were controlled in the study were, the subjects were required to sing Carnatic songs continuously without a break and without hydration. The study was conducted across 2 conditions. One in control condition and other in experimental condition. Acoustical parameters such as fundamental frequency, jitter, shimmer, cepstral peak prominence, smoothened cepstral peak prominence were analysed. Under self-perceptual parameters, perceived phonatory effort and perceived vocal tiredness were used in pre and post tests across the two conditions. Since the sample size of the study was small, a non-parametric test was used. The results revealed that there is no significant difference in between the pre and post scores across both the conditions for all the acoustic parameters. However, both the self-perceptual parameters showed significant increase in the pre and post scores after the vocal loading task, that is in the experimental condition. But, in the control condition, there is no significant difference found between the pre and post test measurements.

No significant changes in the acoustic parameters in Carnatic singers after the vocal loading task might indicate that the singers have a very good control of their breath support while singing as well as the usage of good techniques like open throat voice would not strain their voice even if singing for a prolonged period of time. However, further studies including a large sample size has to be carried out to see if there is a significant difference.

Significant changes in the self-perceptual parameters after the vocal loading task may be due to strain in the laryngeal system induced by the vocal loading task.

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