COMPARISON OF MADHYASTHAYI AND THARASTHAYI BETWEEN CARNATIC CLASSICAL SINGERS WITH AND WITHOUT VOCAL FATIGUE

BINUSHA S

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University of Mysore

Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI,

MYSURU-570006

July 2020

CERTIFICATE

This is to certify that this dissertation entitled **"Comparison of Madhyasthayi and Tharasthayi between Carnatic Classical singers with and without vocal fatigue"** is a bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 18SLP008. 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.

Mysuru,

July, 2020

Prof. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled **"Comparison of Madhyasthayi and Tharasthayi between Carnatic Classical singers with and without vocal fatigue"** 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.

Mysuru,

July, 2020

Dr. Santosh M

Guide

Associate Professor

Department of Speech-Language Sciences

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled **"Comparison of Madhasthayi and Tharasthayi between Carnatic Classical singers with and without vocal fatigue"** is the result of my own study under the guidance of 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.

Mysuru, **Registration number:18SLP008**

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CHAPTER 1

INTRODUCTION

The phenomenon of singing is sensory-motor in nature. Because of the physical skills, demands, and sophistication that is required and demanded, the singers are usually compared with athletes. For a particular style of music, singers suit their voices and use them in a special way (Sundberg, 1990). Further increased anxiety, high stress, poor voice rest, extensive rehearsals are involved by singers (Benninger, Jacobson, Johnson & Johnson, 1994). And so for the development of vocal pathology, singers are considered as a high-risk group (Spair, 1993).

It is evident in the literature that singers are at high risk for developing voice problems. In a study that investigated the point prevalence of voice problems (VPs), through a self-reported survey, reported to be 21% and 18%, and career prevalence is 64% in singing teachers and 33% in controls, respectively (Miller & Verdolini,1995). According to Titze, Lemke and Montequin (1997), the voice problem in a clinical population of singers in the United States is 11.5%. Further, Tepe, Deutsch, Sampson, Lawless, Reilly, and Sataloff (2002), in a pilot survey among young singers, found that in 55% of young choir singers, there was evidence of voice problem. In a study done by Phyland, Oates, and Greenwood (1999) of self- reported voice problems by singers of three groups -79 operas, 57 musical theatres, 31 contemporaries and 86 non- singers found that the prevalence of voice problem was higher 69% (High) in singers than in non –singers (41%). The prevalence of voice problems in different groups of singers is high, as mentioned in all these studies, and depending on the demands and voice use, the rate of prevalence is highly variable (Schutte & Miller, 1993).

The highly evolved art of South India is Carnatic classical singing. It is learned through rigorous practice from gurus. It requires loud singing and low pitched voice for a powerful voice (Arunachalam, Boominathan & Mahalingam, 2014). In Carnatic classical singers, due to the lack of knowledge about vocal hygiene, they are more prone to vocal problems when compared to other groups of singers. A study conducted in Carnatic and light music singers in India (Boominathan & Shurthi, 2005) reported that vocal hygiene in both the group of singers was poor. A survey done by Boominathan, Rajendran, Nagarajan, Seethapathy and Gnanasekar (2008) in professional voice users in India revealed a high point prevalence rate of voice problems (59%) among Carnatic Classical singers. Thus, the need for assessment and proper management for the voice problem among the Carnatic classical singers is very necessary.

There are several vocal symptoms reported by singers. According to Shapi (1993), in a survey done on voice students, many complained of hoarseness, reduced range of pitch and vocal ability, tightness, dryness, pain, vocal fatigue, pitch and voice breaks, and loss of vocal endurance, and flexibility. In another study done by (Arunlchalam et al., 2014), voice change was reported by 42.2% of singers, and difficulty in singing higher pitches was reported by 35.5%. In 31.1% of singers with vocal fatigue, dryness of throat and difficulty in singing low pitch were reported. In 26.7% of singers, pain, and discomfort while singing were reported. 22.2% of singers reported stain, throat tightness. and difficulty in long-duration sustaining of voice during singing.

And also in a few studies, done among Carnatic singers, they were asked to indicate the vocal symptom that is frequently experienced during or after the singing. The major complaints of Carnatic singers in a study conducted by Arunachalam et al., (2014) were change in voice, difficulty in reaching higher notes, dryness, and vocal fatigue. Multiple vocal symptoms were

experienced by the singers; among them, the most prevalent symptom was vocal fatigue (Devadas, Kumar, & Maruthy, 2018). In most of the Carnatic singers the associated symptom with vocal fatigue is a reduction in pitch range, discomfort in the throat, effortful voice production, losing endurance, and difficulty in singing and sustaining higher and lower pitches while singing for some time (Devadas et al., 2018).

Need for the study

Carnatic singers are at high risk for developing voice problems. Vocal fatigue is reported as the prevalent symptom (Devadas et al.,2018), and also vocal fatigue is identified as an early sign of vocal pathology. So it is essential to identify these factors in singers for early identification and intervention. Recent research suggests vocal loading tasks can be used as a predictor of fatigue and as susceptibility to voice problems. According to a study, high pitched phonation is used as a vocal loading task for professional voice users (Aithal, Bellur, John, Varghese & Guddattu, 2012). The present study is aimed to find out if Tharasthayi (phonation at high pitch) in singers can be a vocal loading task that is feasible, reliable, and time-efficient to be used in a clinical setup.

Aim of the study

To compare phonation tasks at *Madhyasthayi* and *Tharasthayi* in Carnatic classical singers with and without vocal fatigue.

CHAPTER 2

REVIEW OF LITERATURE

The current study aimed to compare *Madhyasthayi* and *Tharasthayi* phonations in Carnatic classical singers with and without vocal fatigue. Review of the literature suggested vocal fatigue is one of the main symptoms reported by professional voice users (Solomon, 2008). Devadas, Kumar, and Maruthy (2018) explored the voice problems reported by Carnatic singers with their prevalence and risk factors. In this study the most prevalent symptom was vocal fatigue (81%).

Any underlying vocal pathologies can be identified using either subjective or objective measures. In a study done by Dhaeseleer et al., (2016) highlighted lowered scores on Dysphonia Severity Index (DSI) for those patients who reported vocal fatigue. One of the most important objective measures is acoustic analysis. Arunachalam et al., (2014) in their study, included 45 Carnatic singers. The common problems reported by the singers were discomfort, pain, vocal fatigue, difficulty in singing both high and low pitches, and changes in voice quality. Under acoustic analysis, singing voice and speaking voice was taken, and self- evaluation of a person's voice was taken into account. The results revealed that the frequency of signing was reduced. The female's range was 21.3 semitones, and the male's range was 23.99 semitones. In this study, the frequency range of singing is reduced in singers. The acoustic analysis increases the precision of diagnosis and thus helps in the better and appropriate intervention.

The evidence of vocal fatigue can be studied using a vocal loading task. In a review done by (Fujiki et al., 2016) on VLTs (vocal loading task) to compare their effects on a healthy voice reviewed 28 published studies in total. The vocal loading task in all the studies was time-

consuming. Another study was done by Samuel, Boominathan, Rajendran, Mahalingam, and Gnanvel (2010) on 20 Indian adult males. In this study, the participants were given the task of reading a book which would cause them vocal loading (75-80 dB SPL) for one hour until the participants reported vocal fatigue. The results revealed significantly lowered Maximum Phonation time in participants up to 6 seconds, significantly increased S/Z ratio, and overall change in voice (Grade) using GRBAS based on the perceptual evaluation. Acoustic analysis was done using MDVP, and the results revealed an increase in frequency and amplitude measurements (short and long term), phonatory fundamental frequency range, noise, and voice irregularity related measures after vocal loading. The lowest fundamental frequency was significantly decreased. Several authors have studied the outcome of vocal loading tasks using self-reported measures and aerodynamic measures. (Fujiki & Sivasankar, 2017)

However, a recent study in the literature revealed that high pitch phonation could be used as a vocal loading task, and it is more sensitive than normal phonation to identify voice pathology (Aithal, Bellur, John, Varghese & Guddattu, 2012). They considered 48 normal healthy individuals and measured 8 acoustic parameters. The authors concluded that there was a significant difference between fundamental frequency and average fundamental frequency.. It was also noted that in the frequency range, there was a significant difference between both the tasks, which were attributed to the dynamics of the laryngeal system in vocal laoding tasks to control F0. Relative Jitter, Relative Average perturbation (RAP), and Pitch Perturbation Quotient (PPQ) in females showed Significant differences

Another study in literature was done by comparing high pitch phonation and habitual phonation in professional voice users such as teachers who experienced vocal fatigue and no vocal fatigue (Thomas & Maruthy, 2019). The study considered 60 participants, who were

grouped using a self-reported questionnaire-based (Vocal Fatigue Index) consisting of demographic details, history of voice problems, awareness of vocal hygiene, etc. was given. A voice sample of habitual phonation and high-pitched phonation was recorded and analyzed for deriving 10 acoustic parameters. The results revealed that for Mean F0 and Maximum F0 values in high-pitched phonation tasks in the vocal fatigue group, there was a significant difference in comparison to without vocal fatigue group. This indicates a positive outcome in considering high-pitched phonation (HPP) as a vocal loading task. As the authors have suggested for future directions, research using high pitch phonation to assess and identify vocal problems in different professional voice users like singers who report vocal fatigue is warranted.

CHAPTER 3

METHOD

3.1. Participants

A total of 23 Carnatic classical singers were included as participants in this study. The age range was between 25- 45 years, and they were all from two music schools in Mysuru. The inclusion criteria were 5-10 years of experience in their field of singing. Initially, a voice survey was done to draw information about occupation and health-related factors. Individuals with speech and hearing, respiratory problems, and individuals who intake tobacco, alcohol, and history of smoking were excluded from the current study.

A self-reported questionnaire, Vocal Fatigue Index, that was developed by Nanjundeswaran, Jacobson, Gartner-Schmidt, and Abbott, (2015), was asked to be filled by the singers to group them into vocal fatigue and without vocal fatigue groups. This questionnaire is marked on a scale (5-point Likert scale) and contains 19 questions. And there are three factors in the questionnaire. Singers who score ≥ 24 in factor 1 or ≥ 7 in factor 2 were grouped in vocal fatigue group. The singers who score less than the above norms were grouped into without vocal fatigue group.

In the Vocal Fatigue (VF) group, the male participants were six and female participants were four. There were ten participants in total. Out of which seven participants had more than 15 years of experience, two participants 5-10 years and one participant 11- 15 years of experience in singing. Every individual in this group gave more than 20 open stage performances in a year except five individuals who gave less than 10 in a year. The practice hour for each individual varied from 1- 3 hours per day in a week, and some individuals 2- 4 days in a week and few

individuals practiced all seven days. Almost all the participants were indulged in singing with a loud voice and throat clearing. There were individuals among them who had an additional job along with singing, which involved excessive voice use.

In the Without Vocal Fatigue (WVF) group, there were two male participants and eleven female participants. There are thirteen participants in total. Out of which five participants had more than 15 years of singing experience. Two participants had 11-15 years of singing experience, and six participants had 5-10 years of singing experience. Ten individuals from these groups gave less than 10 open stage performances per year. And the rest three participants gave more than 20 open stage performances per year. The practice hour of each individual varied from 1-3 hours to 4- 6 hours in a week on all 4-7 days. Almost all of them were indulged in singing in a loud voice and throat clearing. None had an additional job along with singing, which involved excessivevoice use. Table 1 and Table 2 shows the demographic details of individual participants. And Table 3 shows VFI scores.

Table 1

Demographic details of Singers without vocal fatigue

Participants	**Age**	**Gender**	**Singing experience**	**Hours of practice in a day**	**Hours of practice in a week**	**No. of open stage performances in a year**
1	33	Female	5-10 years	3-6 hour	4-6 days	< 10
2	26	Female	5-10 years	3-6 hour	4-6 days	< 10
3	31	Female	> 15 years	3-6 hour	7 days	< 10
4	45	Feamle	> 15 years	1-3 hour	7 days	>30
5	39	Female	>15 years	1-3 hour	7 days	21-30

6	28	Female	5-10 years	>6 hours	7 days	<10
7	45	Female	>15 years	1-3 hours	4- 6 years	< 10
8	26	Male	5- 10 years	1-3 hours	4- 6 years	< 10
9	25	Male	5-10 years	3-6 hour	7 days	< 10
10	25	Female	11-15 years	1-3 hour	7 days	< 10
11	44	Female	>15 years	3-6 hours	7 days	< 10
12	35	Female	11-15 years	3-6 hours	4-6 days	< 10
13	26	Female	5-10 years	<1 hour	1-2 days	21-30

Table 2

Demographic details of Singers with vocal fatigue

Participants	**Age**	**Gender**	**Singing experience**	**Hours of practice in a day**	**Hours of practice in a week**	**No. of open stage performance in a year**
1	25	Male	5-10 years	1-3 hour	7 days	<10
2	34	Female	>15 years	1-3 hour	4-6 days	< 10
3	28	Male	>15 years	1- 3 hour	7 days	>30 years
4	26	Male	> 15 years	1-3 hour	7 days	21-30
5	25	Female	5-10 years	<1 hour	1-2 days	21-30
6	25	Female	11-15 years	1-3 hour	2-4 days	>30
7	45	Female	>15 years	>6 hours	7 days	<10
8	45	Female	>15 years	>6 hours	4- 6 days	21-30
9	25	Male	> 15 years	3-6 hours	7 days	< 10
10	25	Male	>15 years	1-3 hour	7 days	< 10

Table 3

VFI Scores of Singers in the VF & WVF group (VF-Vocal Fatigue, WVF-Without Vocal Fatigue)

Singers with vocal fatigue			**Singers without vocal fatigue**		
Subject	**Factor 1**	**Factor 2**	**Subject**	**Factor 1**	**Factor 2**
1	19	11	1	13	0
2	29	18	2	4	1
3	17	8	3	22	1
4	22	14	4	14	0
5	33	14	5	6	2
6	24	12	6	6	3
7	24	10	7	7	0
8	25	12	8	9	0
9	27	8	9	18	6
10	23	9	10	12	6
-	-	-	11	14	7
-	-	-	12	11	2
-	-	-	13	10	0
	Mean= 24.3	Mean=11.6		Mean= 11.07	Mean= 2.23
	SD=4.64	SD= 2.97		SD=4.95	SD=2.60

3.2. Procedure

All the participants in the study were given informed consent form that explained the aim of the study. Voice recording was done using a directional microphone (Sennheiser ME 66 shotgun) coupled with a digital voice recorder (Olympus WS-100). 44KHz was set as the sampling frequency. The recording was done in a quiet room. The mouth of the participant was

10 centimeters away from the microphone. For the *mathyasthayi* phonation task, the participant was instructed to sustain a phonation in their comfortable base pitch (Aadhara shruthi). A change of at least 25 Hz and above habitual phonation was considered as High Pitch Phonation (Aithal, Bellur, John, Varghese & Guddattu, 2012). But in Carnatic singers, this change may not induce vocal fatigue as they are trained to sing high pitches in their everyday singing.

Some studies done on the range of frequency in trained Carnatic singers showed that they covered 2–2.5 octaves comfortably. According to Durga (1997) and Scherer et al. (2008) singing range of Carnatic singers is 2−2.5 octaves. For the *tharasthayi* task, the participant was instructed to sing the whole range, starting from *madhyasthayi* to *tharasthayi* (till the comfortable note) in their Aadhara shruthi. The examiner noted down the highest comfortable note of the *tharasthayi* and instructed the participants to sustain a phonation at that note.

3.3 Acoustic Analysis

A portion of 3-second from the voice sample was taken for acoustic analysis. Multidimensional Voice Program (MDVP) and PRAAT software were used to obtain the acoustic parameters: Mean F0 (Hz), Minimum F0 (Hz), Maximum F0 (Hz), Maximum F0 (Hz), Pitch Perturbation Quotient (PPQ), Relative Average Perturbation (RAP), Smoothened Pitch Perturbation Quotient (SSPQ), Noise to Harmonic Ratio (NHR), Cepstral Peak Prominence, (CPP), Smoothened Cepstral Peak Prominence (SCPP)

One of the acoustic properties of sound is frequency. The vocal cords vibrate during sustained phonation, and the rate at which they vibrate is called the fundamental frequency. The mean fundamental frequency (Mean F0) in females of age 21-50 years was found to be 222.68 Hz in a study done by Ambreen, Bashir, Tarar, and Kausar (2019) using Multidimensional Voice

Program (MDVP) software. Considering the vocal load that professional voice users like singers would have, it could be implied that the fundamental frequency measure of their voice could be affected. Thus, this parameter was considered for this study.

Minnimum F0 and Maximum F0 indirectly reflects the range of F0. In a study done among teachers who experienced symptoms of vocal fatigue and no vocal fatigue symptoms, they showed a significant difference in Minimum F0 and Maximum F0 (Thomas & Maruthy, 2019). Thus this parameter is chosen in this study.

"The average absolute difference between consecutive periods, divided by average period, expressed as a percentage is the percent Jitt"(Teixeira, Oliveira & Lopes, 2013). In a study done by Gelfer, Andrews, and Schmidt (1991) in singers and non-singers, the jitter values were increased after the vocal loading task.

Relative Average Perturbation (RAP) is "the average absolute difference between a period and the average of it and its two neighbors, divided by the average period. It is expressed as a percentage" (Teixeira, Oliveira, & Lopes, 2013). Aithal, Bellur, John, Varghese, and Guddattu (2012) reported that RAP measures were significantly different in females between high pitch phonation and habitual phonation. The authors suggested that this increase is due to the aperiodicity of vocal cords in high pitched phonation tasks.

A comparative evaluation of period to period variability of the pitch at a smoothening factor of 5 within a voice sample is called Pitch Perturbation Quotient (PPQ). PPQ values when compared high pitched phonation and normal phonation and were reported to be increased in females (Aithal, Bellur, John, Varghese, & Guddattu, 2012).

A relative evaluation of either short term or long term difference of pitch period at a smoothening factor of 55 periods within an analyzed voice sample is called Smoothened Pitch Perturbation Quotient (SPPQ). Similar to PPQ, an increase in values for SPPQ were reported in females, although it was not statistically significant. (Aithal, Bellur, John, Varghese, & Guddattu, 2012)

In the frequency range between 70- 4200 Hz, the average ratio of the inharmonic to the harmonic spectral energy is called the Noise Harmonic Ratio (NHR). In a few studies, it has been found that the presence of hoarseness or breathiness was predicted by this parameter NHR. Thus it was chosen for this study. (Childers & Lee, 1991).

CPP is a "measure of the relative amplitude of the cepstral peak prominence in relation to the expected amplitude as derived via linear regression. This measure reflects the degree of regularity or periodicity in the voice signal. Higher values reflect greater periodicity" (Watts & Awan, 2011).

Across time and quefrency domains, the cepstra obtained from CPP is smoothened and this is called Smoothened Cepstral Peak Prominence (SCPP). For speech signals, this measure gives a value that can be a better predictor. But overall CPP measures has found to be a good predictor

3.4 Statistical analysis

SPSS software was used for statistical analysis (Version 20.0). The statistical level of alpha= 0.05 was considered in this study. The *Shapiro-Wilks test* was performed for normality analysis, and the data was not in a normal distribution ($p < 0.05$). Thus, in the current study, non-parametric tests were chosen. The *non- parametric test*, *Wilcoxen sign rank test* was used to

compare phonation type within each group and *Mann- Whitney –U test* to compare phonation type across groups in singers.

CHAPTER 4

RESULTS

The aim of the study was to compare Madhyastayi and Tharastayi phonations between singers with and without vocal fatigue.

Comparison of two phonations (Madhyastayi and Tharastayi) within each the group.

The mean, median, and standard deviation values of the each phonation type across both the groups are given in the Table 4. *Wilcoxon's Sign Rank test* was done to compare two types of phonations within each group. In both singers with and without vocal fatigue groups, the results suggested a significant ($p<0.05$) difference between two phonation types for five acoustic parameters: Mean F0, Min F0, Max F0, CPP, and SCPP. There was no significant difference (> 0.05) in both the groups for other acoustic parameters (RAP, PPQ, SSPQ, NHR, Jitt) (Table 4).

When compared to *Madhyasthayi* phonation, in *Tharasthayi*, the mean values for Mean F0, Min F0, and Max F0 values were significantly higher in both groups of singers. However, the mean CPP and SCPP values were significantly lower during *Tharasthayi* phonation when compared to *Madhyasthayi* phonation in both groups of singers.

Comparison of two groups (singers with and without vocal fatigue) within each phonation type

Similarly, comparison was done between the groups (singers with and without vocal fatigue) within each phonation type. *Mann- Whitney- U test* was used to compare between the groups. The results revealed statisticaly significant ($P<0.05$) for three parameters RAP, PPQ and SPPQ measures in *madhyasthayi* phonation, And also significant difference ($p<0.05$) for three

parameters Mean F0, Min F0 and NHR measures was in *tharasthayi* phonation. Other parameters in both the type of phonation between the two groups do not show any statistical significance. (Table 5)

When compared between two groups, in vocal fatigue group, there are significantly higher mean values for RAP, PPQ, SPPQ in *madhyasthyai* phonation, and significantly higher mean values for NHR in *tharasthayi* phonation. In without Vocal Fatigue group, significantly higher mean values are seen for Mean F0, Min F0 in *tharasthayi* phonation. And significantly higher values are seen for Max F0 measures in *madhyasthayi* phonation.

Table 4

Comparison of Mean, Median and Standard deviation (S.D) values between phonation types (Madhyastayi and Tharastayi) in the groups (VF and WVF) across acoustic parameters (Min F0- Minimum F0, Mac F0- Maimum F0, RAP- Relative Perturbation Measures, PPQ-Pitch Perturbation Quotient, SPPQ- Smoothened Pitch Perturbation Quotient, NHR- Noise to Harmonic Ratio, Jitt- Percent Jitter, CPP- Cepstral Peak Prominence, SCPP- Smoothened Cepstral Peak Prominence)

Paramters	**Type of phonation**	**Singers without VF**			**Singers with VF**		
		Mean	Median	SD	Mean	Median	SD
Mean	Madhyasthayi	194.23	195.07	34.126	170. 76	177.26	35.61
	Tharasthayi	504.39	525.77	104.48	424.08	380.68	85.90
Min F0	Madhyasthayi	172.72	191.31	56.49	165.28	175.28	36.42
	Tharasthayi	464.69	479.86	102.01	380.51	345.13	77.34
Max F0	Madhyasthayi	210.22	206.23	34.11	165.68	185.61	62.67
	Tharasthayi	553.74	583.93	107.78	473.19	416.13	100.22

RAP	Madhyasthayi	0.474	0.355	0.349	0.665	0.645	0.299
	Tharasthayi	0.453	0.430	0.382	0.64	0.500	0.389
PPQ	Madhyasthayi	0.473	0.351	0.371	0.662	0.643	0.292
	Tharasthayi	0.453	0.391	0.238	0.540	0.474	0.305
SSPQ	Madhyasthayi	0.643	0.547	0.334	0.802	0.784	0.233
	Tharasthayi	0.498	0.407	0.324	0.606	0.539	0.226
NHR	Madhyasthayi	0.105	0.115	0.032	0.125	0.133	0.025
	Tharasthayi	0.008	0.086	0.008	0.104	0.103	0.019
Jitt	Madhyasthayi	0.756	0.595	0.618	0.985	0.962	0.563
	Tharasthayi	0.665	0.698	0.389	0.971	0.825	0.563
CPP	Madhyasthayi	27.61	27.14	2.519	26.89	25.18	3.860
	Tharasthayi	22.31	22.41	2.349	23.09	23.29	3.17
SCPP	Madhyasthayi	16.88	16.10	1.902	16.26	15.08	2.78
	Tharasthayi	12.79	11.94	2.316	13.60	14.12	3.12

Table 5

Comparison between phonation type (Madhyastayi and tharastayi) within each group (WVF and VF

Parameters	**Vocal fatigue**		**Without vocal fatigue**	
	/Z/	P	/Z/	P
Mean F0	2.803	0.005*	3.180	0.001*
Min F0	2.803	0.005*	3.180	0.001*
Max F0	2.803	0.005*	3.180	0.001*

RAP	0.153	0.878	0.175	0.861
PPQ	0.663	0.508	0.245	0.807
SPPQ	1.682	0.093	1.678	0.093
NHR	1.682	0.093	1.503	0.133
Jitt (%)	0.255	0.799	0.245	0.807
CPP	2.497	0.013*	3.180	0.001*
SCPP	2.497	0.013*	3.110	0.002*

*Indicates significance at $\alpha < 0.05$ level.

Table 6

Comparison between group (WVF and VF) within Phonation types (Madhyastayi and Tharastayi)

Parameters	Madhyasthayi		Tharasthayi	
	/Z/	P	/Z/	P
Mean F0	1.240	0.215	1.985	0.047*
Min F0	0.930	0.352	2.109	0.035*
Max F0	1.488	0.041*	1.861	0.063
RAP	2.047	0.042*	1.240	0.215
PPQ	2.110	0.035*	1.178	0.239
SPPQ	2.109	0.035*	1.426	0.154
NHR	1.397	0.162	2.545	0.011*
Jitt (%)	1.488	0.137	1.302	0.193
CPP	1.178	0.239	0.620	0.535
SCPP	1.364	0.172	0.558	0.605

*Indicates significance at $\alpha < 0.05$ level.

CHAPTER 5

DISCUSSION

This study aimed at determining if phonation at *tharasthayi* can be used as a vocal loading task in clinical setup for assessment in Carnatic classical singers. In the literature, many kinds of vocal loading tasks have been used. Further, several studies have been done to examine the interaction between the intrinsic and extrinsic vocal loading factors. In literature the most commonly used vocal loading task is loud reading (65-70dB) (Remacle, Finck, Roche & Morsomme, 2012). Other tasks were, singing (Yiu & Chan, 2003; Yiu et al., 2013), repetition of sustained vowels (Rowan, Berndt, Carter, & Morris, 2016), phonating vowels (Enflo, Sundberg, & McAllister, 2013).

There are a few limitations of such tasks when it comes to its clinical application. Mostly it is time consuming when there is a large patient load. In order to overcome these, it is vital to have a task effective enough to induce vocal loading, provide reliable acoustic data, and be time-efficient. According to a study done, prolonged phonation time is also considered as vocal loading, not only phonation at high- intensity levels (Whitling, 2017).

In case of Carnatic classical singers, it is said, the comfortable singing frequency range for Carnatic singers is covering three octaves (*sta:yi:*) Lower octave: *mandrastha:yi:*, mid octave: *madhyasthayi:*, and upper octave: *tha:rasthayi*:) (Arunachalam et al., 2014). A study done in Carnatic singing revealed that when compared to the historical expectation of three-octave singing, Carnatic singers covered 2– 2.5 octaves comfortably (Arunachalam et al., 2014). when vocally fatigued, the singers rated that pitch range of their voices is most affected

(Josephine et al., 1993). And according to (Stone, 1973) compared to low pitched phonation, higher-pitched phonations produced earlier and more easily perceived vocal fatigue.

Physiologically when the cricothyroid and thyroarytenoid muscle in counteraction tense, the vocal folds pitch increases resulting in an increase in their length and stiffness but a decrease in their mass (Hollien, 1962). So, it can be attributed that any task which includes the use of higher vibratory rates, which could be due to increased loudness or pitch can result in vocal loading.

A study was done in the literature to compare high pitch phonation, and habitual phonation in normal individuals reported significant differences in the acoustic parameters (Aithal, Bellur, John, Varghese, & Guddattu, 2012). And also, a study was done to compare habitual phonation and high pitch phonation with and without vocal fatigue in teachers, and there was a significant difference in acoustic parameters (Thomas & Maruthy, 2019). Further, in both the studies, it was concluded that high pitched phonation task could be used as a vocal loading task. Hence the present study considered singers who are professional voice users and aimed to examine the efficiency of phonation tasks at *tharasthayi* when compared to phonation tasks at *madhyasthayi*. Vocal Fatigue Index developed by Nanjundeswaran, Jacobson, Gartner-Schmidt, and Abbott, 2015 was used to group the participants into vocal fatigue (VF) and without vocal fatigue (WVF) group. The control group was the without vocal fatigue group, and the participants who were suspected of having voice problem was considered as vocal fatigue group

In the present study, results suggested significant differences between two phonation types for mean minimum, maximum fundamental frequency values for both the group of individuals. The significantly increased F0 values for phonation at *tharasthayi* compared to phonation at *madhyasthayi* suggests that the desired effect intended for the experimental

manipulation of increased F0 for high pitched phonation was produced successfully by both the group singers. This finding is supported by the study done by (Thomas & Maruthy, 2019), where there was a statistically significant difference in mean values between habitual phonation and high pitch phonation for mean F0, min F0, max F0 measures in both the group of teachers.

In this current study, CPP and SCPP measures were statistically significant in both the groups in *madhyasthayi* phonation. There is no significant difference in CPP and SCPP parameters in the previous study done by (Thomas & Maruthy, 2019) in teachers. But this finding is supported by a previous study done by Balasubramanium et al. (2015) about the cepstral parameter. Results revealed that cepstral parameters were higher among singers. This is due to the harmonic organization in the voice of singers.

The results of the current study based on Mann- Whitney-U test shows in the Vocal fatigue group, there are significantly lower values for mean, minimum F0 values when compared with singers without vocal fatigue group. These results can imply that participants who reported vocal fatigue had poor or decreased vocal fold vibratory rates when compared to those who did not report of any vocal fatigue. The results of the study done by (Thomas & Maruthy, 2019) revealed that during HPP, there is a decrease in mean, minimum, and maximum F0, which supports our present study.

In the current study in the vocal fatigue group, there are significantly higher values for RAP, PPQ, SSPQ values in *madhyasthayi phonation*. Though the phonation perceptually was normal, these acoustic parameters are affected, indicating that these changes may lead to a voice problem. It was detected in phonation in *madhyasthayi* itself. Continuous follow up should be done in order to find if voice problems have been developed in those individuals or not. However, the findings as mentioned above suggest that there could be a relatively increased

functional impact on the vocal folds while using a normal pitch, particularly in the case of females, thus making them more susceptible to develop vocal pathologies (Aithal, Bellur, John, Varghese, & Guddattu, 2012)

The previous study in literature had revealed that the production of a high-pitched voice appears to succeed in improving glottic closure, thereby decreasing the amount of air loss during phonation (Rasp et al., 2016). This may be correlated with the earlier views that the perceptual hoarseness during HPP is diminished (Leden, 1970). But in the current study in the vocal fatigue group, during the phonation task at *tharasthayi*, NHR measures show a significant difference. The increase in NHR measures suggests less glottic closure during *tharasthayi* phonation, and this parameter can be used as a predictor of voice problems in singers.

Because of the significant difference seen in the vocal fatigue group during *tharasthayi* phonation, it can be used as vocal loading tasks in singers to assess their vocal problems. Other parameters in the vocal fatigue group during *tharasthayi* phonation did not show any significant difference; this may be mainly due to the less sample size. Otherwise, it can be attributed to the sensitivity of the parameters in this group of professional voice users. Further studies can be done to produce more significant results with a large sample size and different high pitch phonation tasks with varying levels of frequency.

CHAPTER 6

SUMMARY AND CONCLUSION

A professional voice user is defined as a person who depends on the voice at work. (Stemple et al., 2000). Compared to non-singers, singers tend to report significantly more vocal symptoms (Sapir et al., 1996). So assessment and diagnosis are vital in professional voice users. Because of their significant vocal symptoms, the need of the hour would be to have tools that are more sensitive and less time-consuming in assessment and diagnosing the voice problem in singers.

Literature reports vocal loading task as a good predictor of emerging voice problems. High pitched phonation was successfully used as a vocal loading task in few studies. The current study was aimed to construct a vocal loading task for singers. In previous studies, where they have chosen high pitched phonation as a vocal loading task, the difference between habitual phonation and high pitched phonation was approximately 25 Hz. But in singers, it was assumed that gliding to this particular pitch might not induce vocal loading as they are trained to sing at high pitches. So, the Carnatic classic singers were asked to do a high pitch phonation task at *tharasthayi* (High octave) to induce vocal loading and habitual phonation at *madhyasthay*i (mid-octave). The study considered 23 participants, who were grouped based on the Vocal Fatigue Index (VFI) and also a self- reported questionnaire into vocal fatigue and without vocal fatigue group. Voice samples were recorded and analyzed for 10 acoustic parameters. Statistical analysis was done, and the results revealed a significant difference for Mean F0, Minimum F0, and NHR values for phonation in *tharasthayi* task in the vocal fatigue (VF) group in comparison to without vocal fatigue (WVF) group. This indicates a positive outcome in considering high-pitched

phonation (HPP) at *tharasthayi* as a vocal loading task. Though it shows a positive outcome, further research is needed to find out the reason for the significant results in phonation measures of *madhyasthayi* and non-significant results in most parameters of *tharasthayi* phonation in Carnatic classical singers.

Implications of the study

1) Phonation at *tharasthayi* can be used used as time-efficient vocal loading task in the assessment of vocal problems in Carnatic classical singers.

Limitations of the study

1) Less sample size
2) No grouping of singers in terms of age, gender, and experience of singers was done.

Future Directions

1) A reliability study can be done with a larger sample size, considering age, gender, and experience as a factor.
2) This study considered 10 acoustic parameters, out of which only 3 parameters showed a significant difference for *tharasthayi* task instead more sensitive acoustic parameters can be chosen to explore.
3) High pitched phonation at different frequencies, and various forms can be compared in Carnatic classical singers to find out an appropriate high pitched phonation task that can be more sensitive.

4) High pitched phonation as a vocal loading task to predict vocal symptoms can be done in Hindustani classical singers and also in Western singers.
5) Instead of comparing phonation at *madhyastayi* from their aadhara shurti, a normal habitual phonation can be taken in further studies to see the difference.

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