

**EXPLORATION OF VOCAL FATIGUE IN TRAINED CARNATIC SINGERS
USING VOCAL FATIGUE INDEX-VERSION 2 (VFI)**

Ms. P Niranjana

Register No: 19SLP023

A Dissertation Submitted in Part Fulfillment of Degree of Master of Science

(Speech-Language Pathology)

University of Mysore

Mysuru



ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTTHRI, MYSURU-570 006

September 2021

CERTIFICATE

This is to certify that this dissertation entitled “**Exploration of Vocal Fatigue in Trained Carnatic Singers using Vocal Fatigue Index-Version 2 (VFI-2)**” is a Bonafide work submitted in part fulfillment for degree of Master of Science (Speech-Language Pathology) of the student Registration number 19SLP023. 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 award of any other Diploma or Degree.

Mysuru

September 2021

Dr. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri , Mysuru- 570006

CERTIFICATE

This is to certify that this dissertation entitled “**Exploration of Vocal Fatigue in Trained Carnatic Singers using Vocal Fatigue Index-Version 2 (VFI-2)**” is a Bonafide work submitted in part fulfillment for degree of Master of Science (Speech-Language Pathology) of the student Registration number 19SLP023. This has been carried out under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for award of any other Diploma or Degree.

Mysuru

September 2021

Guide

Dr. K. Yeshoda

Associate Professor in Speech Sciences

Department of Speech-Language Sciences

All India Institute of Speech and Hearing,

Manasagangothri, Mysuru- 570006

DECLARATION

This is to certify that this dissertation entitled “**Exploration of Vocal Fatigue in Trained Carnatic Singers using Vocal Fatigue Index-Version 2 (VFI-2)**” is the result of my own study under the guidance of Dr. K. Yeshoda, Associate Professor in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for award of any other Diploma or Degree.

Mysuru

Registration number: 19SLP023

September 2021

TABLE OF CONTENTS

Chapter	Content	Page number
	List of tables	i
	List of figures	ii
I	Introduction	1-10
II	Review of Literature	11-21
III	Method	22-24
IV	Results	25-33
V	Discussion	34-39
VI	Summary and Conclusion	40-41
	References	42-49

List of tables

Table No.	Title	Page number
1	Summary of studies reporting various changes in measures of vocal fatigue	7
2	Results of Shapiro Wilk's Normality test	26
3	Cross-tabulation of factor wise responses in male Carnatic singers	27
4	Cross-tabulation of factor wise responses in female Carnatic singers	28
5	Mean, median and standard deviation for Factor wise VFI scores for the participants	29
6	F and significance values of Factors (within-subject effects) in males and females (between-subject effects)	30
7	Results of independent t test for gender comparison in Factor 3 and combined percentage of Factor 1 and 2.	32
8	Correlation between Factors and hours of singing in a day	32

List of Figures

Table No.	Title	Page number
1	Percentage values for factor-wise scores of VFI and interaction effects of factors and gender	31

Acknowledgment

I would like to acknowledge and thank my guide, Dr. K. Yeshoda for the constant support and guidance at all stages of this dissertation.

I would also like to extend my gratitude to my parents, and my brother who constantly supported me and motivated throughout the whole journey of post-graduation.

I extend my gratitude to my mentors and professors, Ms. Subhashini Dhandayutham, Ms. Saranyaa Gunalan, Mr. Narendra Kumar, Ms. Vineetha Mary Varghese, Ms. RishabaPriya, Mr. C. Pachaiappan, Ms. Gayathri Krishnan, Dr. Gopi Sankar, Dr. Priya M B, Dr. Rajasudhakar R and others for their valuable guidance and for inspiring my interest in the field of Audiology and Speech-Language Pathology.

My dissertation partners, Sri Ranjani and Abu, thank you for being there always with your patient support and being instrumental in defining the path of my dissertation journey.

I would like to extend my heartfelt gratitude to Vasanthlakshmi maam for the help with statistics and P V Parameshwaran for helping me during data collection by connecting me to several singers.

Special mention to all my corridor mates, everyone from Penguins and Pandas corridor (Dipti, Shejal ,Anju, Mansi, Arva, Bhagya, Anshaba, Kajol and Meena), for all the support, strength, encouragement and love during my sleepless nights. Each and every one of you have become really close to me. And cheers to our breakfast club (Dipti, Shejal, Bhagya and Tanvi), for making mealtimes the best time of the day and making awesome dishes which make you feel like home.

Thank you to my classmates 19 SLP B, for being so amazing and unique in their own ways. You have taught me several lessons in personal life as well as in the professional field. From enjoying our small treats after C1s and C2s, to ranting about the current pandemic and supporting each other throughout the dissertation, it has been quite a journey with you all!

In addition, I would like to thank my friends Janani, Yamini, Swarnpriya, Subha, Deepika, Abishek and my friends from Yolomaaris who made me feel confident in my abilities, and gave their unconditional support as always and added happy distractions to rest my mind outside my research.

I extend my gratitude to all the singers who participated in this study.

CHAPTER I

INTRODUCTION

Humans have fine control over their vocal folds and can produce variations in their perceptual voice by altering the length, shape, and tension of the vocal folds. Humans depend on their voice as a source of income for their livelihood and they are referred to as professional voice users. Voice professionals are the class of working individuals whose remuneration is greatly dependent on their voices. They include teachers, singers, actors, salespersons, politicians, customer care service providers and lawyers (Rubin et al., 2006).

1.1 Professional voice users

According to Koufman & Isaacson (1991), voice users can be classified into four levels, elite vocal performers, professional voice users, non-vocal professionals, and non-vocal non-professional users. Level I: Elite vocal performers include individuals whose livelihood and source of income are profoundly dependent upon their voice. Singers are categorized under elite vocal performers, for whom even minor changes in their quality of voice can have detrimental effects in their careers. Level II: Professional voice users are the class of individuals whose job performance will be affected by even a moderate level of vocal difficulty. Teachers, lecturers, and clergy are examples of professional voice users. Level III: Non-vocal professionals include individuals whose job performance would be impacted if they have a severe voice problem. Lawyers, physicians, businesspeople, and other non-vocal professionals are included in this category. Level IV: This category includes non-vocal non-professionals for whom optimum voice quality is not a prerequisite for their job performance. Clerks, laborers, factory workers and dancers fall under this

category of professional voice users. Vocal demands, techniques, style of voice use and amount of voice use differ among the varied group of professional voice users.

Elite vocal performers, especially singers, have heightened expectations from their vocal system to produce an aesthetically pleasing voice. They are often criticized even for minute changes in their voice. Therefore, they undergo extensive practice sessions to refine their voice and often experience stress during concerts. This nature of voice usage often paves the path for the risk of injury to the vocal mechanism (Phylant et al., 1999). There are varied singing styles that require their unique approach to produce tunes and rhythm. Various singing styles have developed across the globe, varying from one another in terms of vocal scale, quality of tone, and energy. For example, Western music differs from Indian music on the basis that the former is harmonic while the latter is melodic in nature.

1.2 Carnatic music

India is known for its incredible diversity in culture. In India, music has been an integral part of socio-religious life. Classical music, Punjabi music, Indian folk music, Indian pop music are the few singing styles prevalent in India. Cultures and religions influence music; however, Indian classical music remains to be a part of the oldest musical traditions. Classical music includes Hindustani and Carnatic music, and is often associated with northern and southern India, respectively. Classical music has originated from the Vedic age (Sama Veda), and can be traced back to the early or middle eighteenth century when this art form of singing was called 'Sangeeth' (Chandrasekaran et al., 2005; Chakraborty et al., 2014).

Carnatic singing is one of the two subclasses of Indian classical music sung by artists from the Southern states of India, namely Karnataka, Kerala, Tamil Nadu,

Andhra Pradesh and Telangana and also, Sri Lanka. This form of music is learned from teachers (called gurus) who have mastered the nuances of Carnatic singing. The fundamental of this form of singing necessitates the need for an intense low-pitched voice and loud singing. It requires the singer to sing at lower notes in modal register in comparison to Western classical singers who sing with a pitch at a higher range and head register (Arunachalam et al., 2014; Scherer et al., 2008).

Carnatic singing lesson gradations include pitch matching, improving their flexibility across the pitch range, and producing a projected open-throated voice (Devadas et al., 2020). They undergo intense training and practice meticulously to tune their voice and sing precise notes. Such long practice sessions and a lack of proper vocal hygiene practices result in vocal fatigue among singers.

1.3 Vocal fatigue

There is no consensus among voice researchers to identify what defines vocal fatigue. Therefore, it has led to the conceptualization of vocal fatigue in several ways. One school of thought considers vocal fatigue to be a symptom of an underlying functional or organic cause. In contrast, few others believe vocal fatigue is predisposed to phonotrauma and laryngeal pathology. Another school of thought acknowledges vocal fatigue as an isolated phenomenon (Hogikyan & Sethuraman, 1999; Welham & Maclagan, 2003). Various authors have tried to explain vocal fatigue to signify it as a negative vocal adaptation of the functional biomechanics of the larynx occurring due to prolonged usage of voice (Vilkman, 2004; Welham & Maclagan, 2003). From a physiological and kinesiological perspective, vocal fatigue can be described as gradual increase in phonatory effort and gradual decrease in phonatory abilities (McCabe & Titze, 2002). Solomon (2008) included the concept of

voice rest in her definition and proposed that vocal fatigue is primarily manifested as the perception of increased effort which occurs with prolonged voice usage and settles down with rest.

Multiple authors have described vocal fatigue symptomatically. Kostyk & Rochet (1998) included a summary with 18 symptoms of vocal fatigue that included hoarse voice quality, reduced breath support while speaking, breathy voice, unsteady voice, inability to produce voice, tension around the neck/shoulders, irregularities in pitch, throat ache/pain in the neck, inability to sustain typical pitch, throat fatigue, restricted pitch range, tightness/constriction around throat area, lack of vocal carrying power, pain while swallowing, restricted loudness range, increased need to clear throat, need to utilize increased vocal effort, discomfort in chest, ears, or back of neck. Other symptoms which are documented in the literature include elevated levels of laryngeal tension, dryness of throat, coughing, and inability to produce loud voice (D'haeseleer et al., 2017). The symptoms as mentioned above, can be categorized into the following areas: respiratory support for speech, vocal quality, the extent of muscular and structural discomfort, pitch range, dynamic range, and level of effort to produce voice (Welham & Maclagan, 2003).

1.4 Contributors to vocal fatigue

Although the origin of vocal fatigue is vague, Titze (1984) proposed that several biochemical and neuromuscular factors contribute to the development of vocal fatigue (as cited in Solomon, 2008). Mechanisms can be broadly differentiated into peripheral mediated (peripheral nerves and their connections with muscles) and central mediated (mental fatigue). Peripheral factors include neuromuscular fatigue,

non-muscular tissue fatigue and viscosity, whereas central factors would consist of a sense of effort (Solomon, 2008).

Peripherally mediated factors would affect the peripheral nerves and their connections to muscles and the biochemical nature of the vocal folds. Contributions of the peripheral factors on vocal fatigue are explained as follows:

Neuromuscular fatigue: Prolonged usage of voice can result in fatigue to the peripheral nerves, muscles of laryngeal and respiratory system, thus leading to a decline in vocal function or the perception of increased effort during voice production (Solomon, 2008).

Non muscular tissue fatigue and viscosity: Mechanical fatigue refers to a material's ability to endure the amount of strain placed on it earlier to break down. During rapid and frequent vibration of the vocal folds, flexible and non-muscular tissues of the larynx undergo biomechanical fatigue. Additionally, due to the deformation of lamina propria layer and shear stress at the ends of vocal fold tissue, vocal fold mucosa is subjected to mechanical stress at every vocal fold vibration cycle (Solomon, 2008).

At elevated pitch levels, lengthening of vocal folds occurs in the anterior-posterior direction and results in tensile stress. Other forms of stress which are observed in the laryngeal system include contact stress (occurs when vocal folds approximate) and inertial and collision stress (happens when vibratory regions of the vocal folds come into contact).

Another factor that contributes to vocal fold fatigue is viscosity. Tissue viscosity is determined by the extracellular fluid composition and the cellular

environment. The viscous nature of the vocal folds helps to maintain lubrication as well as acts as shock absorbers. Reduced hydration can result in increased heat diffusion and elevated tissue viscosity. In turn, it increases tissue strain and results in tissue fatigue.

Centrally mediated factor includes a **sense of effort**. When activation at the peripheral nervous system falls to a suboptimal rate, it results in a decline in performance, which is reflected as central (or mental) fatigue. Mental fatigue is then perceptually identified to be of increased endeavor. This particular factor has been studied in vigor among professional voice users. Central fatigue cannot be determined or measured through direct measures. Assessment of central fatigue is often done using rating scales and questionnaires (Solomon, 2008).

Singers undergo extensive periods of practice and fine-tune their laryngeal system to produce an optimal voice. Long concerts, singing for extended durations, reduced consumption of water, misuse of voice by singing at high pitch for long durations, consumption of caffeine and caffeine products, performance pressure, elevated levels of anxiety and stress before the performance are few vocal and non-vocal practices exhibited by singers. These characteristics can further lead to the development of vocal fatigue, as explained earlier by the neuromuscular and biochemical factors.

To summarize, singing at inappropriately high or low pitches will lead to elevated laryngeal muscle tension, thus leading to vocal fatigue (Colton et al., 2011; Sander & Ripich, 1983).

1.5 Measures to study vocal fatigue

Studies have attempted to document changes in vocal function under conditions of experimentally inducing vocal fatigue using auditory perceptual, acoustic, laryngoscopic, videostroboscopic and aerodynamic findings on phononormals to illustrate the onset and progression of vocal fatigue (Balasubramaniam et al., 2015; Laukkanen et al., 2008; Xue et al., 2019; Yiu & Chan, 2003). However, these findings cannot be extrapolated to pathological vocal fatigue as it is more realistically challenging.

Table 1

Summary of studies reporting various changes in measures of vocal fatigue.

Auditory perceptual measures	No changes in the listener's perception of vocal fatigue prior to and following the vocal loading task (Stone & Sharf, 1973).
Acoustic measures	Mixed findings have been reported with few authors claiming that vocal loading tasks lead to an increase in fundamental frequency (Gelfer et al., 1991; Vilkman, et al., 1999) and few others suggesting that there is reduction in F_0 (Kooijman et al., 2005; Niebudek-Bogusz et al., 2006). Jitter and shimmer values do not provide clear evidence for acoustic changes following vocal loading task.
Aerodynamic measures	Aerodynamic measures provide promising

results as it gives information regarding the interaction of laryngeal and respiratory subsystems.

The most commonly studied measure is Phonation threshold pressure (PTP). It can detect slight effects during vocal loading tasks. Increased PTP values have been reported for high pitches following vocal loading tasks (Chang & Karnell, 2004; Solomon et al., 2003). PTP, to a certain degree, correlates to self-perceived sense of effort.

Laryngeal appearance

Edema and atypical glottis configuration such as the presence of anterior glottic chink and spindle-shaped glottis have been observed after vocal loading tasks (Solomon et al., 2003).

Though several studies have investigated vocal fatigue using different measures, it is also essential to obtain the self-perceived symptoms of vocal fatigue as it is a reliable indicator for monitoring the vocal health and aids in identification of vocal fatigue. Several self-assessment tools for assessing vocal symptoms and fatigue are available, but it includes items that indirectly assess spoken vocal fatigue. Few of such tools include Voice Handicap Index (VHI) (Jacobson et al., 1997), the voice-related quality of life (V-RQOL)(Hogikyan & Sethuraman, 1999), voice rating scale (Wingate et al., 2007), vocal effort scale (Wingate et al., 2007), vocal performance questionnaire (Deary et al., 2004), voice symptom scale (Deary et al., 2003),

Perceived Phonatory Effort (PPE), Perceived Vocal Tiredness (PVT), Vocal Fatigue Handicap Questionnaire (VFHQ) (Paolillo & Pantaleo, 2015) and Evaluation Of Ability To Sing Easily (EASE) (Phyland et al., 2013). These tools do not directly assess vocal fatigue but have items that indirectly refer back to symptoms of vocal fatigue. Standardized assessment tools such as Voice Handicap Index (VHI) (Jacobson et al., 1997) and the voice-related quality of life (V-RQOL) (Hogikyan & Sethuraman, 1999) are not sensitive to identify and rate vocal fatigue. The number of quantifiable indicators of vocal fatigue is limited.

Vocal Fatigue Index (VFI), originally developed by Nanjundeswaran et al. (2015), is a standardized tool used to differentiate individuals with and those without vocal fatigue. It has the following constructs of vocal fatigue- tiredness of voice and avoidance of use, physical discomfort, and improvement of voice symptoms with rest. VFI-2 is a modification to VFI, which includes 19 items. Due to the reduced item-to-total correlations, two items from the original Vocal fatigue index were excluded. The revised VFI-2 serves as an effective tool for identifying self-reported improvements in voice after voice rest and could be utilized to evaluate the impact of voice therapy on vocal endurance. The questionnaire has good test-retest reliability and high sensitivity and specificity ratings for identifying people with and without vocal fatigue. It may be used across various clinical groups to track symptom progression and change as a result of voice therapy. Also, incorporation of three factors, i.e., tiredness of voice and avoidance of use, physical discomfort and improvement of voice symptoms with rest guides the clinician to study, diagnose and treat several underlying mechanisms which include laryngeal muscular pathology vs. laryngeal tissue fatigue.

1.6 Need for the study

Vocal fatigue is the initial symptom noted before the onset of any vocal pathology. It has been documented in research that Carnatic singers often hesitate from seeking medical help from a specialist for their voice problem (Boominathan et al., 2008; Devadas et al., 2020). In recent times, there has been an increase in the number of Carnatic singers in the industry, thus necessitating the need for studying the impact of singing practice on voice. Improper training would be accompanied by mislearning of singing techniques and ultimately increases the occurrence of vocal fatigue. A majority of Carnatic singers share their origin from India and thus make it essential to study vocal fatigue among them. Although there have been studies done using VFI in the western population, data on Indian population is limited.

In most of the cases, vocal fatigue is perceptually identified by an individual before the onset of voice problems. Thus, it helps in early identification and prevention of probable voice problems. It is essential for professional voice users to know what levels of vocal fatigue is considered typical and what level is considered as 'at risk' and requires them to seek professional help. Hence, the current study aimed to investigate the presence of vocal fatigue among trained Carnatic singers in South Indian population.

CHAPTER II

REVIEW OF LITERATURE

The groups of individuals who depend greatly on their optimal voice quality are called professional voice users. They include actors, singers, teachers, call center advisors, lawyers and clergy etc (Koufman & Isaacson, 1991). The amount of voice usage, demands on voice, presence of stress, occupational demands and extent of travel would vary among the different classes of professional voice users. However, all of them are equally dependent on vocal endurance. Professional voice users have an increased load on their vocal mechanism, which often leads to voice problems (Phyland et al., 1999).

2.1 Professional Singers

Singers have been considered as the most demanding vocal group among other professional voice users. They constitute as Elite professional voice users and are economically dependent on their voice for their source of income. They could be referred as 'vocal athletes' because they perform complex maneuvers which requires their vocal mechanism to have adequate flexibility and good endurance ability (Phyland & Miles, 2019).

Singers undergo extensive practice sessions and vocal training to refine their voice which often results in vocal loading. Studies have reported that increased vocal loading is one of the important factors for the development of dysphonia among professional voice users (Phyland & Miles, 2019; Remacle et al., 2012). They are also predisposed to stress related to their voice more than non-singers (Braun-Janzen & Zeine, 2009). Additionally, they often engage in excessive vocal abusive behaviours

such as talking in a loud voice for extended periods of time, singing at extremely low/high-pitched voice, style of singing and poor vocal hygiene habits which can lead to voice problems (Arunachalam et al., 2014; Sapir, 1993). Various other factors which can contribute to increased risk include the environment in which the singer is performing, exposure to smoke and chemicals, exposure to an air conditioner, consecutive concerts and stage performances, singing extensively for longer periods, use of incorrect technique, singing or talking over a noisy situation and under stress (Arunachalam et al., 2014).

Singers constitute as the most vulnerable population for the incidence of voice disorders. A systematic review and meta-analysis conducted in 2017 reviewed the self-reported voice problems in singers. It was reported that the overall prevalence of dysphonia was higher in singing teachers (55.15%), followed by nonclassical singing styles such as popular music singers (46.96%) and classical singers (40.53%) (Pestana et al., 2017). Major complaints reported by singers included difficulty in projecting voice, soreness, dryness of throat, tightness or pain in throat, increased effort to produce voice, difficulty in singing extreme high/low pitches, strain, change in the quality of voice and vocal fatigue (Arunachalam et al., 2014; Kitch & Oates, 1994).

2.2 Vocal fatigue

Vocal fatigue is a phenomenon resulting from muscle/tissue fatigue and indicated by elevated effort to produce voice with increased duration of voice use and improves with rest. It has been reported in literature that biochemical and neuromuscular changes influence the development of vocal fatigue. Long term usage of voice can result in exhaustion of peripheral nerves, laryngeal and respiratory muscles, further resulting in poor voice quality. This phenomenon is termed as

neuromuscular fatigue. Extensive use of voice for longer durations can deform tissues of the laryngeal system (lamina propria layer of the vocal fold) and further lead to inertial and collision stress at high pitches. Viscosity of the vocal fold layers also plays an essential role in maintaining the integrity of vocal fold function. Dehydration can lead to increased strain to the laryngeal tissues. The previously mentioned factors can be categorized under peripherally mediated factors for vocal fatigue. Predisposition to psychological stress and mental fatigue are also identified as contributors to vocal fatigue (Solomon, 2008).

Few critical indicators for vocal fatigue include decreased pitch and loudness range, increased strain while speaking, pain in the neck and shoulders, worsening of voice by the end of day (Dodderi et al., 2021). Few other symptoms documented in literature include reduced breath support, hoarseness and strained voice quality, lack of flexibility in vocal range (Heidel & Torgerson, 1993; Sapir, 1993).

2.3 Vocal fatigue in Professional voice users

Vocal fatigue has been studied in professional voice users such as teachers (Hunter & Banks, 2017; Sivasankar, 2002), beatboxers (Dodderi et al., 2021), prospective vocal professionals (Anand et al., 2019), actors and speech-language pathologists.

Stemple (1985) contemplated that nearly all voice disorders would exhibit laryngeal fatigue. Further, in 1993, he discussed that the fatigue would result in incomplete closure of vocal folds and results in greater air escape. Therefore, it requires greater air pressure to maintain phonation.

In a retrospective study, Eustace et al., (1996), studied the acoustic and aerodynamic measures (F0, airflow volume and rate, Maximum Phonation Time and jitter) and videostroboscopic measures for vowels /a/,/i/ and/u/ for 88 patients within the age range of 20-79 years who reported with the complaint of vocal fatigue. They observed an increased airflow rate, decreased MPT, and abnormal glottic configurations (anterior, posterior and spindle-shaped glottis chinks) in the participants. The study did not find any relationship between abnormal pitch and laryngeal fatigue in contrast to Koufman & Blalock(1988) and Sander & Ripich(1983) who reported that individuals with fatigue experience difficulties at the extreme ends of the pitch range. Another limitation of this study was that it included patients above the 40 years of age. Age can contribute to physiological changes (calcification of cartilages and bowing of vocal folds that could lead to glottis chinks), resulting in changes in voice quality and respiratory measures (reduced MPT).

Kitch & Oates (1994) utilized retrospective self-reported questionnaire on 10 actors and 10 singers to investigate the perceptual features of vocal fatigue. Actors reported to have difficulty in projecting their voice and rated 'power' aspects to be most affected by vocal fatigue. In contrast, singers reported their voice to be affected in vocal dynamics, pitch range, flexibility and difficulty in achieving optimal quality. They also reported experiencing muscle tension in the throat, neck and jaw during an episode of vocal fatigue.

Boominathan et al. (2008) conducted a study on 400 professional voice users that included singers, teachers, politicians and vendors with 100 participants in each subgroup. The prevalence of voice problem, frequency of occurrence and vocal hygiene practices were studied with the use of a questionnaire. The questionnaire comprised of open-ended as well as forced choice questions (Yes/No). Results

revealed that 48% of politicians and 44% of vendors reported to have voice problems frequently. The reason for this finding could be attributed to intense and adverse work conditions (exposure to smoke and pollution). On the contrary, singers (37%) and teachers (47%) reported that they experienced voice problems occasionally and the explanation for this finding could be linked to the training they received for their voice use. It was reported that all the subjects were engaged in throat clearing, speaking at loud volume for longer durations. They accounted that 70% of singers did not seek professional help for the voice problem even after a week of the vocal symptoms and suggested the reason for the same to the insufficiency of awareness about the problem. Vocal fatigue was accounted to be the most common symptom reported by singers with vocal problems.

Koufman & Blalock (1988) investigated 67 professional voice users (Level I and Level II) who reported laryngeal musculoskeletal tension. They were diagnosed to have laryngeal tension-fatigue syndrome (TFS) and referred to it as 'Bogart- Bacall syndrome'. It is characterized by fluctuating voice quality which gets worse with strain and is often associated with lower speaking fundamental frequency and difficulty to maintain breath support. They also found out that trained professionals (Level I) had developed tension fatigue due to the production of low-pitched voice whereas, untrained professionals (Level III) are prone to develop TFS as a result of muscle tension.

2.4 Vocal fatigue in Singers

Although the duration of voice usage is higher for teachers and actors than singers, the latter group has increased demands to fulfill in a relatively short period. Similarly, the level of mental stress is higher for singers as they have to satisfy the

audience's expectations during a performance. Frequency of travel is also another contributing factor to vocal fatigue among singers. Reduced humidity, increased risk of air-borne infections and lack of adequate rest add on to vocal fatigue (Timmermans et al., 2005).

Gelfer et al.(1991) studied the effect of induced vocal load on trained and untrained female singers. Pre- and post-test measures were obtained by the production of isolated vowels /a/, /i/ and /u/. Subjects were asked to read aloud for 1 hour and sing the 'The Star- Spangled Banner'. They documented that jitter ratio and shimmer values decreased slightly in trained singers, thus suggesting that one hour of loud phonation might not be vocally challenging for singers who undergo vigorous practice sessions on a daily basis. On the other hand, untrained singers displayed an increase in F0 and poor SNR values, indicating that prolonged voice usage negatively affects their vocal function.

The amount of training, nature of training and demands placed on the vocal mechanism varies among singers. The prevalence of voice impairment, disability, and handicap was studied by Phyland et al. (1999) among three groups of singers- musical theatre, opera, contemporary (excluding rock music) and non-singers. They designed a questionnaire to assess singer's vocal behaviours, vocal health and experience for 1 year. It was divided into 2 sections of singing and speaking voice in which the participants were asked to identify if they had experienced the symptom, and if yes, they were asked to rate it on a 5- point Likert scale. They reported that singers experienced more episodes of voice disorders such as oedema and laryngitis than non-singers and concluded that singers reported increased prevalence of vocal disability and handicap over the last 12 months. However, they did not find any significant changes among the three styles of singing.

Prevalence of self-reported voice problems among 190 Carnatic singers and singing teachers was investigated using a questionnaire by Devadas et al (2020). They reported that 35% of Carnatic singers experienced voice problems in their career and 23 % of the singers reported that they experienced recurrence of voice problems since the onset of vocal pathology. They also accounted that 81 % of Carnatic singers reported vocal fatigue as the prevailing symptom and documented that it results from several phonotraumatic behaviors (talking for extended durations, singing at louder intensities and increased jaw and laryngeal muscle tension during singing) exhibited by singers.

Arunachalam et al.(2014), conducted a study on the complaints reported by 45 Carnatic singers who visited a tertiary care center in Chennai and complaints reported were voice change, dry throat, and difficulty in singing higher pitches and vocal fatigue as the chief complaints. Inadequate knowledge of vocal behavior and incorrect use of techniques to project their voice are major risk factors for developing voice problems in professional voice users. Singers reported an average duration of 6 months for which they experienced vocal fatigue. It was concluded that singers took part in singing for longer durations, had poor eating schedule and exhibited frequent throat-clearing habits.

The literature mentioned above supports the notion that singers experience a significant amount of vocal fatigue and thus it is imperative to monitor the vocal and non-vocal habits. Doing so would reduce the risk of voice problems.

2.5 Vocal Fatigue Index (VFI)

There are several methods to measure vocal fatigue- Auditory perceptual (Stone & Sharf, 1973), acoustic (Gelfer et al., 1991; Kooijman et al., 2005; Vilkman et al., 1999), laryngoscopic (Solomon et al., 2003) and, aerodynamic findings (Chang & Karnell, 2004; Solomon et al., 2003). Yet, the most consistent measure is the self-perception of symptoms by the individual.

Vocal Fatigue Index- 2 (VFI-2), a 19- item questionnaire developed by Nanjundeswaran et al. (2015), was used to evaluate vocal fatigue. VFI-2 consists of 19 items that focus on assessing vocal fatigue symptoms and is distributed into three factors. Factor 1 consists of 11 questions (cut-off score for vocal fatigue ≥ 24) and Factor 2 (cut-off score for vocal fatigue ≥ 7) consists of 5 questions are worded negatively and therefore, a higher score indicates greater vocal fatigue. On the contrary, Factor 3 consists of 3 questions (cut-off scores for vocal fatigue ≤ 7) are worded in a positive manner; therefore, a lesser score indicates that vocal fatigue does not improve with rest. All three factors are conceptually different from one another, and therefore, a total score is not obtained.

Vocal Fatigue Index- 2 (VFI-2) focuses on assessing vocal fatigue symptoms and is distributed into three factors. Factor 1 consists of 11 questions (cut-off score for vocal fatigue ≥ 24) which includes statements related to general tiredness of voice and avoidance of voice usage and Factor 2 (cut-off score for vocal fatigue ≥ 7) consists of 5 questions which incorporates statements about physical discomfort associated with voice use. Statements of Factor 1 and Factor 2 are worded negatively and therefore, a higher score indicates greater vocal fatigue. On the contrary, Factor 3 consists of 3 questions (cut-off scores for vocal fatigue ≤ 7) contains items relating to the

improvement of fatigue after a period of rest. Here, statements worded in a positive manner; therefore, a lesser score indicates that vocal fatigue does not improve with rest. All three factors are conceptually different from one another, and therefore, a total score is not obtained.

Vocal fatigue was studied by Keren and Yeshoda (2019) on 100 teachers who were categorized into five groups (Kindergarten, primary teachers, secondary teachers, higher secondary teacher and, physical education teachers). All the teachers were recruited from private schools located in Chennai, Tamil Nadu. The study aimed at exploring the vocal fatigue symptoms reported by different levels of school teachers. VFI-2 was utilized to analyze the self-reported symptoms of teachers. The scores of VFI-2 were analyzed statistically for each factor and to check for gender differences. Results revealed that kindergarten teachers had significantly higher scores than the other groups for Factor 1 and 2. On the other hand, secondary, higher secondary and physical education teachers had obtained higher scores than kindergarten teachers for Factor 3, which could be attributed to the fact that they engage in vocally exhaustive tasks such as group play activities and provide verbal instructions at a louder voice. Gender differences were analyzed in higher secondary, secondary and physical education teachers. Male teachers had obtained significantly higher scores for factor 3 than female teachers in Higher secondary. This reveals that female teachers experience and rated worse self-percept of vocal fatigue than male teachers.

Anuroopa and Yeshoda (2020) conducted a similar study to explore the vocal fatigue among theatre artists. Thirty theatre artists (age range between 20 and 45 years), with an equal distribution of males and females were chosen from Karnataka's well-recognized institutions. Theatre artists have to perform several vocal activities

such as displaying several emotions while enacting in a play or during rehearsals, resulting in abuse and overuse of their voice. Such practices when accompanied with poor vocal hygiene habits can result in vocal fatigue. VFI-2 was administered directly and through electronic modality (for participants who resided in different parts of the state). Statistical analysis revealed that females had higher cut-off scores than males for Factor 2 and were classified into vocal fatigue group. On the other hand, Factor 3 documented higher cut-off scores for both males and females referring to the fact that there is an improvement of vocal fatigue symptoms after a period of rest. However, the scores obtained by theatre artists was not sufficient to classify them into vocal fatigue group. The authors suggest that effective voice training and practice of appropriate vocal habits could explain the findings.

Beat boxers are professional voice users who alter their voice to mimic sounds of animals and musical instruments. This art form is often self-learned and is improvised by trial and error method of learning. Dodderi et al. (2021) studied vocal fatigue in Beat boxers. Vocal fatigue was studied on 37 beatboxers, 40 avocational singers (included choral and contemporary western singers) and 40 non singers (included undergraduate and postgraduate students of commerce and management areas) using Vocal fatigue Index (VFI). Additionally, participants were asked to answer a question 'Do you have vocal fatigue?' to check for self-awareness for which participants had to choose yes, no or do not know. Data was collected through an online survey mode (Google form). They were asked to rate using 0-4 rating scale on the basis of how frequently they experienced the symptoms mentioned in the statements. Results were analyzed for each factor constituting under the VFI. They reported that avocational singers obtained higher rating for factors 1 and 2 in comparison to beat boxers and non-singers who exhibited lowest scores on VFI. Non

singers had highest VFI scores in factor 3 in comparison to the other two groups. Participant's self-awareness of vocal tiredness was also analyzed which revealed that avocational singers (72.5 %) had higher score than beatboxers (48.6 %). Non singers (27.5%) had obtained the least score for self-awareness of vocal fatigue.

2.6 Aim of the study

To explore the self-reported symptoms of vocal fatigue among trained Carnatic singers using Vocal Fatigue Index (VFI)- Version 2.

2.7 Objectives of the study

- To estimate the extent of vocal fatigue prevalent among trained Carnatic singers using Vocal Fatigue Index (VFI)- Version 2.
- To check for gender differences, if any, in the VFI scores among trained Carnatic singers.

CHAPTER III

METHOD

3.1 Participants

A total of thirty trained professional Carnatic singers (15 males and 15 females) from Southern part of India between 21 and 40 years of age (mean age of 25.73 years) participated in the cross-sectional survey. Participants were recruited by snowball sampling method.

3.1.1 Inclusion and Exclusion criteria

Carnatic singers who completed a minimum of 3 years of vocal training, actively engaging in singing, literate in English and who had a basic knowledge of using Google form were included in the present study.

Participants with a history of speech, language, hearing, or cognitive deficits and those with active respiratory tract infections were excluded from the study.

3.2 Material used

Vocal Fatigue Index Version-2 (VFI- 2), originally developed by Nanjundeswaran et al.(2015)was chosen for this study. The tool consists of 19 questions categorized into 3 factors, namely, Factor 1 that included statements relating to tiredness of voice and avoidance of voice use, Factor 2 has statements describing the physical discomfort associated with voice use and, Factor 3 includes statements that indicate improvement of voice symptoms with rest. Rating is based on five- point Likert scale in which '0' represented 'Never' and '4' represented 'Always' as

the end points. A score of '1' corresponded to 'Almost never', '2' corresponded to 'Sometimes' and '3' corresponded to 'Almost always'.

3.3 Procedure

The current study was conducted by adhering to the ethical and COVID- 19 guidelines provided by the institute's research committee. The participants were personally contacted through telephone call and information regarding the purpose, aims, and procedure of the study were explained in detail. The consent to participate in the study was collected verbally during the phone call.

The data was collected via Google form. The Google form was divided into three sections: informed consent and demographic details, singing-related information and statements from Vocal Fatigue Index –Version 2 (VFI-2). The link to the Google form was sent to the participants who agreed to participate through communication platform- WhatsApp and Gmail.

In the first section, demographic details of the participants were collected along with the consent form for the study. Consent was collected in the form of Yes/No question to document their compliance to participate in the study.

The second section included questions which profiled the vocal and non-vocal habits, such as years of experience, average hours of practice in day/and week, average talking hours in a day, average duration of speaking on phone, and the average amount of water consumed in a day.

The last section included statements from the VFI- 2. Participants were instructed to indicate how frequently they experienced the symptoms given in the statements. The rating for these statements was based on a scale from 0 to 4 where '0'

indicated 'Never' and '4' indicated 'Always'. Following the completion of the responses, the participants were asked to 'Submit the form'.

Out of 30 participants, 2 participants (one male and one female) were randomly selected and were instructed to repeat the Google form after 2 weeks of initial response collection to ensure response reliability.

3.4 Analysis

The completed responses were tabulated in a spreadsheet and total scores for each factor were calculated and analyzed using Statistical Package for Social Studies (SPSS) Version 20.0. Scoring was done separately for each factor and further descriptive statistics was carried out to calculate mean and standard deviation of factor wise scores of VFI. Inferential statistics was done to identify gender differences in VFI scores.

CHAPTER IV

RESULTS

The aim of the present study was to explore the self-reported symptoms of vocal fatigue among professional Carnatic singers (15 males and 15 females) using Vocal Fatigue Index- Version 2. Statistical analysis was carried out using SPSS Version 20.0 to analyze the responses procured during the data collection.

The following tests were carried out to analyze the data.

1. Shapiro Wilk test of normality
2. Descriptive analysis of factor wise responses
3. Mixed ANOVA to determine within subject and between subject variations
4. Independent t test to assess gender differences
5. Correlation analysis

4.1 Results of normality

Shapiro-Wilk test of normality was used to check for the normal distribution of data. Table 2 depicts the data which reveals that all the factors, Factor 1 (general tiredness of voice), Factor 2 (symptoms of physical discomfort related to voicing) and Factor 3 (improvement of symptoms with rest) are normally distributed in both male and female populations.

Table 2*Results of Shapiro Wilk's Normality test*

Factors	Gender	Statistic W	Degree of freedom	Significance
Factor 1	Male	0.877	15	.001
	Female	0.944	15	.436
Factor 2	Male	0.910	15	.133
	Female	0.957	15	.634
Factor 1 and 2	Male	0.896	15	.084
	Female	0.957	15	.639
Factor 3	Male	0.903	15	.106
	Female	0.894	15	.078

The results are discussed under the following sub-headings.

- Self-reported symptoms of vocal fatigue in male and female Carnatic singers.
- Factor-wise comparison of scores between male and female Carnatic singers
- Within- and between-subject effects of Factors and Gender in Carnatic singers
- Correlation between factors and vocal and non-vocal habits in Carnatic singers.

4.2 Self-reported symptoms of Vocal Fatigue in male and female Carnatic singers

Cross-tabulations of the responses for each factor were carried out separately using SPSS software. Table 3 depicts the responses for male Carnatic singers. For Factor 1(tiredness with voice use), most frequently reported symptoms included tiredness with the use of voice, hoarseness in voice, limited period of voice use, avoidance of social situations and inability to talk to family after a period of voice

use. Effort to produce voice, weakness in voice after a period of usage and difficulty to project voice were among the less frequently reported symptoms.

Table 3

Cross-tabulation of factor wise responses in male Carnatic singers

VFI Question	Never	Almost never	Sometimes	Almost always	Always
Factor 1					
VFIQ1	3	2	6	3	1
VFIQ2	2	4	4	5	0
VFIQ3	3	4	5	2	1
VFIQ4	5	2	5	1	2
VFIQ5	4	2	5	2	2
VFIQ6	2	0	4	7	2
VFIQ7	3	1	3	7	1
VFIQ8	4	3	8	0	0
VFIQ9	2	3	5	5	0
VFIQ10	4	4	4	3	0
VFIQ11	3	4	5	3	0
Factor 2					
VFIQ1	8	2	5	0	0
VFIQ2	7	2	6	0	0
VFIQ3	6	4	3	2	0
VFIQ4	6	3	6	0	0
VFIQ5	9	0	5	1	0
Factor 3					
VFIQ1	1	2	5	7	0
VFIQ2	2	1	3	4	5
VFIQ3	1	1	5	4	4

Under Factor 2 (physical discomfort with voice usage), less commonly reported symptoms in male Carnatic singers were pain and discomfort in the neck with voice usage. However, throat ache and experience of throat pain in the evening were frequently reported by the singers. In Factor 3 (improvement of symptoms with

rest), male Carnatic singers reported that their voice feels better and required reduced effort to produce voice after a period of rest.

Table 4

Cross-tabulation of factor wise responses in female Carnatic singers

VFI Question	Never	Almost never	Sometimes	Almost always	Always
Factor 1					
VFIQ1	2	3	8	2	0
VFIQ2	0	6	7	1	1
VFIQ3	5	5	4	1	0
VFIQ4	2	3	9	1	0
VFIQ5	5	6	4	0	0
VFIQ6	3	5	7	0	0
VFIQ7	8	5	2	0	0
VFIQ8	5	5	5	0	0
VFIQ9	3	4	6	2	0
VFIQ10	5	3	5	2	0
VFIQ11	3	4	6	1	1
Factor 2					
VFIQ1	4	6	4	1	0
VFIQ2	4	4	5	1	1
VFIQ3	2	6	6	0	1
VFIQ4	3	4	7	1	0
VFIQ5	4	4	7	0	0
Factor 3					
VFIQ1	0	7	2	6	0
VFIQ2	1	0	7	3	4
VFIQ3	1	0	6	3	5

Similarly, Table 4 depicts the cross-tabulation responses by female Carnatic singers. The data reveals that in Factor 1, which is the general tiredness and avoidance of voice use, the most frequently reported symptoms were hoarseness of voice, inability to use voice after a period of voice usage, exhaustion of voice and limited talking after a period of voice usage. Less frequently reported symptoms include

avoiding social situations, difficulty to project voice and an increased sense of effort after a period of voice use.

As observed in Table 4, Factor 2 recorded soreness, throat ache and discomfort in the neck region with voice use as the most commonly reported symptoms among female Carnatic singers. Less frequently reported symptoms were pain in the neck and throat pain at the end of the day with voice usage.

In Factor 3, most singers reported betterment of voice and decreased effort to produce voice with rest.

4.3 Factor-wise comparison of scores between male and female Carnatic singers

Chi-square test could not be administered as the frequencies of responses for each item were less than 5 and the criteria for using chi-square test were not fulfilled. Therefore, descriptive statistics was carried out and the results are shown in Table 5.

Table 5

Mean, median and standard deviation for Factor wise VFI scores for the participants.

	Maximum score	Gender	N	Mean	Standard deviation	Median
Factor 1 total	44	Male	15	19.13	10.25	22.00
		Female	15	14.20	6.01	13.00
		Total	30	16.67	8.63	18.00
Factor 2 total	20	Male	15	4.66	4.15	4.00
		Female	15	6.66	4.46	8.00
		Total	30	5.66	4.35	5.00
Factor 1 and 2 total	64	Male	15	23.80	13.25	27.00
		Female	15	20.86	9.95	20.00
		Total	30	22.33	11.61	23.50
Factor 3 total	12	Male	15	8.40	2.84	10.00
		Female	15	8.26	3.03	8.00
		Total	30	8.33	2.89	9.00

The above table reveals that mean scores of Factor 1 and combined total of Factor 1 and 2 were higher in males than females and mean score of Factor 2 are higher in females than males. The mean scores of Factor 3 were similar for both male and female participants.

4.4 Within- and between-subject effects of Factors and Gender in Carnatic singers

Mixed ANOVA was carried out to analyze the within subject effects for Factor 1 and Factor 2 with gender to determine between-subject effect as presented in table 6. Results revealed that the scores are statistically significant ($F = 9.687$, $p < 0.05$) for Factor 1 percentage and Factor 2 percentage. As the raw scores for Factor 1 and Factor 2 were different, they could not be integrated for analysis, therefore, percentage values were chosen.

Gender differences were also analyzed and it was found that there was no statistical significance ($F = 0.008$, $p > 0.05$) between males and females. Furthermore, interaction effects was studied which revealed that there was an interaction effect observed between factors and gender and, the values were statistically significant ($p \leq 0.05$).

Table 6

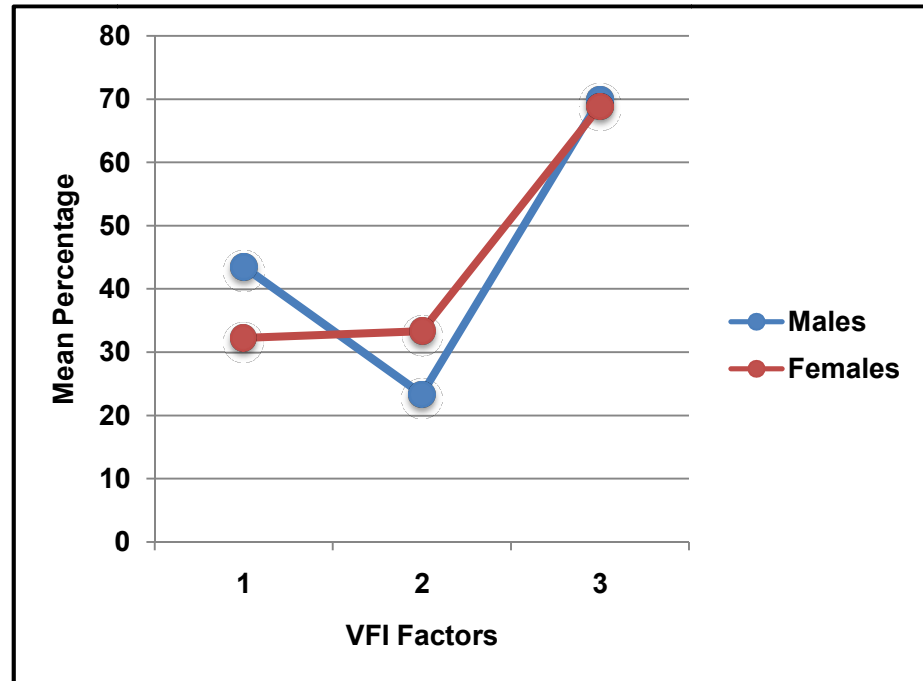
F and significance values of Factors (within-subject effects) in males and females (between-subject effects)

Group	F	Sig.	Effect size
Factors	9.687	.004*	.257
Gender	.008	.929	.000
Factors*Gender	11.959	.002*	.299

Note. *Significance value < 0.05

Figure 1

Percentage values for factor-wise scores of VFI and interaction effects of factors and gender



As observed in Figure 1, Factor 1 had higher mean percentage scores for male Carnatic singers and female Carnatic singers had a higher mean percentage for Factor 2. The mean percentage values for Factor 3 were similar for both male and female groups. Interaction effects were seen but the differences are not significant.

Independent t-test was carried out to analyze the gender based differences for the combined total percentage of Factor 1 and 2 and Factor 3 percentage. There was no significant difference as observed in table 7. Here, Factor 3 percentage was analyzed separately as the scoring and interpretation for Factor 3 was different from scoring of Factor 1 and 2. Therefore, they could not be compared during statistical analysis.

Table 7

Results of independent t test for gender comparison in Factor 3 and combined percentage of Factor 1 and 2.

Group	T	Sig.
Factor 1 and 2 percentage	-0.685	.499
Factor 3 percentage	-.124	.902

4.5 Correlation between vocal and non-vocal habits and Factors in VFI

Table 8

Correlation between Factors and hours of singing in a day

Factors	P	Significance
Factor 1	-.467	.009*
Factor 2	-.367	.046*
Factor 1 and 2	-.495	.005*
Factor 3	-.283	.130

Note. *p < 0.05

Spearman rho correlation was carried out to assess correlation between the factors and vocal and non-vocal habits such as years of experience, average number of singing days in a week, average hours of practice in day/and week, average talking hours in a day, average duration of speaking on phone, and the average amount of water consumed in a day.

Results revealed that there was significant weak negative correlation for Factor 1, Factor 2 and combined total of Factor 1 and 2 and the number of days they sing in a week as observed in Table 8.

The other domains did not have a significant correlation with VFI Factors.

The reliability of responses was tested by comparing the total scores obtained in each factor, which were found to be similar for one male and one female participant.

The following paragraph summarizes the key findings of the current research. Cross-tabulation was used to document the self-reported vocal fatigue symptoms in male and female Carnatic singers. The frequently reported and less commonly reported symptoms of vocal fatigue were documented for each factor separately. Factor-wise comparison of scores between male and female Carnatic singers revealed that males had greater mean values for Factor 1 and a combined total of Factor 1 and 2. Females, on the other hand scored higher values for Factor 2. Both groups obtained similar scores for Factor 3. Within- and between-subject effects were analyzed which revealed significant differences between scores obtained for Factor 1 and 2. Findings revealed that Factor 3 and the combined total of Factors 1 and 2 were not significantly different. Between male and female Carnatic singers, there was no significant difference in VFI scores. However, there were significant interaction effects between the Factors and gender. There was significant correlation between Factor 1, Factor 2, combined total of Factor 1 and 2 and the number of days of singing in a week in Carnatic singers.

CHAPTER V

DISCUSSION

The focus of this study was to examine the symptoms of vocal fatigue among professional Carnatic singers. The findings of this study are presented, along with supporting and contradictory studies and the rationale behind them. For the purpose of ease of understanding, the findings are explained in the following sub-headings.

- Self-reported symptoms of vocal fatigue in male and female Carnatic singers
- Factor-wise comparison of scores between male and female Carnatic singers
- Within- and between-subject effects of Factors and Gender in Carnatic singers
- Correlation between factors and vocal and non-vocal habits in Carnatic singers

5.1 Self-reported symptoms of vocal fatigue in male and female Carnatic singers

Factor-wise responses were documented using cross-tabulations for male and female participants separately. For Factor 1, which represents statements regarding fatigue and avoidance of voice use, male Carnatic singers reported that they experience hoarseness of voice, tiredness, and difficulty to interact with family members after prolonged voice usage and restricted their voice use more frequently. Less commonly reported symptoms of vocal fatigue included weakness, trouble in projecting their voice and increased effort to produce voice.

Female Carnatic singers, on the other hand, frequently reported experiences of hoarseness in voice, exhaustion and a limited ability to talk for long periods of time under Factor 1. Less frequently reported symptoms included increased effort to

produce voice, avoidance of social situations and difficulty to project voice after a period of voice use.

The above mentioned symptoms may occur as a result of muscle group stiffness due to over-activation of muscle groups involved in vocalization and if enough time is not provided for recovery, it would result in structural and physiological changes (McCabe & Titze, 2002).

Statements of physical aspects of discomfort with voice use were covered under Factor 2. Neck pain and discomfort with voice use were among the less common concerns reported by male Carnatic singers. On the other hand, frequent complaints included soreness and throat ache in the evening.

Female Carnatic singers reported that they frequently experienced soreness, discomfort around the neck area, and throat irritation similar to the symptoms reported by males under Factor 2.

The findings given above are consistent with the results reported by Kitch & Oates (1994) who studied the self-reported symptoms of vocal fatigue on 10 actors and 10 singers.

Attempts to sing during episodes of fatigue would result in an increase in neuromuscular fatigue and muscle tension around neck, throat and jaw as these areas are functional during vocalization as well as singing. This could be the possible rationale for the physical discomfort experienced by individuals with vocal fatigue (Kitch & Oates, 1994).

Majority of the male and female Carnatic singers procured similar scores for Factor 3 implying that vocal fatigue gets better with rest. This outcome could be

justified by the fact that vocal rest has a prominent impact on the vocal folds and is protective in nature. Adequate voice rest along with hydration and the maintenance of proper vocal hygiene routine will aid in the recovery process after vocal exertion.

5.2 Factor-wise comparison of scores between male and female Carnatic singers

On calculation of the mean scores for each factor, it was observed that male participants had a higher mean value for Factor 1 and a combined total of Factors 1 and 2. Female participants, on the other hand, had a higher mean value for Factor 2. Factor 3 ratings were similar for both male and female Carnatic singers, suggesting faster recovery of vocal fatigue symptoms following a period of voice rest.

Increased pain sensitivity in females can be hypothesized as one of the reason for the increase in the mean scores for Factor 2 in female Carnatic singers. Similar justification was documented by Keren and Yeshoda (2019) who investigated the vocal fatigue among different levels of school teachers using Vocal Fatigue Index- 2.

Another study investigating the vocal fatigue among theatre artists by Anuroopa and Yeshoda, (2020) revealed that female theatre artists reported to have an increased mean score for Factor 1, Factor 2 and combined total of Factor 1 and 2. In contrast to our findings, they noted that males reported a higher score for Factor 3, implying betterment of vocal fatigue after voice rest. They hypothesized that female actors perceive greater mental stress during performances, which can be one of the rationale for the difference in the findings.

5.3 Within- and between-subject effects of Factors and Gender in Carnatic singers

Within-subject differences i.e., differences in scores between Factor 1 and Factor 2 percentages were noted and it was observed that they were statistically significant. Gender based differences for vocal fatigue was not observed in the findings of the present study. However, interaction effects between the VFI factors and gender was statistically significant. The findings of the current study are in contrary to the research documented in the literature. Researchers have reported that females are at higher risk of voice problems than males as the vocal system and mechanics of males and females differ from each other in terms of structure and physiology. Changes in vocal fold length, size and elastic properties of vocal fold are some of the contributing factors for the differences (Laukkanen et al., 2008).

5.4 Correlation between factors and vocal and non-vocal habits in Carnatic singers

Vocal fatigue can be influenced by several vocal and non-vocal habits, such as the duration and intensity of voice use, the frequency of abusive vocal practices such as screaming, speaking at loud volumes, singing for prolonged periods, and the maintenance of vocal hygiene (Arunachalam et al., 2014; Devadas et al., 2020).

In the present study, significant negative correlations were observed for Factor 1, Factor 2 and a combined total of Factor 1 and 2 and the duration of singing practice done in a day. To simplify, an increase in the amount of singing practice resulted in higher scores of vocal fatigue. The justification for this finding can be attributed to the amount of vocal training performed by the participants. Long hours of rehearsal and use of precise techniques may have also improved the vocal folds' capacity to endure

the vocal load. As a result, vocal folds may have evolved to withstand such long periods of singing practice during the day. The preceding argument is reinforced by findings from Scherer et al 1986, who studied vocal fatigue in a trained and an untrained voice user and reported that trained users are less prone to vocal fatigue.

Summary of the results:

- Frequently reported and less commonly reported symptoms of vocal fatigue among male and female Carnatic singers were documented by cross-tabulating factor-wise responses.
- On comparison between the mean scores of VFI, it was found that males had a higher mean value for Factor 1 and combined total of Factor 1 and 2. This implies that male Carnatic singers experience tiredness of voice and avoided the use of voice more often than female Carnatic singers. On the other hand, mean scores for Factor 2 was higher for female participants, thus suggesting that they experience symptoms of physical discomfort after voice use more frequently than male participants.
- The mean score of Factor 3 was similar in both groups of participants implying betterment of symptoms after a period of voice rest.
- Results of Mixed ANOVA revealed that the percentage VFI for Factor 1 and 2 were significantly different between each other. Factor 3 and a combined total of Factors 1 and 2 were not significantly different.
- There was no significant gender difference for VFI scores between male and female Carnatic singers.
- Interaction effects between the Factors and gender was present and was significantly different.

- There was significant correlation between Factor 1, Factor 2, combined total of Factor 1 and 2 and the number of days of singing in a week.

CHAPTER VI

SUMMARY AND CONCLUSION

Carnatic singers are professional voice users who depend exclusively on their voice for their livelihood. The style involved in singing Carnatic music demands long hours of rehearsal and extensive periods of training. However, such long sessions of practice and consecutive performances during concerts often leads to vocal fatigue and later, develops into voice problems. Acoustic, aerodynamic, laryngoscopic, and auditory perceptual measures are among some of the ways to detect vocal fatigue. However, the most reliable method would include the self-perceived report of vocal fatigue by the individual.

The present study aimed at investigating the self-reported symptoms of vocal fatigue in trained Carnatic singers using Vocal Fatigue Index- 2 (VFI-2). The objectives of the study were to explore the self-reported symptoms of vocal fatigue and to check for any gender differences. VFI-2 was administered to 30 participants aged 21-40 years (equal number of male and female Carnatic singers) through a Google form questionnaire. Demographic details, vocal and non-vocal habits and responses for statements of VFI-2 were collected using the questionnaire.

Results revealed that percentage VFI for Factor 1 and 2 were significantly different between male and female participants. There was no significant gender difference for VFI scores between male and female Carnatic singers. However, interaction effects between the three factors and gender was observed and it was statistically significant. Male participants had higher mean percentage values for Factor 1. On the other hand, female participants scored higher percentage values for Factor 2. Similar trends in percentage values were observed in both male and female

participants for Factor 3. There was significant correlation between Factor 1, Factor 2, combined total of Factor 1 and 2 and the number of days of singing in a week for all the participants. Neuromuscular fatigue, presence of increased mental stress prior to performances, adequate hydration and, increased endurance ability to tolerate higher vocal load were observed from the results in general. And these findings find support from the documented literature in professional voice users.

6.1 Clinical implications

- The current study provides information on the self-reported symptoms in trained Carnatic singers and will facilitate in counseling and educating professional voice users about vocal fatigue and vocal hygiene practices.
- It will guide clinicians in identifying the underlying processes, such as, laryngeal muscular and laryngeal tissue fatigue that could lead to developing voice problems.
- The tool can be used in therapeutic settings to monitor symptom development and document outcomes after voice therapy.

6.2 Limitations and future directions:

- Generalization of the findings of the current study must be done with caution as the sample size was limited to 30 participants. Larger sample sizes may be chosen for future studies to understand and explore the nature and extent of vocal fatigue and also representation of this population.
- Correlation of vocal fatigue among the different styles of singing in Indian population can be attempted in future studies.

REFERENCES

- Anand, S., Bottalico, P., & Gray, C. (2019). Vocal Fatigue in Prospective Vocal Professionals. *Journal of Voice*, 35 (2),247-258.
<https://doi.org/10.1016/j.jvoice.2019.08.015>
- Anuroopa, K.S., & Yeshoda K., (2020). Vocal fatigue in professional theatre artists as quantified by the Vocal Fatigue Index-Version 2. *Unpublished Master's Dissertation*, Submitted to University of Mysore, Mysore.
- Arunachalam, R., Boominathan, P., & Mahalingam, S. (2014). Clinical voice analysis of Carnatic singers. *Journal of Voice*, 28(1), 128-e1.
<https://doi.org/10.1016/j.jvoice.2013.08.003>
- Balasubramaniam, R. K., Shastry, A., Singh, M., & Bhat, J. S. (2015). Cepstral characteristics of voice in Indian female classical Carnatic singers. *Journal of Voice*, 29(6), 693-695. <https://doi.org/10.1016/j.jvoice.2015.01.002>
- Boominathan, P., Rajendran, A., Nagarajan, R., Seethapathy, J., & Gnanasekar, M. (2008). Vocal abuse and vocal hygiene practices among different level professional voice users in India: a survey. *Asia pacific journal of speech, language and Hearing*, 11(1), 47-53.
<https://doi.org/10.1179/136132808805297322>
- Braun-Janzen, C., & Zeine, L. (2009). Singers' interest and knowledge levels of vocal function and dysfunction: survey findings. *Journal of Voice*, 23(4), 470-483.
<https://doi.org/10.1016/j.jvoice.2008.01.001>
- Chakraborty, S., Mazzola, G., Tewari, S., & Patra, M. (2014). *Computational Musicology in Hindustani Music* (1st ed.). Springer Publishing.

- Chandrasekaran, J., Devi, H., Swamy, N., & Nagendra, H. (2005). Spectral analysis of Indian musical notes. *Indian Journal of Traditional Knowledge (IJTK)*, 4(2), 127-131.
- Chang, A., & Karnell, M. P. (2004). Perceived phonatory effort and phonation threshold pressure across a prolonged voice loading task: a study of vocal fatigue. *Journal of Voice*, 18(4), 454-466. <https://doi.org/10.1016/j.jvoice.2004.01.004>
- Colton, R. H., Casper, J. K., & Leonard, R. (2011). Understanding voice problem: A physiological perspective for diagnosis and treatment: Fourth edition. In *Understanding Voice Problem: A Physiological Perspective for Diagnosis and Treatment: Fourth Edition*. Wolters Kluwer Health Adis (ESP).
- Deary, I. J., Webb, A., MacKenzie, K., Wilson, J. A., & Carding, P. N. (2004). Short, self-report voice symptom scales: psychometric characteristics of the voice handicap index-10 and the vocal performance questionnaire. *Otolaryngology—Head and Neck Surgery*, 131(3), 232-235. <https://doi.org/10.1016/j.otohns.2004.02.048>
- Deary, I. J., Wilson, J. A., Carding, P. N., & MacKenzie, K. (2003). VoiSS: a patient-derived voice symptom scale. *Journal of psychosomatic research*, 54(5), 483-489. [https://doi.org/10.1016/S0022-3999\(02\)00469-5](https://doi.org/10.1016/S0022-3999(02)00469-5)
- Devadas, U., Kumar, P. C., & Maruthy, S. (2020). Prevalence of and risk factors for self-reported voice problems among Carnatic singers. *Journal of Voice*, 34(2), 303-e1. <https://doi.org/10.1016/j.jvoice.2018.09.013>
- D'haeseleer, E., Claeys, S., Meerschman, I., Bettens, K., Degeest, S., Dijckmans, C.,

- De Smet, J., Luyten, A. & Van Lierde, K., (2017). Vocal characteristics and laryngoscopic findings in future musical theater performers. *Journal of Voice*, 31(4), 462-469. <https://doi.org/10.1016/j.jvoice.2016.11.018>
- Dodderi, T., Johnson, A., & Aji, A. M. (2021). Vocal Fatigue in Beat Boxers. *Journal of Voice*. Advanced online publication. <https://doi.org/10.1016/j.jvoice.2020.11.019>
- Eustace, C. S., Stemple, J. C., & Lee, L. (1996). Objective measures of voice production in patients complaining of laryngeal fatigue. *Journal of Voice*, 10(2), 146-154. [https://doi.org/10.1016/S0892-1997\(96\)80041-5](https://doi.org/10.1016/S0892-1997(96)80041-5)
- Gelfer, M. P., Andrews, M. L., & Schmidt, C. P. (1991). Effects of prolonged loud reading on selected measures of vocal function in trained and untrained singers. *Journal of Voice*, 5(2), 158-167. [https://doi.org/10.1016/S0892-1997\(05\)80179-1](https://doi.org/10.1016/S0892-1997(05)80179-1)
- Heidel, S. E., & Torgerson, J. K. (1993). Vocal problems among aerobic instructors and aerobic participants. *Journal of communication disorders*, 26(3), 179-191. [https://doi.org/10.1016/0021-9924\(93\)90007-W](https://doi.org/10.1016/0021-9924(93)90007-W)
- Hogikyan, N. D., & Sethuraman, G. (1999). Validation of an instrument to measure voice-related quality of life (V-RQOL). *Journal of voice*, 13(4), 557-569. [https://doi.org/10.1016/S0892-1997\(99\)80010-1](https://doi.org/10.1016/S0892-1997(99)80010-1)
- Hunter, E. J., & Banks, R. E. (2017). Gender differences in the reporting of vocal fatigue in teachers as quantified by the vocal fatigue index. *Annals of Otology, Rhinology & Laryngology*, 126(12), 813-818. <https://doi.org/10.1177/0003489417738788>

- Jacobson, B. H., Johnson, A., Grywalski, C., Silbergleit, A., Jacobson, G., Benninger, M. S., & Newman, C. W. (1997). The voice handicap index (VHI) development and validation. *American Journal of Speech-Language Pathology*, 6(3), 66-70. <https://doi.org/10.1044/1058-0360.0603.66>
- Kitch, J. A., & Oates, J. (1994). The perceptual features of vocal fatigue as self-reported by a group of actors and singers. *Journal of Voice*, 8(3), 207-214. [https://doi.org/10.1016/S0892-1997\(05\)80291-7](https://doi.org/10.1016/S0892-1997(05)80291-7)
- Keren Oviya Babu, & Yeshoda K., (2019). Vocal fatigue using Vocal Fatigue Index (VFI) : A comparison among different levels of school teachers. *Unpublished Master's Dissertation*, Submitted to University of Mysore, Mysore.
- Kooijman, P. G., De Jong, F. I. C. R. S., Oudes, M. J., Huinck, W., Van Acht, H., & Graamans, K. (2005). Muscular tension and body posture in relation to voice handicap and voice quality in teachers with persistent voice complaints. *Folia phoniatrica et logopaedica*, 57(3), 134-147. <https://doi.org/10.1159/000084134>
- Kostyk, B. E., & Rochet, A. P. (1998). Laryngeal airway resistance in teachers with vocal fatigue: A preliminary study. *Journal of voice*, 12(3), 287-299. [https://doi.org/10.1016/S0892-1997\(98\)80019-2](https://doi.org/10.1016/S0892-1997(98)80019-2)
- Koufman, J. A., & Blalock, P. D. (1988). Vocal fatigue and dysphonia in the professional voice user: Bogart-Bacall syndrome. *The Laryngoscope*, 98(5), 493-498. <https://doi.org/10.1288/00005537-198805000-00003>
- Koufman, J. A., & Isaacson, G. (1991). The spectrum of vocal dysfunction. *Otolaryngologic Clinics of North America*, 24(5), 985-988. [https://doi.org/10.1016/s0030-6665\(20\)31062-8](https://doi.org/10.1016/s0030-6665(20)31062-8)

- Laukkanen, A. M., Ilomäki, I., Leppänen, K., & Vilkmann, E. (2008). Acoustic measures and self-reports of vocal fatigue by female teachers. *Journal of Voice*, 22(3), 283-289. <https://doi.org/10.1016/j.jvoice.2006.10.001>
- McCabe, D. J., & Titze, I. R. (2002). Chant therapy for treating vocal fatigue among public school teachers: A preliminary study. *American Journal of Speech-Language Pathology*, 11(4), 356-369. [https://doi.org/10.1044/1058-0360\(2002/040\)](https://doi.org/10.1044/1058-0360(2002/040))
- Nanjundeswaran, C., Jacobson, B. H., Gartner-Schmidt, J., & Abbott, K. V. (2015). Vocal Fatigue Index (VFI): development and validation. *Journal of Voice*, 29(4), 433-440. <https://doi.org/10.1016/j.jvoice.2014.09.012>
- Niebudek-Bogusz, E., Fiszer, M., Kotylo, P., & Sliwinska-Kowalska, M. (2006). Diagnostic value of voice acoustic analysis in assessment of occupational voice pathologies in teachers. *Logopedics Phoniatrics Vocology*, 31(3), 100-106. <https://doi.org/10.1080/14015430500295756>
- Paolillo, N. P., & Pantaleo, G. (2015). Development and validation of the voice fatigue handicap questionnaire (VFHQ): clinical, psychometric, and psychosocial facets. *Journal of Voice*, 29(1), 91-100. *Journal of Voice*. <https://doi.org/10.1016/j.jvoice.2014.05.010>
- Pestana, P. M., Vaz-Freitas, S., & Manso, M. C. (2017). Prevalence of voice disorders in singers: systematic review and meta-analysis. *Journal of voice*, 31(6), 722-727. <https://doi.org/10.1016/j.jvoice.2017.02.010>
- Phyland, D., & Miles, A. (2019). Occupational voice is a work in progress: active risk management, habilitation and rehabilitation. *Current opinion in otolaryngology*

& *head and neck surgery*, 27(6), 439-447

<https://doi.org/10.1097/MOO.0000000000000584>

Phyland, D. J., Pallant, J. F., Benninger, M. S., Thibeault, S. L., Greenwood, K. M., Smith, J. A., & Vallance, N. (2013). Development and preliminary validation of the EASE: a tool to measure perceived singing voice function. *Journal of Voice*, 27(4), 454-462. <https://doi.org/10.1016/j.jvoice.2013.01.019>

Phyland, D. J., Oates, J., & Greenwood, K. M. (1999). Self-reported voice problems among three groups of professional singers. *Journal of Voice*, 13(4), 602-611. [https://doi.org/10.1016/S0892-1997\(99\)80014-9](https://doi.org/10.1016/S0892-1997(99)80014-9)

Remacle, A., Morsomme, D., Berru e, E., & Finck, C. (2012). Vocal impact of a prolonged reading task in dysphonic versus normophonic female teachers. *Journal of voice*, 26(6), 820-e1. <https://doi.org/10.1016/j.jvoice.2012.06.002>

Rubin, J. S., Sataloff, R. T., & Korovin, G. S. (2005). *Diagnosis and Treatment of Voice Disorders, Third Edition* (3rd ed.). Plural Publishing, Inc.

Sander, E. K., & Ripich, D. E. (1983). Vocal fatigue. *Annals of Otology, Rhinology & Laryngology*, 92(2), 141-145. <https://doi.org/10.1177/000348948309200209>

Sapir, S. (1993). Vocal attrition in voice students: survey findings. *Journal of Voice*, 7(1), 69-74. [https://doi.org/10.1016/S0892-1997\(05\)80113-4](https://doi.org/10.1016/S0892-1997(05)80113-4)

Scherer, R. C., Radhakrishnan, N., Boominathan, P., & Tan, H. (2008). Rate of change of Fo in performance singing. *The Journal of the Acoustical Society of America*, 123(5), 3379-3379. <https://doi.org/10.1121/1.2934014>

Sivasankar, M. (2002). Effects of vocal fatigue on voice parameters of Indian

- Teachers. *Indian Journal of Otolaryngology and Head and Neck Surgery*, 54(3), 245-247. <https://doi.org/10.1007/BF02993116>
- Solomon, N. P. (2008). Vocal fatigue and its relation to vocal hyperfunction. *International Journal of Speech-Language Pathology*, 10(4), 254-266. <https://doi.org/10.1080/14417040701730990>
- Solomon, N. P., Glaze, L. E., Arnold, R. R., & van Mersbergen, M. (2003). Effects of a vocally fatiguing task and systemic hydration on men's voices. *Journal of Voice*, 17(1), 31-46. [https://doi.org/10.1016/S0892-1997\(03\)00029-8](https://doi.org/10.1016/S0892-1997(03)00029-8)
- Stemple, J. C. (1984). *Clinical voice pathology: Theory and management* (1st ed.). Columbus, OH, Charles E. Merrill.
- Stemple, J. C. (1993). *Voice Therapy: Clinical Studies* (1st ed.) [E-book]. St. Louis : Mosby.
- Stone ,R. E., & Sharf, D. J. (1973). Vocal change associated with the use of atypical pitch and intensity levels. *Folia Phoniatica et Logopaedica*, 25(1-2), 91-103. <https://doi.org/10.1159/000263673>
- Timmermans, B., Vanderwegen, J., & De Bodt, M. S. (2005). Outcome of vocal hygiene in singers. *Current opinion in otolaryngology & head and neck surgery*, 13(3), 138-142. <https://doi.org/10.1097/01.moo.0000163351.18015.b6>
- Vilkman, E. (2004). Occupational safety and health aspects of voice and speech professions. *Folia Phoniatica et Logopaedica*, 56(4), 220-253. <https://doi.org/10.1159/000078344>
- Vilkman, E., Lauri, E. R., Alku, P., Sala, E., & Sihvo, M. (1999). Effects of prolonged oral reading on F0, SPL, subglottal pressure and amplitude characteristics of

glottal flow waveforms. *Journal of Voice*, 13(2), 303-312.

[https://doi.org/10.1016/S0892-1997\(99\)80036-8](https://doi.org/10.1016/S0892-1997(99)80036-8)

Welham, N. V., & Maclagan, M. A. (2003). Vocal fatigue: current knowledge and future directions. *Journal of voice*, 17(1), 21-30. [https://doi.org/10.1016/S0892-1997\(03\)00033-X](https://doi.org/10.1016/S0892-1997(03)00033-X)

Wingate, J. M., Brown, W. S., Shrivastav, R., Davenport, P., & Sapienza, C. M. (2007). Treatment outcomes for professional voice users. *Journal of voice*, 21(4), 433-449. <https://doi.org/10.1016/j.jvoice.2006.01.001>

Xue, C., Kang, J., Hedberg, C., Zhang, Y., & Jiang, J. J. (2019). Dynamically Monitoring Vocal Fatigue and Recovery Using Aerodynamic, Acoustic, and Subjective Self-Rating Measurements. *Journal of Voice*, 33(5), 809-e11 <https://doi.org/10.1016/j.jvoice.2018.03.014>

Yiu, E. M. L., & Chan, R. M. (2003). Effect of hydration and vocal rest on the vocal fatigue in amateur karaoke singers. *Journal of Voice*, 17(2), 216-227. [https://doi.org/10.1016/S0892-1997\(03\)00038-9](https://doi.org/10.1016/S0892-1997(03)00038-9)