ANALYSIS OF VOICE IN YAKSHAGANA FOLK ARTISTS

A thesis submitted to the University of Mysore for the degree of

DOCTOR OF PHILOSOPHY (Ph .D)

IN

SPEECH AND HEARING

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September 2006.

TO

MY FATHER
&
HUSBAND

"THE WIND BEHIND MY WINGS"

CERTIFICATE

This is to certify that this thesis entitled, **"ANALYSIS OF VOICE IN YAKSHAGANA FOLK ARTISTS"** submitted by Ms. KALAISELVI. P. S. for the degree of **Doctor of Philosophy** to the University of Mysore, Mysore was carried out at All India Institute of Speech and Hearing, Mysore.

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Place: Mysore
Date: September 2006.

Director,
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CERTIFICATE

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Dr. M. Jayaram,
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Place: Mysore
Date: September 2006

DECLARATION

I Declare that this thesis entitled **"ANALYSIS OF VOICE IN YAKSHAGANA FOLK ARTISTS"** submitted herewith for the award of degree of **Doctor of philosophy** to the University of Mysore, Mysore is the result of work carried out by me at All India Institute of Speech and Hearing, under the guidance of **Dr. M. Jayaram,** (Professor, Department of Speech pathology and Audiology, NIMHANS, Bangalore). I further declare that this thesis or part therefore, has not been submitted earlier to any University for the award of any degree or diploma.

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Date: September 2006

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Contents

Chapter 1 Introduction 1-14

1.1 Factors Affecting Voice Production 3

1.1.1 Physical Factors 3

1.1.2 Psychological Factors 4

1.1.3 Environmental Factors 4

1.2 Professional Voice Users 5

1. 3 Voice Problems in Singers and Actors 6

1.4 Yakshagana 7

1.4.1 Demands on the Voice of Yakshagana Artists 9

1. 5 Statement of the Problem 11

1.6 Objectives of the Study 12

1.7 Implications 14

Chapter 2 Review 15-42

2.1 Professional Voice Users 18

2.2 Causes of Voice Disorders in Professional Voice Users 18

2.3 Disorders Resulting from Vocal Misuse and Abuse 19

2.4 Voice Problems in Professional Voice Users 22

2.4.1 Voice Problems in Singers 22

2.4.2 Voice Problems in Theatre Artists 28

2.5 Yakshagana 32

2.5.1 Voice Problems in Yakshagana Artists 35

2.6 Evaluation of Voice 36

Chapter 3 Method 43 - 63

3.1 Objectives 43

3.2 Subjects 44

3.3 Materials 47

3.4 Recording of Samples 48

3.5 Recording Schedule 50

3.6 Acoustic Analyses 50

3.6.1 Frequency Related Measures 51

3.6.1.1 Habitual Frequency of Voice [FO (Hz)] 51

3.6.1.2 Fundamental Frequency in Speech [SFO (Hz)] 51

3.6.1.3 Frequency Range in Phonation [FR (Hz)] 52

3.6.1.4 Jitter (F0%) 52

3.6.1.5 Extent [EFF] and Speed of Frequency Fluctuations [SFF] 53

3.6.2 Amplitude Related Measures 53

3.6.2.1 Mean Intensity [MI (dB)] 53

3.6.2.2 Intensity Range in Phonation [IR (dB)] 54

3.6.2.3 Shimmer (dB) 55
3.6.2.4 Extent [EIF] and Speed of Intensity Fluctuations [SIF] 55
3.6.3 Spectral Related Measures 56
3.6.3.1 Harmonic to Noise Ratio [HN Ratio (dB)] 56
3.6.3.2 Long-Term Average Spectra [LTAS] 56
3.6.4 Electroglottographic Measurement [EGG] 57
3.6.4.1 Open Quotient [OQ] and Speed Quotient [SQ] 59
3.6.5 Respiratory Related Parameters 59
3.6.5.1 Vital Capacity [VC (cc)] 60
3.6.5.2 Mean Air Flow Rate [MAFR (cc/sec)] 60
3.6.5.3 Maximum Phonation Duration [MPD (sec)] 61
3.6.5.4 S/Z Ratio 61
3.7 Analyses 61

Chapter 4 Results 64-100

4.1 Subjects 64
4.2 Voice Complaints by Yakshagana Artists 65
4.3 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Nature of Voice Complaints by the Subjects 66
4.4 Voice Characteristics of Different Groups of Subjects 69

4.4.1 Comparison of the Voice of Normals and Yakshagana Artists 69

4.4.2 Comparison between Normals, Yakshagana Dancing Artists and Bhagavathars 72

4.5 Discriminant Analysis 77

4.6 Voice Index 81

4.7 Short-Term Effects of Yakshagana Performance and Voice Rest on the Voice Characteristics of Yakshagana Dancing Artists 83

4.7.1 Difference Between Condition 1 and Condition 2 (Short-Term Effect of Yakshagana Performance): Dancing Artists 85

4.7.2 Difference Between Condition 2 and Condition 3 (Short-Term Effect of Vocal Rest): Dancing Artists 86

4.7.3 Difference Between Condition 3 and Condition 1: Dancing Artists 87

4.8 Short-Term Effects of Yakshagana Performance and Voice Rest on the Voice Characteristics of Yakshagana Bhagavathars 87

4.8.1 Difference Between Condition 1 and Condition 2 (Short-Term Effect of Yakshagana Performance): Bhagavathars 89

4.8.2 Difference Between Condition 2 and Condition 3 (Short-Term Effect of Vocal Rest): Bhagavathars 90

4.8.3 Difference Between Condition 3 and Condition 1: Bhagavathars 90

4.9 Voice Index Scores of Yakshagana Dancing Artists and Bhagavathars Across the Three Conditions (Cl, C2, and C3) 91

4.10 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit on Voice Characteristics 94

Chapter 5 Discussion 101-126

5.1 Subjects 102

5.2 Assessment of Voice Parameters 103

5.3 Voice Complaints by Yakshagana Artists 104

5.4 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Nature of Voice Complaints by the Subjects 106

5.5 Voice Characteristics of Different Groups of Subjects 108

5.6 Discriminant Analysis 117

5.7 Voice Index 117

5.8 Short-Term Effect of Yakshagana Performance on Voice: Yakshagana Dancing Artists and Bhagavathars 119

5. 9 Effect of Short-Term Voice Rest on Voice: Yakshagana Dancing Artists and Bhagavathars 123

5.10 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Acoustic Characteristics of Voice 124

Chapter 6 Summary and Conclusions 127-135

References 136-148

Chapter 1

Introduction

"If it is true that the eyes are the mirror of the soul, then surely the voice is its loud speaker".

Luschinger and Arnold (1965)

The need for communication is achieved through spoken language and it is the voice that is modified to achieve speech sounds. The ability to use vocal apparatus to express feelings, describe an event and to establish communication is unique to human beings. Boone (1977) considers the act of speaking as a very specialized way of using the vocal mechanism, demanding a combination or interaction of the mechanisms of respiration, phonation, resonation, and articulation.

The physiology of voice production is remarkably complex. Preparations are made in the cerebral cortex of the brain for production of voice. Many other brain centers are involved in sending appropriate impulses to the nerves and muscles required for phonation. The brain also receives kinesthetic and auditory feedback information and makes adjustments to control the voice sounds produced. Phonation involves a complex interaction between power source, oscillator and resonators. Power is generated by the lungs with the help of chest, abdomen and back musculature whose combined action produces a high-pressure air stream. As the respiratory system is preparing to provide the airflow, the two vocal folds begin to approximate towards each other. Once they reach appropriate level of adduction, the airflow from the lungs forces the vocal cords apart, an impulse of air escapes through the glottis, subglottal pressure drops, vocal cords are sucked into adductory state, and the whole process repeats . Based on the voice thus produced, the brain maintains or alters impulses sent to the voice and respiratory musculature. Rapid, complex adjustments at the subglottal level are necessary during phonation because the resistance in the vocal tract changes almost continuously as the vocal folds adduct and abduct during vibration.

The quasi-periodic complex tone produced by the "source" is then "filtered" by the vocal tract, as per the source-filter theory (Fant, 1960). The quality of the voice thus produced depends on the myoelastic properties of the vocal folds and the vocal tract. Communication via spoken language is hampered or even rendered impossible when the production of vocal sound is faulty. Since the voice is governed by such a complex set of dimensions, it is quite natural that it is affected by various intrinsic and extrinsic factors.

1.1 Factors Affecting Voice Production

1.1.1 Physical Factors

Physical make up of a person plays a significant role in shaping his/her voice. The shape and size of jaw, teeth, tongue and lips determine, in part, the sounds that the person makes. Illness can affect the way voice is produced. Consistent vocal abuse through yelling, screaming, smoking and many other factors can temporarily or even permanently affect one's voice. Vocal nodule is one of the commonly seen conditions affecting voicing in singers, actors, teachers, athletic coaches, cheerleaders and others who strain their voices (Schutte, 1980).

As we age, our vocal apparatus begins to deteriorate. Vocal folds become thinner and tighter in men accounting for increased fundamental frequency of voice with advancing age (Hollien and Ship, 1972). On the other hand, the vocal folds become thicker and loose in women, which explains the lowering of fundamental frequency of voice with advancing age (McGlone, and Hollien, 1963). Mucus linings become dry with advancing age, and lead to hoarse voice (Greene and Mathieson, 1989). Flexibility is reduced with age (Biever and Bless, 1989; and Aronson, 1990). Diet and medications affect our voices by dehydrating the mucus linings and vocal folds (Sataloff, 1997).

1.1.2 Psychological Factors

Voice production is not only influenced by the psychological status of an individual, but also reflects the psychological status of an individual. For example, use of a marked pitch range may indicate extroversion; use of high habitual pitch may suggest nervousness while nasality may be linked to neuroticism (Street and Hopper, 1982).

There is some evidence to link particular voice qualities to anxiety, depression and despair. The use of a narrow frequency range with low habitual pitch and a slow speech rate has been thought to be associated with depression while a breathy, irregular voice with a fast speech rate is associated with anxiety (Gudykunst, 1986). A high-pitched, harsh voice may indicate stress and tension (Deary, Wilson, Cardig and Mackenzie, 2003).

1.1.3 Environmental Factors

The physical and psychological factors influencing voice assume greater significance if the speakers have a difficult speaking-environment to deal with in addition. The effects of physical and psychological factors on voice are compounded when one has to use voice in a large, dusty or polluted hall or theater, which has poor acoustics, poor amplification and/or high noise levels. Lectures and speech given in open fields in rural settings pose particular problems for speakers because, apart from the open air, the speakers also have to encounter dusty situations (Schutte, 1980).

1.2 Professional Voice Users

There is an increasing segment of the population which is dependent on vocal communication for its livelihood like actors, singers, lawyers, cheer leaders, etc. They are referred to as professional voice users. Murry and Rosen (2000) define professional voice users as those who require the use of their voice to maintain income.

Professional voice users who over use their voice (teachers and lawyers), those who abuse their voice under adverse circumstances (cheer leaders, street venders), and those who use voice for recreational purposes (singers and actors) are more likely to experience voice problems than others who do not use voice for their living (postman, typist, etc.). Extensive voice use can lead to vocal fatigue. In fact, vocal fatigue is reported to be the most common voice problem in professional voice users such as singers, actors and radio / television personalities (Koufman and Blalock, 1988). Gotass and Starr (1993) considered vocal fatigue, as a problem that begins to occur as the speaking day progresses, is most evident at the end of the day, and which usually disappears by the following morning. The common voice symptoms noted in professional voice users with vocal fatigue include an inability to speak loudly (Vilkman, Lauri, Alku, Sala and

Sihvo, 1999), hoarse/husky/breathy voice quality (Scherer, Titze, Raphael, Wood, Ramig and Blager, 1986), an increase in habitual pitch (Gelfer, Andrews and Schmidt, 1991; Stemple, Stanley and Lee, 1995), pain in the throat and tremor, reduced pitch range, unsteady voice (Kostyk and Rochet, 1998; Rantala, Paavola, Korkko and Vilkman, 1998) etc. Singers, teachers, and actors who use their voice for a vocation often indulge in vocal overuse or abuse. They are at high-risk for dysphonia (Sapir, Atias and Shahar, 1990).

1.3 Voice Problems in Singers and Actors

Singing involves a more prolonged and sustained voice production while speech is a series of transient sounds. Therefore, singers, particularly the amateur, untrained or inadequately trained singers are more susceptible to voice problems.

The voice problems commonly encountered by singers are hoarseness, loss of vocal range, deteriorating quality, breaking in to different registers or exhibiting other uncontrolled aberrations (Sataloff, 1997). Hogikyan, Appel, Guinn and Haxer (1999) reported that factors like shouting and screaming, poor singing techniques, too loud singing, style of singing, singing outside of natural range, excessive throat clearing, excessive coughing and rehearsing when fatigued were responsible for vocal nodules in singers.

Acting places tremendous, varied and complex demands on the vocal mechanism. Actors are frequently engaged in emotionally charged behaviours, often producing voice accompanied by extreme physical exertions, or sudden emotional outbursts, such as screaming, shouting, grunting, groaning and sobbing depending upon their role in the play. All these are usually considered as vocally violent behaviours. These behaviours involve extremes in pitch and loudness, increase of muscular tension and explosion of air across the partially closed/open folds (Ryker, Roy and Bless, 2000). Novak, Dlouha, Capkova and Vohradnik (1991) reported that their subjects (45 professional dancing artists) reported subjective feelings of voice fatigue after a theatrical performance.

1.4 Yakshagana

Yakshagana is a unique form of folk art practiced in the Southern states of India. Yakshagana, "the music of celestials" is a form of dance drama, a famous folk art of South Indian states of Karnataka, Tamilnadu and Andhra Pradesh. It is a rich artistic blend of rare music, vigorous dance movements, extempore speech and gorgeous costumes. This art combines the features of opera as well as drama, and is considered to be a media for moral education as well as mass entertainment.

Yakshagana is performed predominantly in South Canara, Malnad region and certain parts of North Canara districts of Karnataka. The active season is from December to May, i.e. after the crop of paddy has been harvested. It is essentially performed at night on a platform in open air with themes usually based on Hindu epics like the Ramayana and the Mahabharata. Almost all dramas of Yakshagana include enacting of fights, or warfare of some story from Hindu mythology. Yakshagana includes two types of artists - the dancing artists who sing, dance and act; and the singers (called Bhagavathars) who only sing. Figure 1.1 depicts an Yakshagana play.

Figure 1.1: Yakshagana play

The dancing artists sing with great effort and do robust dances in colourful costumes. Yakshagana has a lot of prose dialogue, which the dancing artists themselves render. When the dancing artists stop their speech, the musical theme is sung, and while it is sung the dancing artists do 'abhinaya' (dance or acting). Prolonged singing, particularly in the high-pitched range, emotional outbursts in theatrical acting coupled with high levels of physical exertion are typical features of the folk art of Yakshagana. These can be expected to result in vocal abuse in Yakshagana artists.

1.4.1 Demands on the Voice of Yakshagana Artists

It is necessary to remember, as said earlier, that there are two types of artists in any Yakshagana performance - the Bhagavathar (the lead singer) and the dancing artists (the characters of Yakshagana). Though the chief role of the Bhagavathar is to sing, he also indulges in dialogue delivery, albeit occasionally. Most of the times, he would be doing so above the level of the sound created by the "chande" which is a percussion instrument emitting high frequency tones and which is usually played at high intensity levels. On the other hand, the dancing artists render dialogues, dance, act, and occasionally sing as well. They sing keeping their voice high above that of the background "chande". As the daincing artists also have to act and dance (often involving forceful, robust and vibrant movements), the combined effect of physical exertion (dancing and acting) and singing at high (frequency and intensity) voice can be presumed to be detrimental to their voice production.

With the kind of instruments in the background, the singing of both the dancing artists and the Bhagavathars in Yakshagana has to be very loud in order to project the same to the crowds. Generally, these artists cultivate an open-throat, effortful vocal style, dwelling primarily in the upper register to reach this goal (Karanth, 1975). Holding the breath on high notes is considered a feat of virtuosity that earns outbursts of praise from the audience. At climactic moments, the singer conveys dramatic bursts of emotion by exploring the uppermost notes in his register; as they are the ones most likely to cut through the ambient noise in the performance area and make an impact on the listeners (Karanth, 1975).

The demands made on the voice of Yakshagana artists may lead to vocal abuse, if practiced. In order to create the illusion of illness or high emotion, the dancing artist may modify breathing or tighten the shoulders and jaw or constrict the voice, any of which may put added pressure on the vocal mechanism, hi addition, within the given circumstances of the play, the dancing artist may be required to laugh hysterically or sob or scream or shriek or cough or choke or even die. Certain costumes may also restrict physical mobility and this may affect voice production. For example, high collars, heavy crowns, heavy make-up artificial beards and moustaches, which are glued to the actor's skin etc., can lead to difficulties. They may be wearing prosthetic devices to alter their dentition and jaw line that make vocal projection and articulation more difficult. Such behaviours are generally accepted to be vocally abusive and may place them at risk for developing voice disorders.

1. 5 Statement of the Problem

Negative vocal change during and after performance is potentially problematic for singers and actors, their directors, and professionals such as laryngologists, speech pathologists, acting teachers, and singing teachers who are interested in these. The significance of vocal change after performance is, however, not well understood. There has been no empirical study on the effects of such 'hard and effortful" performance on the voice of Yakshagana artists or practitioners of any other form of classical dance. Almost no guidelines are available to singers and actors which tell them whether altered vocal functioning is a "normal" effect of performance or a change that signals vocal misuse and the onset of vocal dysfunction.

There are a number of laboratory studies reported in the literature which mention the effects of vocal loading tasks (Neils and Yairi, 1987; Sander and Ripich, 1983; Hill, Oates, Healey and Russel, 1988). However, these tasks cannot adequately simulate a live performance. Further, these laboratory studies suffer from methodological limitations such as failure to account for variability in the wide range of variables that may interact to affect performance, small sample sizes, lack of consideration of individual differences in vocal response, and use of a small range of vocal tasks and outcome measures of voice.

Paucity of empirical findings on the effects of performance on voice in these artists necessitates further well-designed studies in this area. The reliability and applicability of results will be wider if the methodology provides for evaluation of the voice of artists after a live performance. In line with these recommendations, the present study investigated both the short- and long-term effects of performance on the voice of both types of Yakshagana artists - Bhagavathars and dancing artists. Analysis of the voice of these artists prior to Yakshagana performance and comparison of these results with those from matched normals may reflect the long-term effects of Yakshagana on the voice of these artists. Analysis and comparison of the voice of both groups of artists before and after a given performance will indicate the short-term effects of Yakshagana on their voice. In addition to this, the aim was to study the effect of a short period of voice rest (ranging from 10-12 hours) on their voice following an Yakshagana performance.

1.6 Objectives of the Study

The objectives of the study were to:

a) make a comparative analysis of acoustic and respiratory parameters of voice of normal speakers and Yakshagana artists, both the Bhagavathars and the dancing artists,

b) investigate the effect of a live Yakshagana performance on the voice of both the dancing artists and the Bhagavathars (short-term effect), by comparing their voice parameters prior to and following Yakshagana performance,

c) study the effect of a short voice rest, ranging from 10-12 hours, following an Yakshagana performance on vocal parameters, in both groups of artists, and

d) combine all parameters of voice to arrive at a voice index which is an overall indicator of the status of the voice of a given speaker.

The voice parameters used in the present study were (a) fundamental frequency (F0), (b) speaking fundamental frequency (SFO), (c) frequency range (FR), (d) speed of fluctuations in frequency (SFF), (e) extent of fluctuations in frequency (EFF), (f) jitter, (g) mean intensity (MI), (h) range of intensity (IR), (i) speed of fluctuations in intensity (SIF), (j) extent of fluctuations in intensity (EIF), (k) shimmer, (1) harmonic to noise ratio (HNR), (m) alpha, beta and gamma ratios of long-term average spectrum (LTAS), (n) open quotient (OQ), (0) speed quotient (SQ), (p) vital capacity (VC), (q) mean airflow rate (MAFR), (r) maximum phonation duration (MPD), and (s) S/Z ratio.

1.7 Implications

Acting and singing in Yakshagana requires a more prolonged and effortful voice production compared to natural speech. Therefore, Yakshagana artists are susceptible to voice problems. Long hours of voice use, in both rehearsals and live performance, may lead to many voice problems in Yakshagana artists. The frequency and intensity level at which these artists sing and deliver dialogues places them at higher risk for vocal abuse.

The results of this study would not only help us to understand the physiology of voice production in these artists, but may also generate useful information for vocal education of these artists and others of their kind. More importantly, the study may throw information on how human voice maintains its normality even when subjected to prolonged demands and pressures over a long time.

Chapter 2

Review

Communication is recognized as one of the most fundamental components of human behavior. According to Fisher (1975), one form of communication which people use most effectively to foster interpersonal relationships is speech. With it, they give form to their innermost thoughts, their dreams, ambitions, sorrows and joys. In a real sense, speech is the key to human existence. It bridges the differences and distances, and helps to give meaning and purpose to human life. Voice is more than a means of communication of verbal messages. Voice constitutes the matrix of verbal communication involving all parameters of human speech and the unique self, one presents to the world.

Voice has linguistic and nonlinguistic functions. Voicing has been found to be a major 'distinctive' feature in almost all languages. Voicing provides more phonemes and makes the language broader. If voicing is 'absent' or used abnormally, then it would constitute a speech disorder. At the semantic level too, voice plays an important role. The use of different pitches - high and low - with the same string of phonemes convey different meanings. Speech prosody, which includes intonation, stress and rhythm of a language is a function of vocal pitch, loudness as well as phonetic duration. At the non-linguistic level voice reveals speakers' identity (Schutte, 1980), personality and emotional status (Markel, Meisels and Houck 1964).

Speech and voice is the result of a complex interplay of physical and emotional events. The first event in the brain is the recognition of a motivation (a desire or need) to communicate. Such a desire leads to formulation of ideas and feelings which are then translated by the brain into language and speech. Speech is achieved by the synchronized action of the phonatory, laryngeal and respiratory systems. The whole process is complex and sophisticated.

The respiratory muscles contract to compress air in the lungs. As a result, the compressed air is forced to flow upward through the trachea and larynx. This action supplies power for vocal fold vibration, and generation of voice and speech. The voice-activating respiratory muscles then relax so that air can enter the lungs for the next cycle. As air starts flowing upwards for the next respiratory cycle because of the difference in the lung and atmospheric pressure, the two vocal folds begin to approximate. Once they are closed adequately, air pressure builds up against them, thus setting them into vibration (Zemlin, 1998). This is regulated, in part, by information coming into the brain through our sensory systems as we listen to our own speech. As long as the vocal folds are close enough to provide some resistance to the breath stream, and relaxed enough to vibrate, tiny puffs of air will be released through the glottis as the vocal folds alternately open and close. The succession of air pulses creates a sound wave in the vocal tract. Thus, the vibration of vocal folds is induced by a complex combination of aerodynamic, muscular and elastic forces in the larynx. The sound wave or the air stream, as it passes through the vocal tract, gets its human quality through resonance (Baken, 1987).

The sound waves then pass through the upper vocal tract including the throat and mouth. Depending on the shape of the throat and the mouth cavities, certain components of the sound wave will be amplified. This phenomenon is known as resonance. The articulators of speech - tongue, jaw and lips - obstruct the sound wave as it passes through the mouth. This helps to shape the stream of air and voice into speech sounds, that is, vowels and consonants.

The information in the preceding paragraphs implies that the production of voice is a highly complex task and that it can be affected by various physiological and pathological factors. Physiological factors are those related to the functioning of respiratory, phonatory, and articulatory systems. The pathological factors include structural abnormalities of respiratory, phonatory and articulatory muscles as well as disease processes affecting these systems. Voice plays a major role in speech and hence, in communication. Therefore, it is very important to monitor the voice continuously and seek experts' help if any abnormality in voice quality is observed.

2.1 Professional Voice Users

Professional voice users constitute an ever-increasing segment of the population who depend on their voice for a daily living (Murry and Rosen, 2000). Professional voice users include singers, actors, politicians, and teachers, among others.

Professional voice users are classified into different groups based on the circumstances in which they work. They include those who use their voice for a long period of time (politicians, teachers in classrooms, telephone users, shopkeepers, and venders, etc.), those who use their voice under adverse circumstances (persons working in noisy or polluted environments - factory workers, workers in airplanes, sports arenas, trains, blacksmiths, etc.), and those who use their voice for special purposes (singers, theatre artists, etc.). Of these professional voice user groups, the voice of singers and actors has been the topic of extensive research. The demands on the voice of actors and singers are much higher compared to other professional voice users as even a slight vocal difficulty may have serious repercussions on their performance.

2.2 Causes of Voice Disorders in Professional Voice Users

In general, it is said that a voice disorder exists when quality, pitch or loudness differ from the voices of others of similar age, sex, and culture (Greene and Mathieson, 1989; Titze, 1994). A voice disorder can also be said to exist when the flexibility of use of voice is different from that seen in individuals of the same age and gender. Professional voice users can develop voice problems like anybody else, but it is the set of voice problems that they develop as a result of overuse of their voice that makes them unique.

Sapir (1993) is of the opinion that vocal misuse and abuse are the predominant reasons, which lead to voice problems in those who place high demands on their vocal mechanism. This compliments the description of Sataloff (1997) on the factors leading to voice problems in professional voice users. Sataloff (1997) identified misuse and abuse (poor singing techniques, among others), chronic medical problems (esophageal reflux, allergies, etc), environmental factors (performance in smoky, dry environments), and emotional factors (stage fright, anxiety, etc) as some of the causes. Continuous vocal misuse and abuse can lead to vocal nodules, vocal polyps, and laryngitis, which in turn lead to voice problems.

2.3 Disorders Resulting from Vocal Misuse and Abuse

The commonly reported voice problems of actors and singers are acute laryngitis, polyps, vocal nodules, and contact ulcers and these can be attributed to vocal abuse (Brodnitz, 1955). The most common disorder resulting from vocal abuse and misuse is a condition of vocal nodules or vocal nodes (Kay, 1982; Benjamin and Croxon, 1987; Lancer, Snyder, Jones and Le Boutillier, 1988; McFarlane and Watterson, 1990). Vocal nodules are known by different names like singer's nodules, screamer's nodules, cheer leader's nodules or teacher's nodules (Lancer, Syder, Jones and Le Boutillier, 1988) depending on the group of persons in whom such nodules are seen. Nodules are small and benign growths on vocal folds as a result of vocal abuse. They form at that area which receives maximum pressure, and repeatedly, when the folds come together to vibrate. Nodules can be acute or chronic. Medial compression of vocal folds and asymmetrical fold vibration due to vocal nodules dramatically alter the quality of voice. The voice in such conditions is usually described as raspy, hoarse and breathy (Dworkin and Meleca, 1997).

People who use excessive force to bring vocal folds together for speech may experience contact ulcer. Since the ulcers form at the tip of the vocal processes of the arytenoid cartilages rather than on the vibrating muscular tissues of the vocal folds, the vocal symptoms are often not dramatic, particularly in the early stages of ulceration before granulation occurs. People with this type of voice disorder often complain of vocal fatigue and may feel pain in the throat, especially while talking. These symptoms increase with continued voice use throughout the day. Voice is typically characterized by hoarse - harsh quality with a glottal fry overlay. Pitch may be too low and volume tends to be loud (Dworkin and Meleca, 1997). Tracheal pressure and glottal resistance are usually increased, mean transglottal airflow is reduced;

jitter is higher than normal, and a pronounced degree of noise is evident in the vocal signal, together with a low H/N ratio (Dworkin, and Meleca, 1997). Theatrical artists are likely to experience contact ulcers more than general population.

Vocal polyps are most often caused by an acute and violent episode of vocal abuse. Vocal polyp is a benign, circumscribed, fluid filled outgrowth of tissue that rises from the superficial layer of the lamina propria. They can form anywhere along the length of the vocal fold. Hemorrhagic polyps are partially filled with blood, which accounts for the purple appearance. Fibrous polyps contain dense strands of connective tissue, and edematous polyps are generally smooth, soft, pliable, and translucent. Polyp deforms and laterally displaces the free edge of the opposing vocal fold during phonation, resulting in incomplete glottic closure. The quality of voice is hoarse - breathy, pitch is abnormally low, and volume range is substantially limited (Dworkin and Meleca, 1997).

Laryngitis is an inflammation or swelling of the vocal folds. It may be caused by excessive use of voice, by bacterial or viral infections, or by irritants such as inhaled chemicals or the back up of stomach acid into the throat (gastro esophageal reflux). The resultant voice is hoarse, breathy in quality, low pitched and reduced in volume. The affected persons may experience vocal fatigue depending upon the severity of the pathology (Dworkin and Meleca, 1997).

2.4 Voice Problems in Professional Voice Users

2.4.1 Voice Problems in Singers

Singers use their voices in very special ways, influenced by and, creating aesthetic values. Bunch (1995) defined singing as a sensory-motor phenomenon that requires particular balanced physical skills. Teachy, Kahane, and Beckford (1991) consider singing voice as the product of a delicate balance of physiologic control, artistry and technique. Singers are known to outperform other professional voice users through superior control of respiratory, laryngeal, and articulatory dynamics while singing although no differences may be seen in the speaking voice (Shipp and Izdebski, 1975; Watson and Hixon, 1985). Therefore, singing requires a complex and delicate manoeuvring of the vocal mechanism to bring about subtle and fast changes in voice. Hence, even minor problems may produce adverse effect on singing voice.

Singers are found to be very sensitive to even small changes in their singing voice. There are a variety of factors that affect singing voice. The occupational demands on voice are much greater in singers than in other professional voice users (Bunch, 1995). They are, for example, required to speak and sing for long periods, often in stressful situations where optimal voice quality and projection are demanded. Hence, good vocal training is vital for this group of professional voice users to conserve and use it effectively with least effort. In fact, singers with limited or no training are at risk for development of many voice problems.

The most commonly observed voice symptoms in singers are vocal fatigue and hoarseness. Vocal fatigue may be characterized by hoarse voice, diminished range (especially at higher frequencies), reduced vocal endurance, onset delays with high soft phonation, a sense of increased effort to sing, a need for longer warm-up and a greater degree of day-to-day variability in voice than expected (Hogikyan, Appel, Guinn and Haxer, 1999; Murry and Rosen, 2000). Vocal fatigue usually occurs as a result of negative vocal adaptation that takes place as a consequence of prolonged voice use, misuse of abdominal or neck musculature, or over singing, or singing too loudly and for too long. Singers tend to develop voice problems as a result of overcompensation of the speech production mechanism. Compensatory strategies stem from inadequate respiratory dynamics or excessive muscle tension typically localized to the larynx as a result of infection, and irritation to the larynx which occurred due to vocal fatigue. Emotional reaction stemming from the stresses of one's daily lifestyle also leads to compensatory strategies (Hoffman - Ruddy, Lehman, Crandell, Ingram and Sapienza, 2001).

There are two methods of breathing, hypofunctional and hyperfunctional, which are inefficient and tension producing and therefore, may be considered as faulty breathing methods in singers. In hypofunctional breathing, there isn't a support mechanism to provide adequate breath pressure for proper functioning of vocal folds. This is commonly observed in beginning singers. It is caused by a lack of awareness of the actual demands of singing. Hyperfunctional breathing involves too much physical activity of the breathing mechanism and is commonly observed in experienced singers (Mc Kinney, 1994). The causes of hyperfunctional breathing could be - (a) the misconception that the ability to sing long phrases is in direct relationship to the quantity of air we can inhale, and (b) the fear of running out of breath in a public performance. However, the ability to sing long phrases comes primarily from the efficiency of the vocal fold action. It is the result of good laryngeal adjustment, not of lung capacity. Taking in too much of air not only wastes energy, but also creates unnecessary tension in both the breathing mechanism and larynx. Continued practice in taking excessive breath results in too much air being packed into the chest and too much breath pressure pushing back against the vocal folds, with a consequent loss and flexibility (Mc Kinney, 1994).

Teachy, Kahane and Beckford (1991) studied the vocal mechanics in untrained professional singers. They reported that singers exhibited voice disorders as a result of repeated indulgence of vocal abusive behaviors like hard glottal attacks, over articulation, excessive loudness and throat clearing. The most frequent reason was improper breath support and control of respiratory drive. The report also mentioned that lack of vocal training, cigarette smoking, insufficient monitoring of vocally abusive speaking behaviors, over participation in singing activities, and Jack of awareness of vocally abusing behaviors were some of the other precipitative factors which exacerbated voice problems in untrained singers.

Brown (1996) has listed a number of causes, which lead to phonatory disorders in singers. They include, too loud singing, using voice for too long, pushing with breath, straining for high notes, squeezing for low notes, tension in the shoulders, neck muscles and muscles of articulators, too rigid posture, breathing too high or low, distortion of facial muscles, carrying low voice too high, overuse of voice, faulty speaking habits, imitation of poor voice models, singing too much with young voices, and trying to sing difficult notes before they are technically ready. Phyland, Oates and Greenwood (1999) reported greater incidence of laryngeal pathologies in three types of singers (opera, theatre, and contemporary) compared to nonsingers. Hoarseness, vocal fatigue, pain in throat and change in the pitch of speaking voice were the major voice symptoms reported as affecting their performance and voice.

The commonly observed phonatory faults in singers are those arising from basic malfunctioning of the laryngeal mechanism: (1) Hypofunctional phonation - failure to demand enough and appropriate level of activity of the laryngeal mechanism. It is one of the most prevalent vocal faults and is common among young singers, but can persist throughout adult life (Mc Kinney, 1994). The primary cause of hypofunctional phonation is an incomplete closure of the glottis. (2) Hyperfunctional phonation - demanding too much from the laryngeal mechanism. The primary cause for this type of phonation is excessive tension in the vocal folds and other laryngeal muscles. It results in a voice quality, which is described as tight, tense, hard or strained. When a hyperfunctional phonation is accompanied by hyperfunctional breath support, the voice quality is further described as harsh, strident, rasping, grating, rough, constricted and strangulated (Sundberg, 1987). Hyperfunctional phonation, if used persistently, can result in severe vocal problems (Mc Kinney, 1994).

Voice characteristics of dysphonic singers have been studied widely in the Western countries and they have reported deficits in several areas of voice production. These included increased respiratory capacity (Hixon and Hoffman, 1978; Mc Kinney, 1994) due to lack of understanding about the respiratory physiology thereby causing unnecessary tension in the breathing mechanism and larynx while singing, abrupt vocal fold contact associated with hard glottal attack which is suggestive of excess tension in the vocal folds, reduced phonation time reflecting deficient laryngeal valving and/or reduced breath support, abnormal levels of frequency perturbation (Teachy, Kahane, and Beckford; 1991), reduced dynamic range (Kitch, Oates, and Greenwood, 1996; Rosen and Murry, 2000), increased closing and speed quotients, and increased high frequency spectral energy (Welham and Maclagan, 2004).

Though voice characteristics of singers and the problems they experience have been studied extensively, only a few studies have investigated the effects of performance on the voice of singers, especially Indian singers. Most of the studies reported have investigated only the effect of simulated vocal performance task (Ryker, Roy and Bless, 2000; Welham and Maclagan, 2004) on the voice of singers. In an acoustic and perceptual analysis of the voice of 10 tenors before and after a live performance, Kitch, Oates and Greenwood (1996) reported varying outcomes following performances, with some participants experiencing vocal deterioration and others vocal improvement. Difference in vocal training and performance experience were suggested as potential contributors to participant variability.

While it appears that the vocal mechanism may respond negatively to the demands of professional voice use, little is known about the nature and progression of vocal fatigue. This is particularly true with the performing voice. As stated by Kitch, Oates and Greenwood (1996), it is unclear whether transient vocal deterioration associated with a period of performance should be considered normal or a cause for clinical concern. It has been suggested by a number of authors that vocal fatigue may be related to other pathological voice conditions (Colton and Casper, 1996; Koufman, Blalock, 1988; Burzynski and Titze, 1985). If this suggestion is correct, than determination of the process and identifying important features of vocal fatigue is a critical area of investigation. Understanding the natural limits of the phonatory system as well as the nature of dynamic changes towards such limits would significantly augment current practices in voice care.

2.4.2 Voice Problems in Theatre Artists

Theatre performers are one of the largest groups of professional voice users who develop voice disorders because of abusive speaking or singing habits, especially hyperfunctional voice techniques. Acting frequently necessitates vocal production that explores a wider range than usual, in terms of loudness, pitch, rhythm and vocal quality. These projection skills in actors may be the result of alteration in the overall shape of the vocal tract which leads to an increase in spectral energy in the higher part of the spectrum (Smith, Finnegan, and Karnell, 2005; and Pinczower and Oates, 2005). Optimum projection is related to the breathing mechanism, resonators, and intelligibility of the text. These attributes are gained through vocal training. Lack of vocal training may lead to inappropriate projection by increasing laryngeal muscle tension, and constriction, resulting in vocal strain (Benninger, Jacobson, and Johnson, 1994). When the demand of characterization adds to this, it may place them at greater risk for developing voice disorders than other professional voice users.

Actors are also expected to enact many emotions, and to give in to the given circumstances of the plays they are in ("you have discovered that both your sister and wife have been murdered", "some one close to you has died in an accident', etc.). Realization of some of these emotions through voice may be considered to be vocally abusive behaviors. Such behaviors involve use of pitch and loudness in their extremes, increased muscular tension and forced and effortful explosion of air across the partially closed vocal folds (Roy and Bless, 2000). Actors, using vigorous voices, often encounter vocal trauma, hoarseness and other vocal symptoms when they assume a strained rough phonatory style for character portrayal (Sander and Ripich, 1983).

In addition to demands on their performance, other contributing environmental variables include physical interference with costumes and improper amplification ranging from inferior microphone placement to no amplification at all (Sataloff, 1997). There are various types of vocal challenges that contribute to a high-risk situation for performers. Some of those challenges include the stage environment, where the setting is frequently out doors with competing noise from crowds, traffic, or construction (Doherty and Shipp, 1988). Another performance challenge is the excessive amount of performance time, with as many as seven to eight 30-minute shows required daily (Hoffman - Ruddy, Lehman, Crandell, Ingram and Sapienza, 2001). Costumes present another environmental constraint. Some costumes are extremely heavy or restricting, and can result in poor posture in order for the performer to portray the character accurately (eg., hunchback). Also, some costumes may be difficult to tolerate because of an extreme amount of heat, resulting in physical fatigue. Others can be filled with feathers or hair and may be dirty or dusty leading to chronic allergic reactions or sinus infections. Similarly, the presence of large volume of smoke on stage, which the performers inhale before and during a performance, can affect their voice. Environmental conditions such as these can cause problems to laryngeal system in the form of dehydration, chronic laryngitis and chronic laryngeal muscle tension (Hoffman - Ruddy, Lehman, Crandell, Ingram and Sapienza, 2001).

Johnson (1994) lists several vocal behaviors thought to contribute to voice disturbance including loud talking, yelling, screaming, hard glottal attack, and speaking outside acceptable physiological range. Most of these behaviors are common to actors and characterize many of their vocal exertions during performance. Such behaviors are generally accepted to be vocally abusive, and may contribute to vocal fold mucosal injury and voice mutation.

Professional voice users have variously described the problems that they experience in their voice or related to voice usage. Vocal fatigue, general physical fatigue, throat fatigue, throat tightness or constriction, strained or tense throat, difficulty in producing and sustaining voice, reduction in pitch range and greater difficulty in producing higher pitches are some of the descriptions given (Raphael and Scherer, 1987).

Vocal change after performance is not well understood in the case of theatre artists as in the case with singers. There have been very few studies on this issue. Froeschels (1939) carried out one of the earliest investigations on the effects of performance on voice. Froeschels viewed subjects' larynges through direct laryngoscopy after a singing performance and reported that incomplete closure was a common effect, mainly in singers who he considered used poor vocal technique. However, Froeschels did not examine the singers before they performed; therefore, it is not possible to attribute his finding of incomplete glottal closure to performance. Novak, Dlouha, Capkova and Vohradnick (1991) investigated vocal changes in actors after a theatre performance. Their results showed that many of the subjects, particularly those with less vocal training, complained of vocal fatigue. However, no deterioration could be detected in their voice on a long-term average spectral analysis.

The work of Novak, Dlouha, Capkova and Vohradnick (1991) seems to be the only empirical study of the effect of live performance on voice. There is, however, a body of laboratory research that has some bearing on the question of vocal change after performance (Neils and Yairi, 1987; Sanders and Ripich, 1983; Hill, Oates, Healey and Russel, 1988). Together, this body of research suggests that occupational vocal loading may result in an elevated phonatory threshold, increased FO (Eskanazi, Childers, and Hicks, 1990; Kitch, Oates, and Greenwood, 1996; Kostyk and Rochet, 1998; Rantala, Paavola and Korkko, and Vilkman, 1998), reduced dynamic range (Sataloff, 1997; Raphael and Scherer, 1983; and Kitch, Oates, and Greenwood, 1996), reduced harmonic to noise ratio (Eskanazi, Childers, and Hicks, 1990; and Kitch, Oates, and Greenwood 1996), increased frequency and intensity perturbation (Sundberg, Elliot, Gramming, and Nord, 1993), increased closing and speed quotients, reduced spectral tilt and increased high frequency spectral energy (Welham, Maclagan, 2003).

Because of the limited knowledge that we have on the effects of performance on voice, further studies are required to advance our knowledge in this area. This can be done if investigators examine naturalistic performances **and improve** the methodological limitations of previous research. Therefore, the present exploratory study measured change in the voice of Yakshagana dancing artists and Bhagavathars following a live performance.

2.5 Yakshagana

Yakshagana is a combination of dance, music, spoken word, costume make up and stage technique (Karanth, 1975). It is a typical folk form of drama, commonly performed at night on a platform-like stage **in** open air with themes based on Hindu epics like the Ramayana, the Mahabharatha, and other mythological tales.

A Yakshagana performance commences with a pooja to Shri Ganesh. Loud background music is provided by chande and maddale (various types of drums) and tala (cymbals) handled by a team of three. The producer, director and the master of ceremonies is the Bhagavathar. Every actor must have good physique and excellent stamina, and should sing, dance, act and converse for almost the whole night. He should also have a sound knowledge of Hindu scriptures. In every act, there will be Gods, Goddesses, kiratas (mischief mongers), kimpurushas (mythological figures) and demons.

All the dancing artists of Yakshagana are expected to dance first behind the curtain before they enter the stage, then while entering, and thirdly while the song is sung. The dance behind the curtain is very elaborate especially in the case of the entry of the antihero, when the mood is heightened, or when a dancing artist enters in anger, or when someone is about to fight. The play has an accompanying songster (Bhagavathar) who sings keeping time. There is a shruthi instrument or drone, a 'mridangam' (a percussion instrument to keep time), and a special drum called 'chande' (a predominantly high frequency percussion instrument which is hit with wooden sticks to generate sharp sounds) which are played during scenes of exchange of angry words, fights, hurried entrance and while depicting travel of characters through long distances. The theme is in both song and verse. These are sung by the Bhagavathars and the dancing artists. The speech of dancing artists elaborately explains the contents of the song. Sometimes, the dancing artists also sing a part of the song, depending on the character they are portraying along with musicians (Karanth, 1975). Figure 2.1 depicts a scene from an Yakshagana performance.

Figure 2.1: An Yakshagana performance

Yakshagana has always been a "hereditary" art and the passing of the art to the next generation as well as mastering of the art of 'Yakshagana" (including all practical aspects of music, dance, make-up and performance) is done in informal ways. Interested boys join a troupe at a fairly early age. There are no classes for the newcomers. Learning is based on observation, imitation and trying out. Sometimes one of the senior members of the troupe may show some steps or teach a song. The practical mode of learning allows the student 'growing up with' and 'growing into' the art form. It is systematic to some extent and moves through the preliminary dances and characters to minor characters before specializing in particular roles and character types. The point to be noted however is that all the training is informal, and that there is no scope for any vocal education or counseling.

Some efforts are made in recent years to make this whole process a bit formal. Yakshagana schools or centers, founded after the 1970s, have strived to establish a formal basis of transmission of the art. Teachers, senior and junior students live together under one roof sharing chores and meals in a kind of 'gurukula' (residential school in which system a student stays in the house of the teacher himself doing the household chores of the teachers' house) mode. The classes start in June and end with the annual festival in May, next year. In this one-year period, the students are exposed to all aspects of the art and thus the tradition of versatile art continues (Katrin, 2005).

2.5.1 Voice Problems in Yakshagana Artists

Changes in voice after a prolonged vocal performance has been reported in singers (Kitch, Oates and Greenwood., 1996), theatre artists (Novak., Dlouha, Capkova, and Vohradnik 1991) and other professional voice users (Rantala, Paavola, Korkko and Vilkman, 1998; Rantala, Vilkman and Bloigu, 2002). The reasons for vocal changes may be prolonged voice use (singers, teachers, etc.), or use of a loud voice (cheer leaders, actors, etc.). Prolonged voice usage, use of loud voice and strenuous physical movements, in combination, may have greater implications on vocal performance. Yakshagana play involves both singing and acting. A Yakshagana performance usually starts at 10 o'clock in the night and ends at seven to eight hours after, the next morning. Yakshagana is also well known for use of a high frequency percussion instrument called 'chande'. The

Bhagavathars and dancing artists are expected to sing and speak over and above the noise of this instrument and a noise of a 1000 member strong audience who watch the performance. It can, therefore, be seen that both the Bhagavathars and the dancing artists have to endure prolonged period of strenuous voice usage. Hence, it can be said that the Yakshagana artists are more prone to vocal abuse than other group of professional voice users.

Therefore, the present exploratory study aimed to measure changes in the vocal function of Yakshagana Bhagavathars and dancing artists after a live performance task and a retest after a period of vocal rest. While holding greater methodological challenges, research of this nature is more likely than controlled laboratory studies to replicate the multifaceted reality of occupational vocal loading. The solo performance task was chosen as it has not been investigated with respect to voice abuse and vocal fatigue and may provide greater participant challenge than the choral task used by Kitch . Oates, and Greenwood (1996). Vocal function changes were documented using acoustic parameters because of their noninvasive nature as well as availability of instrumentation to the investigators.

2.6 Evaluation of Voice

Voice is a complex phenomenon that requires multiple measures to describe its characteristics. Subjective evaluation of the patient and routine examination are certainly valuable in the assessment of vocal function. However, it is no longer adequate to listen to the patient's voice and document the voice quality as sounding hoarse, harsh, or breathy as such documentation relies mainly on the judgment and experience of the clinician. With advances in technology, the perspectives of assessment and treatment of voice disorders have changed. Suggestions to view the function of voice production as related to various systems and to describe voice with reference to different positions of vocal tract (Perkins, 1971) have been made. There are several methods for assessment of vocal function including video fluoroscopy, video stroboscopy, video endoscopy, laryngeal electromyography, high-speed cinematography, photoelectric glottography, ultra sonography, electroglottography, and aerodynamic and acoustic analysis of voice.

Hirano (1981) has pointed out that it is necessary to use as many parameters of voice as possible in assessing voice and its disorders. Thus a single phonation can be assessed in different ways: aerodynamically, acoustically, electrographically, spectrally, etc. Objective instrumental measures of the acoustic speech signal allow the clinician to quantify important aspects of physiological function and may be used to corroborate or supplement subjective and perceptual measures. Acoustic analyses can facilitate accurate measurement of rate, duration and fluency-continuity aspects of speech and phonation. These speech production features provide further valuable diagnostic information regarding the integrity, function, and use of speech and vocal apparatus. There are a variety of software programs designed for clinical use, which provide real time (immediate feedback) displays and values for a variety of acoustic features. Vaghmi software (VSS, Bangalore, 1998) is one such program used for analysis of voice samples in the present study.

One of the most popular methods of measuring the pattern of vocal fold contact is the electroglottograph, which is noninvasive, safe and easy to perform. An electrode is positioned on each side of the thyroid cartilage. A low voltage current is passed between the electrodes. The principle of electroglottography is based on the fact that tissue is a moderately good electrical conductor, whereas air is an extremely poor conductor. Therefore, during the glottal cycle, the electrical impedance across the larynx rises (as the glottis opens) and falls (as the vocal folds come into increasingly intimate contact). Electroglottography, therefore, provides a measure of vocal fold contact. It can also be correlated with stroboscopic images. Electroglottography provides a perspective on vocal fold contact unobtainable in any other practical way.

Aerodynamic measures provide information about the laryngeal function that can be obtained with noninvasive approach. Clinical measures of phonatory and/or nasal flow rates and flow volumes are most commonly obtained with a face mask attached to a flow transducing unit. A plethysmograph or electro-aerometer may be used to transduce the aerodynamic signal to an electrical one that can be further analyzed and converted to standard units (cc per second or ml per second) and compared with norms. Vital capacity is considered an important measure of respiratory function as it reflects the total volume of air available for phonation, thus indirectly depicting the condition of the respiratory system. Mean airflow rate (MAFR) measured during production of a steady-state open vowel provides an estimate of glottic impedance, since oral resistance is at a minimum when the upper vocal tract is open. High phonatory flow rates are generally indicative of poor glottic valving, whereas low phonatory flow rates indicate hyper valving, provided the sub glottal pressure is kept constant, but may also reflect low intensity and/or poor respiratory support. Phonatory flow volume may also be measured to provide a value for cumulative flow (CC or ml) during a maximum performance test such as maximum phonation duration.

Hirano (1981) has remarked that the acoustic analysis of the voicing signal may be one of the most attractive methods for assessing phonatory function or laryngeal pathology because it is noninvasive, inexpensive and provides objective and quantitative data.

Research laboratories in voice have generated various subjective and objective voice indices to assess voice function. The voice handicap index (VHI) was one such index developed by Jacobson, Johnson, Grywalski, Silbergleit, Jacobson, Benninger, and Newman (1997) to assess patients' perception of severity of their voice disorder. It consisted of 30 questions divided by content into three realms: functional, emotional and physical. The questionnaire is completed by the patient using a 5-point rating scale to indicate his/her response. The higher the score, the more severe the patient's perception of disability due to the voice problem. However, it provides only a measure of self-perception of severity of the problem and does not consider objective voice parameters.

Multi dimensional voice index (Piccirillo, Painter, Fuller, and Fredrickson, 1998) was developed to identify objective parameters that are associated with voice function. However, the index considered only sub glottic pressure, airflow at the lips, frequency range, and maximum phonation time. Since multiple voice parameters are important to assess vocal function, this type of simple classification is not adequate for clinical assessment of vocal function. More recently, Wuyts, DeBodt, Molenberghs, Remade, Heylen, Millet, Lierde, Raes, and Heyning (2000) attempted to develop an index (dysphonia severity index) by means of a multivariate analysis to establish an objective and quantitative correlate of the perceived voice quality. However, this index considered only highest frequency, lowest intensity, maximum phonation time, and jitter. Again, this is not adequate to clinically assess vocal function as it considered only four parameters of voice. Therefore, there is a need for an objective voice index, which would combine acoustic, aerodynamic, and electroglottographic parameters of voice to assess vocal function.

Hence, it was decided to use the following parameters in the present study, as these parameters reflect various aspects of voice and the functioning of the systems involved in voice production: (a) fundamental frequency (FO), (b) speaking fundamental frequency (SFO), (c) frequency range (FR), (d) speed of fluctuations in frequency (SFF), (e) extent of fluctuations in frequency (EFF), (f) jitter, (g) mean intensity (MI), (h) range of intensity (IR), (i) speed of fluctuations in intensity (SIF), (j) extent of fluctuations in intensity (EIF), (k) shimmer, (1) harmonic to noise ratio (HNR), (m) alpha, beta and gamma ratios of long-term average spectrum (LTAS), (n) open quotient (OQ), (0) speed quotient (SQ), (p) vital capacity (VC), (q) mean airflow rate (MAFR) (r) maximum phonation duration (MPD), and (s) S/Z ratio. An objective voice index combining acoustic and aerodynamic parameters will be developed to quantify vocal function.

This is an exploratory study in the sense that no research has been conducted on the voice characteristics of Yakshagana artists or the effect of prolonged Yakshagana performance on the voice of its practitioners. The characteristics of the voice of singers and theater artists have been well documented. Yakshagana is an art form wherein the performers have to indulge in both singing and acting. The varied demands on their singing voice, the conditions under which singing is done, and singing under extreme physical exertion mean that the voice of Yakshagana artists is subjected to greater pressure than the voice of either singers or actors alone. Added to this is another factor of duration of Yakshagana play. An Yakshagana play lasts for 7 to 8 hours, and a given character, particularly the main ones, will have to perform for 60% to 65% of this time on a given day. On top of this is the fact that Yakshagana dramas are played day-after-day during the season, for 5 - 6 months in a year. All these put tremendous physical as well as psychological pressure on the laryngeal mechanism of the practitioners of Yakshagana. It is only natural to expect that sooner or later there would be consequences for the voice of Yakshagana artists. Understanding these consequences would help in counseling the artists on voice care, and vocal education to avoid long-term and permanent damage to their vocal mechanism. Therefore, the present study was undertaken to understand the short — and long — term effects of overuse of voice.

Chapter 3

Method

The purpose of this investigation was to study the short- as well as long term effect of Yakshagana performance on the voice of Yakshagana artists, both the Bhagavathars and the dancing artists. The identification of affected vocal parameters in these artists due to inappropriate use of voice during Yakshagana performance would indicate the need for vocal education of Yakshagana artists as well as other artists of their kind. The effect of short voice rest (10-12 hours) on the vocal parameters following a Yakshagana performance was also investigated. Detailed investigation in this direction would help the speech pathologists to understand better the nature of vocal abuse, and factors contributing to it.

3.1 Objectives

The main objectives of the study were to:

a) make a comparative analysis of the acoustic and respiratory related parameters of voice of normal speakers and Yakshagana artists, both the Bhagavathars and the dancing artists,

b) investigate the effect of a live Yakshagana performance on the voice of Yakshagana artists (short-term effect), both the dancing artists and the Bhagavathars, by comparing their voice parameters prior to and following Yakshagana performance,

c) study the effect of short voice rest, ranging from 10-12 hours, following an Yakshagana performance, on vocal parameters, in both groups of artists, and

d) combine all parameters of voice to arrive at a voice index which is an overall indicator of the status of voice of a given speaker.

3.2 Subjects

A group of 60 Yakshagana artists, all males, participated in the study. The group included 30 dancing artists and 30 Bhagavathars. Dancing artists ranged in age from 21 - 49 years with a mean age of 32.9 years. Bhagavathars ranged in age from 24 - 48 years with a mean age of 36.5 years. Some of them had longer experience, in the art, of as much as 25 years. This experimental group was divided into two groups consisting of 30 Yakshagana singers (hereafter referred to as Bhagavathars) and 30 Yakshagana actors (hereafter referred to as dancing artists).

Yakshagana artists had to fulfill the following criteria to be included in the study:

a) They must be practicing Yakshagana - either as a Bhagavathar or an actor (dancing artist) for at least 5 years in the immediate past. They must have performed in at least 100 episodes of Yakshagana.

b) They should have had no illness affecting their laryngeal, respiratory or articulatory systems.

c) They should have normal hearing.

d) They must be in the age range of 20 to 50 years.

A control group of 30 normal subjects , all males, in the age range of 21-46 years (mean age - 31.4 years) were included in the study. The normal subjects should have had no experience in Yakshagana, or any other form of dance-drama over a long period of time to be eligible to participate in the study.

it is not intended to say that Yakshagana artists were not normal. It is only for the convenience of differentiation between subjects in the control and experimental groups that the phrase normal subjects has been used to refer to control subjects.

The subjects in the control group fulfilled all the selection criteria as the subjects in the experimental group except that they were not Yakshagana artists. Table 2.1 shows subject details.

Sl No	Normals	Yakshagana Dancing Artists		Yakshagana Bhagavathars	
	Age	Age	Experience	Age	Experience
1	22	34	13	36	15
2	28	39	20	38	13
3	35	49	24	44	20
4	21	36	15	24	7
5	40	22	8	34	15
6	32	31	8	41	20
7	28	34	16	36	10
8	24	28	6	44	20
9	46	26	7	48	27
10	25	48	25	43	23
11	23	33	16	29	7
12	36	38	20	36	13
13	28	43	25	28	11
14	40	29	7	48	20
15	24	30	9	30	13
16	36	46	21	33	9
17	42	39	8	37	20
18	26	21	6	34	17
19	30	26	7	28	9
20	32	35	15	71	6

21	36	31	17	34	14
22	29	28	7	31	8
23	28	23	8	42	21
24	34	40	22	45	24
25	41	33	15	36	21
26	36	24	7	47	25
27	29	31	13	34	18
28	35	36	20	35	23
29	35	31	15	43	21
30	21	24	8	30	10

Table 3.1: Age and experience (in years) of subjects

3.3 Materials

The following phonation and speech samples were recorded from each subject:

a) phonation of vowel /a/ for measurement of fundamental frequency (F0), jitter (F0%), speed of frequency fluctuations (SFF), extent of frequency fluctuations (EFF), mean intensity (Ml), shimmer, speed of intensity fluctuations (S1F), extent of intensity fluctuations (EIF), harmonic to noise ratio (HNR), open quotient (OQ), and speed quotient (SQ),

b) spontaneous speech about their experience in the profession for measurement of speaking fundamental frequency (SFO) and alpha, beta and gamma ratios of long-term average spectrum,

c) phonation of vowel /a/ from the lowest to the highest frequency, following imitation of a model, for measurement of frequency range,

d) phonation of vowel /a/ from the lowest to the highest intensity, following following imitation of a model, for measurement of intensity range,

e) expiration and sustained phonation of /a/ for measurement of vital capacity, mean airflow rate, and maximum phonation duration, and

f) sustained production of /s/ and /z/ for measuring S/Z ratio.

3.4 Recording of Samples

The phonation and speech samples were recorded in a quiet environment. The subjects were comfortably seated and recordings were made onto a multi channel (three) portable mini digital disc recorder (Sony MZ - R3) with a sampling rate of 44.1 kHz and 16 bit precision. Acoustic and electro glottographic signals were simultaneously recorded. The microphone was placed at about 6 inches from the mouth for audio-recording. The subjects were instructed to relax and phonate vowel /a/ or speak about their profession in their natural voice. Phonation of vowel /a/ from the lowest to the highest frequency and from lowest to the highest intensity, following imitation of a model, was obtained to note down the frequency and intensity range, respectively.

Electroglottographic (EGG) signal was recorded for vowel /a/ only. Electrodes were connected to EGG unit. Output of EGG was recorded on to a multi channel portable mini digital disc recorder (Sony Mz-R3).

Subjects were also asked execute the respiratory tasks. The respiratory parameters were measured using a portable spirometer (Vitalograph-2120). Subjects were instructed to take a deep inhalation and expire as much of air as possible (in one breath) in to the mouthpiece of the portable spirometer to measure the vital capacity. The subjects were instructed to take a deep inhalation and phonate /a/ as long as possible into the mouthpiece of a portable spirometer to measure mean airflow rate. Subjects were instructed to take a deep inhalation and phonate /a/ as long as possible into the microphone of the digital tape recorder to measure maximum phonation duration. Subjects were also instructed to take a deep inhalation and sustain fricatives /s/ and /z/ alternatively into the microphone of the digital tape recorder to measure S/Z ratio.

3.5 Recording Schedule

Recording of voice and measurement of respiratory related parameters were made three times in the case of Yakshagana artists as follows:

a) 30 minutes to 1 hour before the Yakshagana performance (Condition 1)

b) 10 to 30 minutes after the Yakshagana performance (Condition 2)

c) After 10-12 hours of vocal rest, the next evening, to see the effects of vocal rest (Condition 3).

3.6 Acoustic Analysis

Recorded voice samples were digitized at a sampling frequency of 16 kHz with 12-bit precision and stored on to the computer. All acoustic parameters were extracted using Vaghmi software (Voice & Speech Systems, Bangalore, 1998). The instrumentation set up is shown in Figure 3.1.

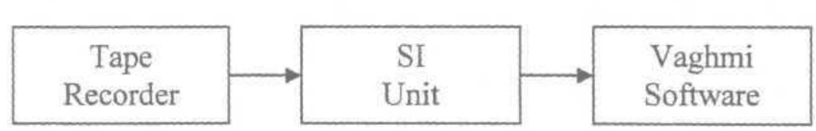

Figure 3.1: Block diagram of instruments used for acoustic analysis.

3.6.1 Frequency Related Measures

3.6.1.1 Fundamental Frequency of Voice [FO (Hz)]

It is the average frequency of a phonation sample averaged over blocks of 32 milliseconds length. Frequency was extracted every 10 milliseconds and averaged. Figure 3.2 shows a typical F0 curve for vowel /a/.

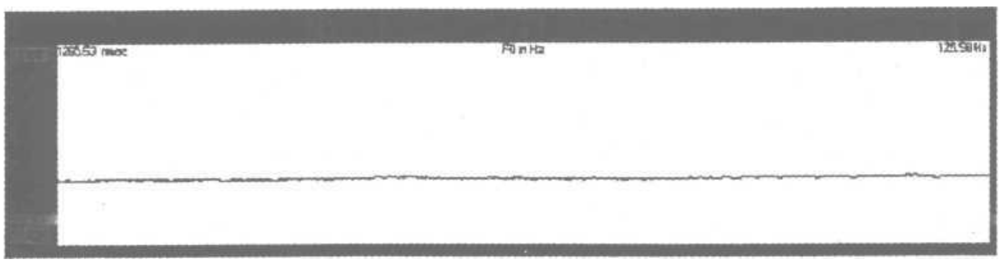

Figure 3.2: Illustration of F 0 extraction from phonation.

3.6.1.2 Fundamental Frequency in Speech [SFO (Hz)]

It is the average of frequencies of a speech sample averaged over blocks of 32 milliseconds length of sample. Frequency is extracted every 10 milliseconds (except pause) and averaged. Figure 3.3 shows a typical F0 curve for speech.

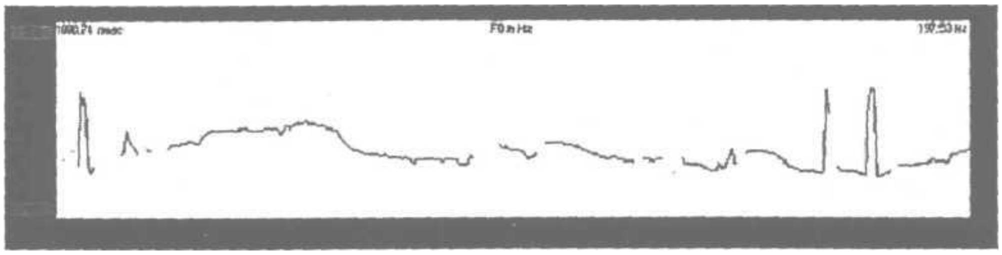

Figure 3.3: Illustration of FO extraction from speech.

3.6.1.3 Frequency Range in Phonation [FR (Hz)]

It is the difference between the highest and the lowest frequencies an individual can phonate. Figure 3.4 shows a typical frequency curve for frequency range.

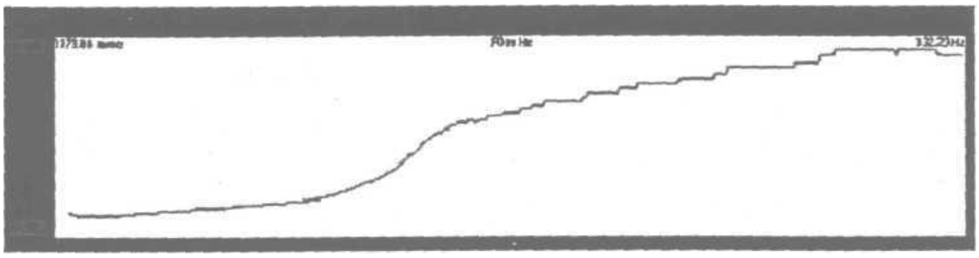

Figure 3.4: Frequency range in phonation (left end is the lowest frequency and right end is the highest frequency).

3.6.1.4 Jitter (F0%)

Jitter is the cycle - to - cycle variation in the frequency of voice of a sustained phonation. The Vaghmi software computes jitter with the following formula:

$$\overset{j=N-l}{S}[1/(N-1)] \quad \text{Abs} \; [FO \; G) - FO \; (j+1)]$$

where FO (j) is the fundamental frequency for the j^{th} cycle, and N is the number of cycles analyzed.

3.6.1.5 Extent [EFF] and Speed of Frequency Fluctuations [SFF]

Variations greater than $\pm$ 3 Hz in fundamental frequency of a sample of sustained phonation of vowel /a/ are considered as fluctuations. The mean of all fluctuations greater than 3 Hz in a second is termed the extent of fluctuations in frequency and the number of such fluctuations in one second is termed speed of fluctuations.

3.6.2 Amplitude Related Measures

3.6.2.1 Mean Intensity [MI (dB)]

It is the sound pressure level of a sample of phonation of vowel /a/. Subjects were instructed to phonate vowel /a/ at a comfortable pitch and loudness. Using INTON program of Vaghmi software, intensity was averaged over blocks of 32 milliseconds length of sample. Average intensity was read from the digital display of the software. Figure 3.5 shows a typical intensity curve extracted from phonation of vowel /a/.

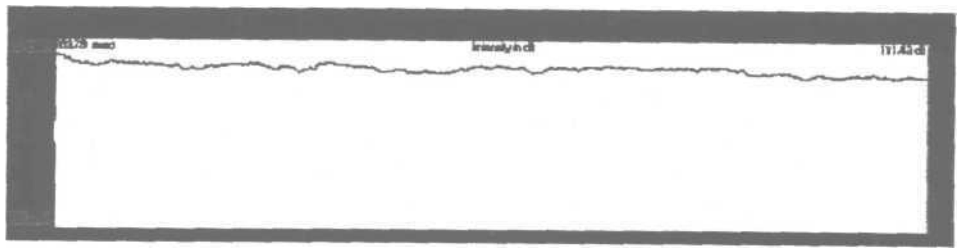

Figure 3.5: Intensity curve for phonation.

3.6.2.2 Intensity Range in Phonation [IR (dB)]

It is the difference between the maximum and minimum sound pressure levels that an individual can produce. Figure 3.6 illustrates a typical intensity range curve in phonation of vowel /a/.

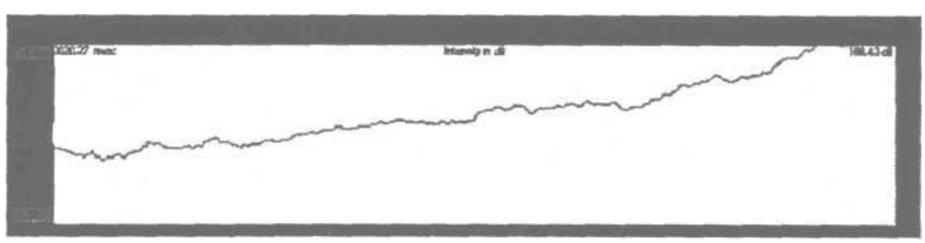

Figure 3.6: Intensity range in phonation (left end is the lowest intensity and right end is the highest intensity).

3.6.2.3 Shimmer (dB)

Shimmer is the cycle - to - cycle variation in the amplitude of a sustained phonation. The Vaghmi software computes shimmer in the dB scale with the following formula:

$$\sum_{j=1}^{j=N-1} [1/(N-1)]\ \mathrm{Abs}[I(j)-I(j+1)]$$

where I (j) is the intensity in dB of the j^{th} cycle, and N is the number of cycles analyzed.

3.6.2.4 Extent [EIF] and Speed of Intensity Fluctuations [SIF]

Variations greater than $\pm$ 3 dB in the intensity of a sample of sustained phonation of vowel /a/ are considered as fluctuations. The mean of all fluctuations greater than 3 dB in a second is termed the extent of fluctuations in intensity and the number of such fluctuations in a second is termed speed of fluctuations.

3.6.3 Spectral Related Measures

3.6.3.1 Harmonic to Noise Ratio [HN Ratio (dB)]

It is the ratio between the sound pressure level of harmonics and noise in a glottal signal. H/N ratio was extracted from the spectra of laryngeal signal of vowel /a/ recorded from electroglottogram using 'HNR' program of Vaghmi software. This is usually obtained by measuring the intensity of harmonics and the noise. Figure 3.7 shows a typical glottal spectra of vowel /a/ from which H/N ratio is extracted.

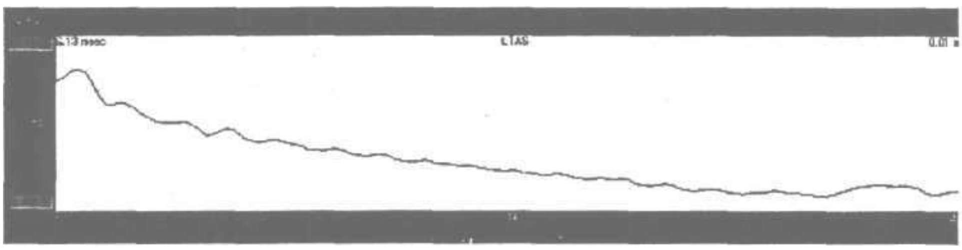

Figure 3.7: Glottal spectra of vowel /a/.

3.6.3.2 Long-Term Average Spectra [LTAS]

Long-term average spectra provide information on the energy at various frequencies in speech signal. A speech sample of duration of 3 seconds was used to obtain LTAS. Figure 3.8 shows a typical LTAS of speech signal. Three ratios were extracted from LTAS as follows:

a) α Ratio: It is the ratio of energy between 0-1 kHz, and 1-5 kHz.

b) ß **Ratio:** It is the ratio of energy between 0-2 kHz and 2-5 kHz.

c) γ **Ratio:** It is the ratio of energy between 0-1 kHz and 5-8 kHz.

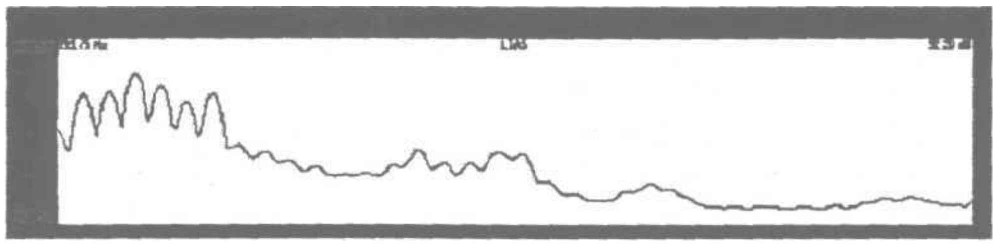

Figure 3.8: LTAS of a speech signal.

3.6.4 Electroglottographic Measurement [EGG]

The principle of conduction of electricity is used in EGG. Two electrodes, one emitter and the other receiver, are placed externally on either side of thyroid lamina of the subject. High frequency low voltage current is passed through the emitter. The current transmitted to the receiver is amplified and fed to a visual display unit. Figure 3.9 shows the vocal fold displacememnt pattern in one cycle of phonation and the EGG signal.

Electroglottographic (EGG) signal was recorded for vowel /a/. Electrodes were placed externally on either side of the thyroid alae and were connected to EGG unit (Voice & Speech System, Bangalore). Output of EGG was recorded onto a digital disc using a portable mini digital disc recorder (Sony

Mz-R3). The recorded signal was digitized on to the computer and displayed as a time (x-axis) vs. voltage (y-axis) waveform. On visualization of EGG, the

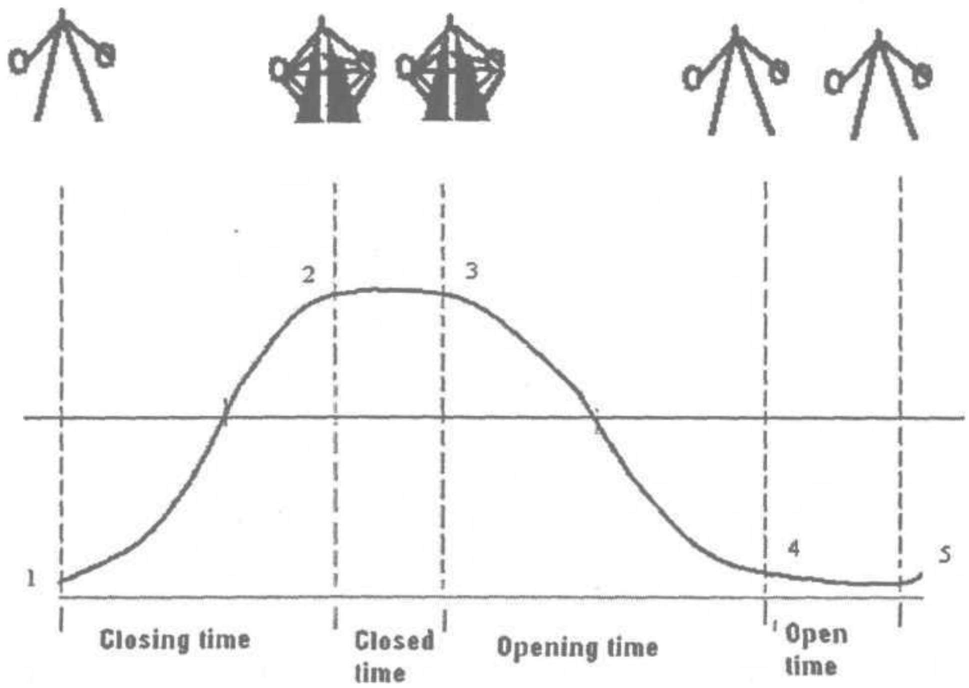

Figure 3.9: Schematic view of vocal fold movements (upper view), and EGG signal (lower view).

the ending of opening (-ve peak), closure (+ve peak), end of closure, and beginning of opening of vocal folds were marked manually for the middle 5 consecutive cycles. Open quotient and speed quotient were extracted from these markings. A schematic representation of these markings is shown in Figure 3.10.

3.6.4.1 Open Quotient [OQ] and Speed Quotient [SQ]

Open quotient is the ratio of open phase to total time while speed quotient is the ratio of opening to closing time.

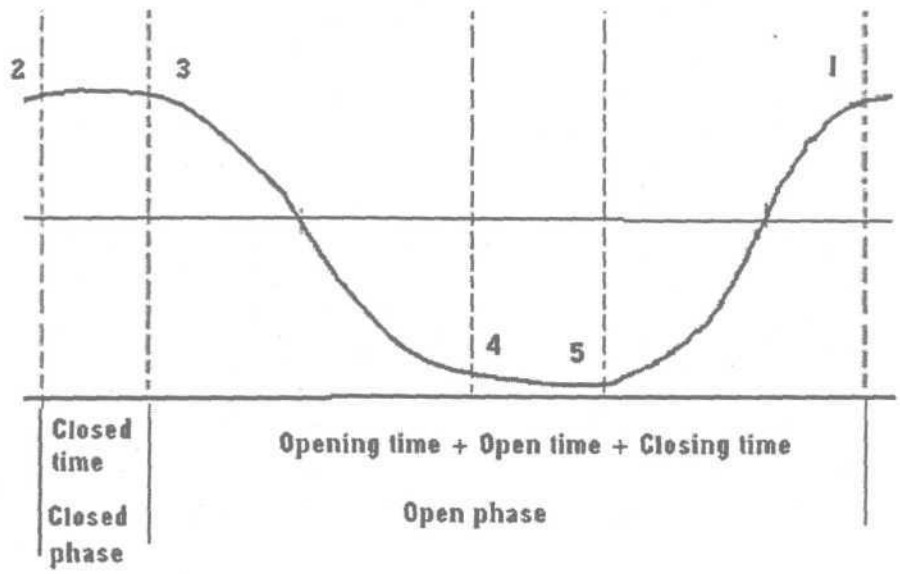

Figure 3.10: A schematic representation of markings of various events on EGG.

3.6.5 Respiratory Related Parameters

The subjects were required to do the following tasks for measuring respiratory related parameters.

3.6.5.1 Vital Capacity [VC (cc)]

Vital capacity is the volume of air exhaled after a deep inhalation. Vital capacity was read from the digital display on Vitalograph 2120 in cc. Figure 3.11 shows the instrumentation for obtaining vital capacity and other respiratory related measures.

Figure 3.11: Illustration of measurement of vital capacity using portable spirometer (Vitalograph 2120).

3.6.5.2 Mean Air Flow Rate [MAFR (cc/sec)]

Mean airflow rate (MAFR) was measured as the volume of air expired in one second during phonation of vowel /a/. The experimenter noted the digital display of duration of phonation and the volume of air exhaled from the portable spirometer. Mean airflow rate was calculated by dividing the volume of expired (phonation volume) air by phonation time.

3.6.5.3 Maximum Phonation Duration [MPD (sec)]

Maximum phonation duration (MPD) was measured as the duration for which an individual can sustain phonation after a deep inhalation. The experimenter noted the digital display of duration of phonation from the digital tape recorder.

3.6.5.4 S/Z Ratio

It is the ratio of the duration of sustained production of /s/ and /z/. The experimenter noted the digital display of the duration of /s/ and /z/ production from the digital tape recorder to obtain s/z ratio.

3.7 Analyses

Six types of analyses were carried out:

a) Analysis of the acoustic and respiratory parameters of the voice of Yakshagana artists and comparing them with those from normals. This analysis will give the long-term effects of Yakshagana performance on the voice of these artists. Separate analysis and comparison was made in the case of Yakshagana dancing artists and Bhagavathars.

b) Analysis of acoustic and respiratory parameters of voice recorded immediately after an Yakshagana performance, and comparison of these results with those from an analysis of pre - performance recording [(a)-above]. This comparison will give short-term effects of Yakshagana performance on the voice of Yakshagana artists. Again, separate analysis and comparison was made in respect of Yakshagana dancing artists and Bhagavathars.

c) Analysis of acoustic and respiratory parameters of voice recorded 10-12 hours after an Yakshagana performance, and comparison of these results with those from the post-performance recordings [(b)-above]. This comparison will give short-term effects of voice rest on the voice of Yakshagana artists. Separate analysis and comparison was made in respect of Yakshagana dancing artists and Bhagavathars.

d) Analysis of the relationship between characteristics of subjects (for example, years of Yakshagana performance, smoking, etc.) with the subjective complaints of voice made by the subjects, as well as with the results of acoustic analysis of voice.

e) A discriminant function analysis of the characteristics of voice to see if results of acoustic analysis of voice can reliably separate the three groups of subjects.

f) Combine all the measurements made into one index which may reflect the overall status of a person's voice.

Chapter 4

Results

The present study was undertaken to analyze the characteristics of the voice of Yakshagana artists, both the Bhagavathars and the dancing artists. Years and years of voice usage, often under abusive circumstances, may have affected the voice of these artists. Vocal misuse or abuse, as described earlier, may lead to the development of voice disorders in professional voice users. This study employed the objective method of acoustic analysis to find the effect of years of Yakshagana performance on the voice of Yakshagana artists. The scheme of the study provided for analysis of both short and long-term effects of Yakshagana on the voice of its practitioners.

4.1 Subjects

Sixty subjects, consisting of 30 Bhagavathars and 30 dancing artists were selected for the study. Dancing artists were in the age range of 21-49 years with a mean age of 32.9 years while the Bhagavathars were in the age range of 24-48 years with a mean age of 36.5 years. There was also a third group of 30 normal subjects in the age range of 21 - 46 years with a mean age of 31.4 years.

4.2 Voice Complaints by Yakshagana Artists

Subjects in both the experimental groups, dancing artists and Bhagavathars reported experiencing certain problems in their voice from time to time. The complaints included vocal fatigue (unable to continue speaking after usage of voice for some time), change in voice quality, voice breaks, irritation and dryness in the throat, among others. However, none of the subjects had been suffering from, or had been treated for laryngeal or respiratory related diseases. Complaints as reported by subjects are summarized in Table 4.1. It appears that ahnost the same number of subjects in each group seems to experience voice problems even though the pattern of usage and years of practice are different in the two groups.

An interesting bit of information obtained from the subjects pertained to their habit of alcohol and tobacco usage. Eighty-six and ninety percent of Yakshagana dancing artists had the habit of alcohol usage and smoking, respectively. In contrast, only 13.3% and 50% of the Bhagavathars reported usage of alcohol and smoking. Additionally, 53.3% of dancing artists, and 46.6% of Bhagavathars had tobacco chewing habit.

Voice Symptoms	Dancing Artists (%)	Bhagavathars (%)
Vocal fatigue	73.3	60.0
Change in voice quality	63.3	86.6
Irritation/dryness in the throat	40.0	33.3
Voice breaks	36.6	40.0
Pain/burning sensation in the throat	23.3	16.6
Loss of pitch range	46.6	53.3

Table 4.1: Voice complaints reported by Yakshagana dancing artists and Bhagavathars

4.3 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Nature of Voice Complaints by the Subjects

Whether or not duration of Yakshagana practice, the habits of smoking, alcohol usage and tobacco chewing were associated with the nature of voice complaints made by the subjects was analyzed using chi-square test for independence of attributes (test for association). The results are presented in Table 4.2. Cramer's V was calculated to find the extent of association between these factors. Cramer's V ranges from 0 to 1 and a value of 1 indicates perfect association. The subjects were grouped on the basis of duration of Yakshagana practice, alcohol usage, smoking and tobacco habit. Accordingly, the subjects were assigned into two groups one group had artists who had >14.8 years experience (N = 33) and the other with <14.8 years experience (N = 27). 14.8 =years was the average duration for which the subjects were practicing Yakshagana.

Similarly, subjects were put into two groups on the basis of alcohol usage [alcohol users (N = 30) and non users of alcohol (N = 30)], smoking [smokers (N = 42) and non-smokers (N = 18)], and tobacco chewing (those who had the habit (N = 30) and those who did not (N = 30)].

Voice Symptoms	Years of Yakshagana	Smoking	Alcohol	Tobacco Chewing
	< 14.8 years Vs > 14.8 years	Smokers Vs Non-smokers	Users Vs Non- users	Users Vs Non -users
	——Crammer's V——			
Vocal Fatigue	0.21	0.08	0.28*	0.35*
Change in voice quality	0.53*	0.21	0.19	0.04
Irritation/dryness in the throat	0.62*	0.20	0.14	0.21
Voice breaks	0.82*	0.16	0.10	0.31*
Pain/burning sensation in the throat	0.21	0.06	0.08	0.17
Loss of pitch range	0.79*	0.07	0.13	0.13

Table 4.2: Crammer's V values showing the relationship between years of Yakshagana practice, smoking, alcohol usage and tobacco

chewing habit on the nature of voice complaints by Yakshagana artists.

* - significantly different at 0.05 level

The results in Table 4.2 can be summarized as follows:

a) Subjects with more than 14.8 years of Yakshagana years are statistically more likely to complain of change in voice quality, irritation/dryness in the throat, voice breaks and loss of pitch range in their voice than subjects with less than 14.8 years of Yakshagana practice.

b) Yakshagana artists with or without smoking habit are likely to experience similar problems in their voice.

c) However, Yakshagana artists with alcohol habit are statistically more likely to complain of vocal fatigue than Yakshagana artists who do not have the habit.

d) Similarly, Yakshagana artists who had tobacco-chewing habit are more likely to complain of vocal fatigue and voice breaks than Yakshagana artists who did not have tobacco-chewing habit.

4.4 Voice Characteristics of Different Groups of Subjects

4.4.1 Comparison of the Voice of Normals and Yakshagana Artists

The mean values of acoustic, electroglottographic, and respiratory measures were compared between normals and Yakshagana artists (Yakshagana dancing artists + Yakshagana Bhagavathars) using Mann Whitney's two independent samples test. Mann Whitney's two independent samples test was employed for comparison because of unequal size of the two groups [normals (N = 30); Yakshagana artists (N = 60)].

Any person can vary his/her voice to a greater extent because the vocal mechanism is very flexible. The anatomy and physiology of the vocal mechanism is so sophisticated that voice may not be considered abnormal or deviant even if one of its attributes varies widely. Therefore, the present study adopted a significance level of 1% (0.01 level) for the statistical significance of differences.

The results of Mann Whitney's test for the significance of difference of mean scores of the two groups for all the voice parameters are given in Table 4.3. Results of comparison show that the two groups of normals and Yakshagana artists were significantly different from each other on most of the parameters analyzed except with regard to fundamental frequency, speed and extent of intensity fluctuations, gamma ratio of long-term average spectmm, and open quotient.

Voice Parameters	Normals		Yakshagana Artists		Z
	Mean	SD	Mean	SD	
FO	115.6	15.2	125.2	18.6	2.41
SFO	129.0	14.1	149.8	21.9	4.45*
FR	197.9	84.7	246.8	88.8	2.65*
Jitter	0.7	0.5	2.3	1.9	4.65*
SFF	0.3	0.1	1.1	0.7	2.68*
EFF	0.5	0.1	1.5	1.2	2.81*
MI	45.2	4.9	49.4	4.0	3.67*
IR	45.4	4.5	50.2	4.1	4.67*
Shimmer	0.3	0.2	0.7	0.6	3.23*
SIF	0.2	0.1	0.3	0.1	0.48
EIF	0.5	0.1	0.3	0.1	0.68
Alpha	96.4	13.8	57.5	26.9	6.20*
Beta	912.2	238.8	657.7	337.1	3.60*
Gamma	3680.0	1949.8	3246.2	1350.5	0.80
HNR	24.6	2.1	22.5	2.7	3.33*
OQ	0.5	0.2	0.6	0.2	0.07
SQ	1.3	0.1	1.9	0.7	3.68*
VC	2715.0	438.0	3316.1	493.8	3.83*
MAFR	120.4	23.3	154.6	29.6	4.93*
MPD	24.1	4.4	28.1	4.2	3.27*
S/Z	0.9	0.1	1.2	0.2	3.27*

Table 4.3: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency

range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in normals and Yakshagana artists. A 'z' value of 2.65 is significant at 0.01 level.

* - significantly different.

The results in Table 4.3 can be summarized as follows:

a) Mean speaking fundamental frequency, mean frequency range, mean jitter, mean speed and extent of fluctuations in frequency was significantly higher in Yakshagana artists compared to normal subjects.

b) Mean intensity, mean intensity range and mean shimmer were significantly higher in Yakshagana artists than in normals.

c) Mean alpha and beta ratio (long-term average spectrum) and mean harmonic to noise ratio was significantly less in Yakshagana artists than in normals.

d) Mean speed quotient was significantly higher in Yakshagana artists than in normals.

e) Mean values of respiratory measures - vital capacity, mean airflow rate, maximum phonation duration, and S/Z ratio - were all significantly higher in Yakshagana artists compared to normals.

4.4.2 Comparison between Normals, Yakshagana Dancing Artists and Bhagavathars

Since the nature of vocal performance of the two groups of Yakshagana dancing artists and Bhagavathars are different, one-way analysis of variance was performed to see how the two groups of Yakshagana artists differed from each other **as** well as from normals. The mean values of voice parameters of the three groups of normals, Yakshagana dancing artists, and Bhagavathars and the results of one-way ANOVA are given in Table 4.4. As the main effects were significant, Duncan's post hoc pair-wise comparison test was carried out to see which of the given two groups differed significantly. Results showed that the Yakshagana dancing artists and Bhagavathars significantly differed from normals on almost all the voice parameters while the two groups of Yakshagana artists - dancing artists and Bhagavathars differed from each other only on a few parameters. Results in Table 4.4 are summarized in Table 4.5.

Voice Parameters	Normals		Dancing Artists		Bhagavathars		
	Mean	SD	Mean	SD	Mean	SD	F
FO	115.6	15.2	121.5	17.5	128.9	19.8	4.28
SFO	129.0	14.1	148.0	23.3	151.5	20.5	11.31*
FR	197.9	84.7	243.9	101.8	249.7	75.9	3.10
Jitter	0.7	0.5	2.7	2.3	1.9	1.6	11.02*
SFF	0.3	0.1	1.2	1.1	0.9	0.3	3.41

EFF	0.5	0.1	1.4	1.1	1.6	1.4	4.87*
Mean I	45.2	4.9	49.0	4.1	49.9	4.0	9.90*
IR	45.4	4.5	50.9	3.8	49.6	4.3	13.85*
Shimmer	0.3	0.2	0.8	0.6	0.5	0.4	8.12*
SIF	0.2	0.1	0.4	0.1	0.2	0.1	2.83
EIF	0.5	0.1	0.5	0.1	0.2	0.1	1.52
Alpha	96.4	13.8	56.7	28.2	58.4	25.7	27.52*
Beta	912.2	238.8	576.2	254.0	739.3	420.9	8.50*
Gamma	3680.0	1949.8	3335.4	1026.0	3157	1686.9	0.59
HNR	24.6	2.1	22.3	2.5	22.7	2.9	6.80*
OQ	0.5	0.2	0.7	0.2	0.4	0.1	8.14*
SQ	1.3	0.1	1.7	0.6	2.0	0.7	10.74*
VC	2715.0	438.0	2809.0	510.0	3823.3	477.5	49.98*
MAFR	120.4	23.3	155.6	37.5	153.6	21.6	14.57*
MPD	24.1	4.4	24.2	3.9	32.0	4.4	33.01*
S/Z	0.9	0.1	1.2	0.2	1.1	0.1	5.60*

Table 4.4: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in normals and Yakshagana artists and results of analysis of variance. F value of 4.87 is significant at 0.01. Degrees of freedom = 2, 87.

* - significantly different.

Normals Vs Dancing Artists	Normals Vs Bhagavathars	Dancing Artists Vs Bhagavathars
SFO	SFO	Shimmer
Jitter	Jitter	Beta
EFF	EFF	VC
MI	MI	MPD
IR	IR	OQ
Shimmer	Alpha	
Alpha	Beta	
Beta	HNR	
HNR	SQ	
OQ	VC	
SQ	MAFR	
MAFR	MPD	
S/Z	S/Z	

Table 4.5: Parameters that were significantly different between any two groups given.

The results in Table 4.4 and 4.5 can be summarized as follows:

a) Both Bhagavathars and dancing artists had significantly higher mean speaking fundamental frequency compared to normals. Bhagavathars had the highest mean speaking fundamental frequency followed by dancing artists and normals. However, the difference in mean speaking fundamental frequency was not significant between dancing artists and Bhagavathars.

b) Mean jitter was significantly higher in dancing artists and Bhagavathars than in normals. However, dancing artists and Bhagavathars did not differ from each other with respect to mean jitter though dancing artists had higher jitter values than Bhagavathars.

c) Mean extent of fluctuations in frequency was significantly higher in Bhagavathars and dancing artists than in normals. But Bhagavathars and dancing artists did not differ significantly though Bhagavathars had a higher mean fluctuation than dancing artists.

d) Mean intensity and intensity range were significantly higher in dancing artists and Bhagavathars than in normals. Mean intensity was the highest for Bhagavathars followed by dancing artists and normals. On the other hand, mean intensity range was highest for dancing artists followed by Bhagavathars and normals. However, dancing artists and Bhagavathars did not significantly differ from each other with respect to mean intensity and intensity range.

e) Mean shimmer was significantly higher in dancing artists than in Bhagavathars and normals. However, Bhagavathars and normals did not differ significantly from each other though mean shimmer was higher in Bhagavathars than in normals.

f) Mean alpha and beta ratios (long - term average spectrum) and mean harmonic to noise ratio were significantly higher in normals than in dancing artists and Bhagavathars. Normals had the highest mean values of alpha, beta, and harmonic to noise ratio followed by Bhagavathars and dancing artists. Furthermore, results revealed a significantly higher beta ratio in Bhagavathars compared to dancing artists.

g) Mean open quotient was significantly higher in dancing artists than in normals and Bhagavathars. On the contrary, mean speed quotient was found to be significantly higher in Bhagavathars and dancing artists compared to normals. However, Bhagavathars and dancing artists did not differ significantly with respect to speed quotient.

h) Mean vital capacity and mean maximum phonation duration were significantly higher in Bhagavathars than in normals and dancing artists. However, dancing artists and normals did not differ significantly with respect to vital capacity and maximum phonation duration though dancing artists had a higher vital capacity and maximum phonation duration than normals.

i) Mean airflow rate was significantly higher in dancing artists and Bhagavathars compared to normals. However, the difference in mean airflow rate was not statistically significant between the two experimental groups.

j) Mean S/Z ratio was significantly higher in dancing artists and Bhagavathars than in normals. Dancing artists had the highest mean S/Z ratio followed by Bhagavathars and normals. However, the difference was not statistically significant between the two experimental groups.

4.5 Discriminant Analysis

Next, the issue of whether the subjects could be reliably classified as belonging to one of the three different groups, namely normals, Yakshagana dancing artists, and Bhagavathars was analyzed through discriminant analysis (Fisher, 1936). The direct method of simultaneously extracting the scores on all the 21 voice parameters in a discriminant equation was followed. As a result of this analysis, two canonical discriminant functions were extracted. The significant level of both the functions was < 0.001. The percentage of variance explained by the two functions was 74% and 26%, respectively. On the basis of the values of the two discriminant functions, 96.7% of all the subjects could be classified correctly, as can be seen in Table 4.6 (average of correct identification of normals - 96.7%; dancing artists 93.3%; and Bhagavathars - 100%).

Actual Group	Predicted group Membership		
	1 Normals	2 Dancing Artists	3 Bhagavathars
1. Normals	29 (96.7%)	1 (3.3%)	0 (-)
2. Dancing Artists	1 (3.3%)	28 (93.3%)	1 (3.3%)
3. Bhagavathars	0 (-)	0 (-)	30 (100%)

Table 4.6: The results of discriminant analysis on the basis of 21 voice parameters entered simultaneously and group membership of subjects.

The pooled within-groups correlations between each of the voice parameters and the two canonical discriminant functions are given in Table 4.7.

Voice Parameters	Function 1	Functio:
VC	0.465*	-0.398
SQ	0.241*	0.03]
F0	0.232*	0.146
MI	0.220*	0.122
EFF	*0.156**	0.080
F0	*0.152**	*-0.023*
FR	*0.120**	0.085
EIF	-0.084*	0.057
Gamma	-0.056*	-0.015
MPD	0.363	-0.367*
OQ	-0.070	0.335*
Shimmer	0.087	0.324*

IR	0.204	0.311*
Beta	-0.114	-0.308*
Jitter	0.137	0.301*
Alpha	-0.207	-0.298*
MAFR	0.239	0.250*
S/Z Ratio	0.124	0.208*
SIF	-0.036	0.201*
HNR	-0.155	-0.192*
SFF	0.099	0.158*

Table 4.7: Pooled vvithin-groups correlations between voice parameters and canonical discriminant functions for three groups of subjects.

'*' signifies the largest absolute correlation between the given voice parameter and both the discriminant functions.

Table 4.8 shows the standardized canonical functions coefficients for all the voice parameters.

Voice Parameters	Function 1	Function 2
F0	-0.061	-0.021
SF0	0.292	-0.058
FR	-0.068	-0.096
Jitter	0.496	-0.384
SFF	-0.284	0.532
EFF	0.318	-0.313
MI	0.378	-0.113
IR	0.157	0.498

Shimmer	-0.128	0.374
SIF	-0.277	-0.064
EIF	-0.020	0.117
Alpha	-0.148	-0.485
Beta	-0.067	-0.220
Gamma	-0.298	0.094
HNR	-0.201	-0.105
OQ	-0.004	0.581
SQ	0.300	0.170
VC	0.500	-0.282
MAFR	0.446	0.300
MPD	0.623	-0.379
S/Z Ratio	0.172	0.288

Table 4.8: Canonical discriminant function coefficients for all voice parameters.

A scatter plot of individual subjects and the group centroids of the three groups, namely, (a) normals, (b) Yakshagana dancing artists, and (c) Yakshagana Bhagavathars based on the values of the two canonical discriminant functions is shown in Figure 4.1. The distance between the centroids of Yakshagana dancing artists and Bhagavathars from normals was almost equal. It can be seen that normals, Yakshagana Bhagavathars, and dancing artists clearly differ from each other as a group.

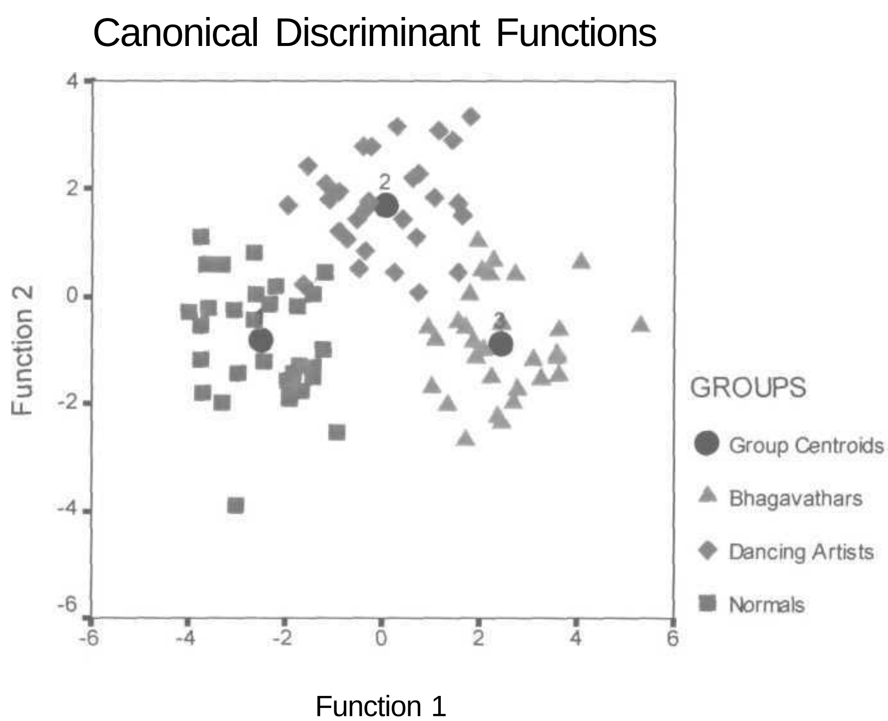

Figure 4.1: Scatter plot of the individual discriminant score and the group centroids of normals, Yakshagana dancing artists, and Bhagavathars

4.6 Voice Index

Through discriminant analysis, discriminant scores were obtained for each subject in normal, dancing artist and Bhagavathar groups for all voice parameters except frequency and intensity fluctuations (speed and extent). Frequency and intensity fluctuations were excluded from the analysis as these measures provide the same information on stability of vocal fold vibration like jitter and shimmer. These discriminant scores were considered as dependent variables and the remaining seventeen voice parameters as independent variables.

The following linear combination of 17 parameters with discriminant scores (DS) as dependent variables were obtained using linear regression.

DS =-14.542-FO x 0.0009 + SFO x 0.017 - FR x 0.0014 + Jitter x 0.118 + MI x 0.077 + IR x 0.038 - Shimmer x 0.014 - Alpha x 0.017 - Beta x 0.00037 - Gamma x 0.00011 - HNR x 0.077 + OQ x 0.2 + SQ x 0.403 + VC x 0.00097 + MAFR x 0.013 + MPD x 0.126 + S/Z ratio x 1.282.

DS can be considered as "Voice index". The reliability of the voice index was tested for a sample of 30 normals, 30 dancing artists and 30 Bhagavathars. Results are presented in Table 4.12 under a separate section. However, the summary of results for pre-performance condition (Cl) are given in Table 4.9 here.

Subjects	Average	Range
Normals	-2.434	-4.470 to - 0.599
Dancing Artists	1.271	0.123 to 2.228
Bhagavathars	1.215	0.011 to 2.857

Table 4.9: Average and range of voice index scores in normals, Yakshagana dancing artists and Bhagavathars.

A discriminant score lesser than or nearer to zero is normal. As it moves away from zero on the +ve side, the voice becomes more and more deviant.

Accordingly, the voice of dancing artists in the study is different from that of normals, and the voice of dancing artists is more deviant than the voice of both normals and Bhagavathars.

The results in Sections 4.5 and 4.6 can be summarized as follows:

Both groups of Yakshagana artists and normals are expected to fall in a specific category because of their different nature of voice usage. This is indeed true and evident from the discriminant analysis (Section 4.5). Further, Yakshagana artists are expected to have a higher voice index score because of their long-term voice usage in Yakshagana performance. Again, this is confirmed from the voice index score (Section 4.6). Both groups of Yakshagana artists demonstrated poorer voice index scores indicating voice deterioration after performance and better voice index scores after vocal rest indicating voice improvement after performance. However, the voice index scores after voice rest did not return to their pre-performance level (Table 4.13).

4.7 Short-Term Effects of Yakshagana Performance and Voice Rest on the Voice Characteristics of Yakshagana Dancing Artists

Measures of voice were compared between three conditions, namely, pre-performance (condition 1), immediately after Yakshagana performance (condition 2), and after 10-12 hours of vocal rest (condition 3). The data were analyzed with repeated measure ANOVA. The results of repeated measure ANOVA along with mean values and SD are given in Table 4.10.

However, as we were interested in the short-term effect of Yakshagana performance as well as short-term effect of vocal rest, the mean values have been compared between condition 1 and condition 2 (short-term effect of Yakshagana performance) and condition 2 and condition 3 (effect of vocal rest).

The results in Table 4.10 were subjected to Bonferroni's pair-wise multiple comparison test to see if (a) condition 1 and condition 2 (short-term effect of Yakshagana practice), and (b) condition 2 and condition 3 (short-term effect of vocal rest) were significantly different or not.

Voice	Condition 1		Condition 2		Condition 3		
Parameters	Mean	SD	Mean	SD	Mean	SD	F
FO	121.5	17.5	134.6	27.8	122.7	17.7	7.03*
SFO	148.0	23.3	152.3	21.4	146.4	18.2	1.51
FR	243.9	101.8	199.9	80.2	234.5	83.5	5.39*
Jitter	2.7	2.3	4.1	2.8	2.6	2.3	12.95*
SFF	1.2	1.1	3.0	1.6	0.9	1.7	15.92*
EFF	1.4	1.1	2.7	1.6	1.2	1.1	11.40*
Mean I	49.0	4.1	50.0	4.6	50.0	4.1	1.15
IR	50.9	3.8	50.2	3.2	50.9	3.1	0.76
Shimmer	0.8	0.6	1.2	0.7	0.8	0.6	4.09
SIF	0.4	0.1	0.6	0.5	0.2	0.1	1.89

EIF	0.5	0.1	1.0	0.5	0.2	0.1	3.79
Alpha	56.7	28.2	48.2	24.9	56.9	30.0	1.30
Beta	576.2	254.0	919.3	516.0	717.2	227.2	3.07
Gamma	3335.4	1026.0	3004.2	2313.5	3766.4	1998.6	1.01
HNR	22.3	2.5	19.7	3.3	23.1	3.7	18.43*
OQ	0.7	0.2	0.9	0.3	0.8	0.2	6.79*
SQ	1.7	0.6	1.8	0.6	2.1	1.0	1.93
VC	2809	510.0	2521.3	541.2	2800.7	462.7	18.35*
MAFR	155.6	37.5	176.8	44.9	149.6	37.3	12.14*
MPD	24.2	3.9	20.8	4.0	24.4	3.8	49.11*
S/Z	1.2	0.2	1.4	0.4	1.1	0.19	12.37*

Table 4.10: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in Yakshagana dancing artists for pre-performance (Condition 1), post-performance (Condition 2), and 10-12 hours post performance (Condition 3) and results of repeated measure ANOVA. F value of 5.39 is significant at 0.01. Degrees of freedom = 2, 116.

* - significantly different.

4.7.1 Difference Between Condition 1 and Condition 2 (Short-Term Effect of Yakshagana Performance): Dancing Artists

The results in Table 4.10 and the results of Bonferroni's pair-wise multiple comparison test can be summarized as follows:

a) Mean fundamental frequency, mean jitter, mean speed and extent of frequency fluctuations, mean open quotient, mean airflow rate, and mean S/Z ratio were significantly higher in condition 2 (immediately after Yakshagana performance) than in condition 1 (pre-performance).

b) Mean frequency range, mean harmonic to noise ratio, mean vital capacity, and mean maximum phonation duration were significantly less in condition 2 (immediately after Yakshagana performance) compared to condition 1 (pre-performance).

4.7.2 Difference Between Condition 2 and Condition 3 (Short-Term Effect of Vocal Rest): Dancing Artists

a) Mean fundamental frequency, mean jitter, mean speed and extent of frequency fluctuations, mean airflow rate, and mean S/Z ratio were significantly less in condition 3 (10-12 hours after vocal rest) than in condition 2 (immediately after Yakshagana performance).

b) Mean frequency range, mean harmonic to noise ratio, mean vital capacity, and mean maximum phonation duration were significantly higher in condition 3 (10-12 hours after vocal rest).

4.7.3 Difference Between Condition 3 and Condition 1: Dancing Artists

Comparisons were also made using repeated measure ANOVA and Bonferroni's pair-wise multiple comparison test between condition 3 (after vocal rest) and condition 1 (pre-performance) to see if voice parameters returned to their pre-performance level after vocal rest. The results (Table 4.10) revealed significant difference only for the mean value of open quotient. Open quotient was significantly less in condition 3 compared to condition 1.

4.8 Short-Term Effects of Yakshagana Performance and Voice Rest on the Voice Characteristics of Yakshagana Bhagavathars

As with Yakshagana dancing artists, the voice measures were compared between the three conditions - pre-performance (condition 1), immediately after Yakshagana performance (condition 2), and after 10-12 hours of vocal rest (condition 3) in the case of Yakshagana Bhagavathars also. The data were analyzed with repeated measure ANOVA. The results of repeated measure ANOVA along with mean values and SD are given in Table 4.11. Further, the results in Table 4.11 were subjected to Bonferroni's pair-wise multiple comparison test to see if (a) condition 1 and condition 2 (short-term effect of Yakshagana practice), and (b) condition 2 and condition 3 (short-term effect of vocal rest) were significantly different or not. The results given in Table 4.11 are summarized below in Sections 4.8.1 to 4.8.3 for Yakshagana Bhagavathars.

Voice Parameters	Condition 1 Mean	SD	Condition 2 Mean	SD	Condition 3 Mean	SD	F
FO	128.9	19.8	140.3	29.1	127.27	19.6	7.28*
SFO	151.5	20.5	154.2	24.9	149.71	20.0	0.91
FR	249.7	75.9	244.4	97.0	270.88	99.6	1.38
Jitter	1.9	1.6	3.0	2.2	1.92	1.7	8.06*
SFF	0.9	0.3	2.2	2.2	1.09	2.1	6.13*
EFF	1.6	1.4	2.3	1.5	1.24	1.0	8.16*
Mean I	49.9	4.0	50.9	4.4	50.7	4.1	0.71
IR	49.6	4.3	49.6	4.8	49.8	3.5	0.02
Shimmer	0.5	0.4	1.0	1.0	0.49	0.4	4.04
SIF	0.2	0.1	0.4	0.1	0.11	0.4	2.07
EIF	0.2	0.1	0.6	0.2	0.22	0.8	1.97
Alpha	58.4	25.7	67.2	25.2	69.94	39.1	1.35
Beta	739.3	420.9	445.9	280.4	751.18	378.6	6.82*
Gamma	3157	1686.9	2044	1051.3	2466.61	1354.7	5.43*
HNR	22.7	2.9	20.0	2.9	22.42	2.6	22.21*
OQ	0.4	0.1	0.5	0.1	0.53	0.1	2.47
SQ	2.0	0.7	2.3	1.0	2.5	1.0	2.32
VC	3823.3	477.5	3325	465.3	3345.1	599.2	15.23*
MAFR	153.6	21.6	164.7	27.3	158.16	31.1	1.99
MPD	32.0	4.4	27.8	4.2	28.01	6.1	14.06*
S/Z	1.1	0.1	1.2	0.3	1.12	0.2	2.84

Table 4.11: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (mean I), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ). speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation

duration (MPD), and S/Z ratio in Yakshagana Bhagavathars for pre-performance (Condition 1), post-performance (Condition 2), and 10-12 hours post performance (Condition 3) and results of repeated measure ANOVA. F value of 5.43 is significant at 0.01. Degrees of freedom -*2,* 116.

* - significantly different.

4.8.1 Difference Between Condition 1 and Condition 2 (Short-Term Effect of Yakshagana Performance): Bhagavathars

The results in Table 4.11 and the results of Bonferroni's pair-wise multiple comparison test can be summarized as follows:

a) Mean fundamental frequency, mean jitter, mean speed and extent of frequency fluctuations were significantly higher in condition 2 (immediately after Yakshagana performance) than in condition 1 (pre-performance).

b) Mean beta and gamma ratios of long-term-average spectrum, harmonic to noise ratio, vital capacity, and maximum phonation duration were significantly less in condition 2 (immediately after Yakshagana performance) than in condition 1 (pre-performance).

4.8.2 Difference Between Condition 2 and Condition 3 (Short-Term Effect of Vocal Rest): Bhagavathars

a) Mean beta ratio of long-term average spectrum and harmonic to noise ratio were significantly higher in condition 3 (10-12 hours after vocal rest) compared to condition 2 (immediately after Yakshagana performance).

b) Mean fundamental frequency, jitter, speed and extent of frequency fluctuations were significantly less in condition 3 (10-12 hours after vocal rest) compared to condition 2 (immediately after Yakshagana performance).

4.8.3 Difference Between Condition 3 and Condition 1: Bhagavathars

Comparisons were also made between condition 3 (after vocal rest) and condition 1 (pre-performance) using repeated measure ANOVA and Bonferroni's pair-wise multiple comparison tests to see if voice parameters returned to their pre-performance level. However, the results indicated significant differences only for the mean values of gamma ratio of long-term average spectrum, vital capacity, and maximum phonation duration. All these measures were significantly less in condition 3 than in condition 1.

4.9 Voice Index Scores of Yakshagana Dancing Artists and Bhagavathars Across the Three Conditions (Cl, C2, and C3)

The individual voice index scores were calculated for the following three conditions in both the groups of Yakshagana artists' separately - (1) before performance (Cl), (2) 10-30 minutes after performance (C2), and (3) after 10-12 hours of voice rest (C3) based on the equation described in Section 4.6. It was said earlier that voice index reflects the overall status of voice of a given individual. 'Voice index' of normals, dancing artists and Bhagavathars were indeed different (Table 4.9). It has also been shown that the voice of both Yakshagana dancing artists and Bhagavathars are indeed different following Yakshagana performance as well as after vocal rest from the pre-performance voice (Tables 4.10 and 4.11). Then, extending the logic behind voice index, one should get a different voice index value before and after performance, as well as before and after vocal rest. The results are given in Table 4.12.

SI. No.	Normals	Dancing Artists			Bhagavathars		
		Cl	C2	C3	Cl	C2	C3
1	-2.121	1.582	1.989	1.881	2.014	2.033	1.517
2	-0.599	1.256	2.287	1.873	0.567	2.132	1.345
3	-3.241	1.342	2.463	1.893	2.659	2.712	2.195
4	-2.490	1.245	1.896	1.538	1.714	2.482	1.776
5	-3.420	0.304	1.974	0.884	1.006	2.274	2.234

6	-1.946	0.178	2.132	1.635	. 1.321	1.532	1.512
7	-4.470	1.699	3.389	2.936	0.213	0.868	0.363
8	-3.373	2.262	2.901	2.863	0.563	1.326	0.968
9	-1.910	1.796	2.521	2.500	0.321	1.577	0.996
10	-3.638	0.751	1.967	1.267	2.271	2.728	1.704
11	-1.567	2.199	2.896	2.299	0.938	2.335	2.131
12	-1.912	1.485	1.651	1.568	1.237	2.490	1.363
13	-2.272	2.288	3.101	2.791	0.432	0.832	0.556
14	-2.919	1.945	1.583	2.363	1.958	2.220	2.199
15	-2.261	0.832	1.861	1.334	0.011	0.964	1.916
16	-1.465	1.264	2.804	1.546	0.326	1.256	0.836
17	-1.245	1.325	2.675	2.132	0.532	2.316	2.156
18	-2.966	2.158	2.883	2.564	1.582	2.068	1.814
19	-3.291	0.505	1.018	0.539	1.325	3.132	1.998
20	-2.296	2.135	2.285	2.213	0.734	1.865	1.643
21	-3.291	0.762	2.131	1.538	1.653	2.883	2.386
22	-1.826	1.156	1.732	1.596	0.334	0.936	0.331
23	-1.968	0.158	1.325	0.356	1.661	3.216	2.863
24	-2.791	1.829	2.123	1.993	0.732	2.731	1.813
25	-3.858	0.123	0.963	0.475	0.543	2.131	1.648
26	-1.745	0.367	1.283	0.967	1.326	2.328	2.011
27	-2.116	1.378	1.936	1.905	1.538	2.106	2.000
28	-1.964	1.325	2.325	1.356	2.857	2.963	2.920
29	-2.578	1.833	2.051	1.847	2.120	2.388	2.269
30	-1.497	0.639	1.326	1.061	1.963	2.015	2.362
'erage	-2.434	1.271	2.114	1.723	1.215	2.094	1.727

Table 4.12: Individual and average voice index scores for 30 normals, 30 Yakshagana dancing artists and 30 Bhagavathars (Cl: pre-performance, C2: 10-30 minutes after perfonnance. C3 - 10-12 hours after voice rest).

The results indicated that voice index scores increased to some extent after performance compared to pre-performance level in both groups of Yakshagana artists and reduced somewhat with 10-12 hours of voice rest. Furthermore, the results also revealed that voice index scores after vocal rest (condition 3) were higher than voice index scores in pre-performance (condition 3) level.

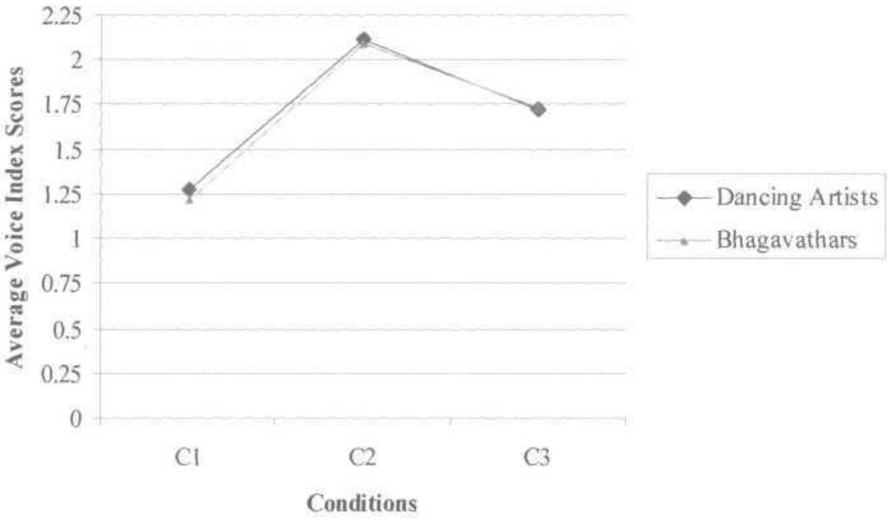

Figure 4.2: Average voice index scores of Yakshagana dancing artists and Bhagavathars in Cl (before performance), C2 (10-30 minutes after performance) and C3 (10-12 hours after voice rest) conditions.

4.10 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit on Voice Characteristics

The relationship between years of Yakshagana practice, the habits of smoking, alcohol usage, and tobacco chewing and voice characteristics (results of acoustic and respiratory analysis) was investigated separately using Mann Whitney's two independent samples test. Mann Whitney's two independent sample test was employed because of the unequal size of the two groups of subjects. For example, smokers were 42 in number while non-smokers were 18 in number. Dancing artists and Bhagavathars were considered together for analysis. The results are tabulated in Tables 4.13 to 4.16.

Voice Parameters	Years of practice > 14.8 years		Years of practice <14.8 years		
	Mean	SD	Mean	SD	Z
FO	127.2	18.3	123.5	19.5	0.70
SFO	152.7	23.4	147.3	20.5	0.48
FR	270.5	90.9	227.4	83.9	2.07
Jitter	2.2	2.2	2.4	2.2	0.46
SFF	1.0	0.2	1.1	0.9	0.61
EFF	1.7	1.2	1.3	1.1	0.47
MI	48.9	4.5	50	3.6	0.96
IR	50.8	2.8	49.8	4.9	0.67
Shimmer	0.6	0.5	0.7	0.6	0.54

SIF	0.2	0.1	0.3	0.1	0.14
EIF	0.3	0.1	0.2	0.1	0.12
Alpha	66.1	47.2	56.5	25.5	0.24
Beta	630	336.3	680.4	372	0.27
Gamma	3166.4	1494.8	3311.5	2118.6	0.17
HNR	22.4	2.2	22.6	3	0.36
OQ	0.5	0.2	0.5	0.2	0.54
SQ	1.8	0.6	1.9	0.8	0.38
VC	3150	658.8	3452.1	727.7	1.56
MAFR	151	29.4	157.6	31.3	0.52
MPD	27.2	5.4	28.8	5.9	1.33
S/Z	1.1	0.2	1.2	0.2	0.76

Table 4.13: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in Yakshagana artists with > 14.8 years and <14.8 years of experience and results of Mann Whitney test. No voice parameters showed significant difference at 0.01 level.

Voice	Smoking		Non- smoking		
Parameters	Mean	SD	Mean	SD	**Z**
FO	127.1	19.3	120.9	17.8	1.05
SFO	153.9	21.5	140.1	19.8	2.12
FR	258.1	94.6	220.2	69.7	1.37
Jitter	2.9	2.4	0.9	0.3	4.06*

SFF	J.I	1.7	1.1	1.4	0.38
EFF	1.5	1.6	1.7	1.7	0.71
MI	49.4	4.4	49.7	2.9	0.02
IR	50.69	4.3	49.4	3.4	1.02
Shimmer	0.8	0.6	0.4	0.2	1.88
SIF	0.3	0.9	0.0	0.0	1.82
EIF	0.4	1.0	0.0	0.0	1.82
Alpha	58.2	28.9	67.0	51.3	0.55
Beta	638.5	349.3	702.6	372.1	0.56
Gamma	3389.8	1977.6	2911.1	1510.8	0.70
HNR	22.3	2.6	23.0	2.8	0.68
OQ	0.6	0.2	0.5	0.1	2.45
SQ	1.8	0.7	2.1	0.6	1.44
VC	3165.7	708.6	3667.2	585.7	2.47*
MAFR	155.7	33.6	152.1	21.6	0.35
MPD	27.2	5.9	30.3	4.6	2.06
S/Z	1.1	0.2	1.1	0.1	0.08

Table 4.14: Mean and standard deviation (SD) of fundamental frequency (FO), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in Yakshagana smoking and non-smoking artists and results of Mann Whitney test. Z value of 2.47 is significant at 0.01.

* - significantly different.

Voice Parameters	Alcohol Mean	SD	Non - Alcohol Mean	SD	Z
FO	124.5	18.5	125.8	19.7	0.10
SFO	152.5	22.9	147	20.8	0.81
FR	249.8	96.2	243.7	82.8	0.05
Jitter	3.3	2.6	1.3	1.2	3.65*
SFF	1.2	1.9	0.8	1.2	0.58
EFF	1.5	1.6	1.5	1.6	0.13
MI	49	4.7	49.9	3.1	0.87
IR	51.1	4.2	49.4	3.9	1.36
Shimmer	0.8	0.7	0.4	0.4	2.45*
SIF	0.4	1.1	0.1	0.0	2.78*
EIF	0.5	1.2	0.1	0.0	2.78*
Alpha	55.7	28.4	66	43.6	1.01
Beta	623.3	342.6	692.2	368.2	0.57
Gamma	3528.6	1030.4	2963.9	1036.9	1.05
HNR	22.1	2.5	22.9	2.8	0.93
OQ	0.6	0.2	0.4	0.1	0.21
SQ	1.8	0.6	1.9	0.8	0.16
VC	2931	631.2	3701.33	561.2	4.21*
MAFR	155.5	37.9	153.69	20.9	0.10
MPD	25.1	4.7	31.13	5.0	4.17*
S/Z	1.16	0.23	1.129	0.1	0.66

Table 4.15: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR). maximum phonation

duration (MPD), and S/Z ratio in Yakshagana artists with alcohol and non- alcohol usage and Mann Whitney test. Z value of 2.45 is significant at 0.01.

* - significantly different.

Voice Parameters	Tobacco chewing		Non - tobacco chewing		
	Mean	SD	Mean	SD	Z
FO	124.6	20.5	125.8	17.6	0.28
SFO	152.8	23.4	146.6	20.0	1.05
FR	257.5	92.6	236	85.5	0.94
Jitter	2.0	1.2	2.7	2.2	1.73
SFF	0.7	0.1	1.4	1.3	1.28
EFF	1.3	1.6	1.7	1.6	0.95
MI	50.1	3.7	48.8	4.3	1.30
IR	49.9	3.9	50.6	4.3	0.45
Shimmer	0.7	0.4	0.6	0.5	1.04
SIF	0.2	0.1	0.4	0.1	1.24
EIF	0.2	0.1	0.3	0.2	1.19
Alpha	66.1	47.6	55.6	20.9	0.20
Beta	590.4	329.1	725.1	371.1	1.47
Gamma	2887.3	1657.7	3605.2	1988	1.51
HNR	22.0	2.2	23.1	3.1	1.63
OQ	0.5	0.2	0.5	0.2	0.54
SQ	1.8	0.6	1.9	0.7	0.54
VC	3218.0	700.2	3414.3	714.2	1.07
MAFR	153.7	29.5	155.5	31.8	0.02
MPD	27.6	5.5	28.6	5.9	0.56

S/Z	1.2	0.1	1.2	0.2	0.89

Table 4.16: Mean and standard deviation (SD) of fundamental frequency (F0), speaking fundamental frequency (SFO), frequency range (FR), jitter, speed of fluctuations in fundamental frequency (SFF), extent of fluctuations in fundamental frequency (EFF), mean intensity (MI), intensity range (IR), shimmer, speed of fluctuations in intensity (SIF), extent of fluctuations in intensity (EIF), alpha, beta, and gamma ratios of LTAS, harmonic to noise ratio (HNR), open quotient (OQ), speed quotient (SQ), vital capacity (VC), mean airflow rate (MAFR), maximum phonation duration (MPD), and S/Z ratio in Yakshagana artists with the habit of tobacco chewing and non- tobacco chewing and the results of Mann Whitney test. No voice parameters showed significant difference at 0.01 level.

The results in Tables 4.13 to 4.16 can be summarized as follows:

a) Mean values of acoustic and respiratory voice parameters of Yakshagana artists who had greater than 14.8 years of Yakshagana practice and those artists who had less than 14.8 years of Yakshagana practice were not significantly different (Table 4.13).

b) Mean value of jitter was higher in Yakshagana artists with the habit of smoking than those who were non-smokers. On the other hand, the mean value of vital capacity was significantly less in Yakshagana artists with the habit of smoking than non-smoking artists (Table 4.14).

c) The mean values of jitter, shimmer, speed and extent of intensity fluctuations were significantly higher in Yakshagana artists with the habit of alcohol usage than Yakshagana artists with who were non users of alcohol. On the contrary, vital capacity and maximum phonation duration were less in Yakshagana artists with alcohol usage than those who were not alcohol users (Table 4.15).

d) Mean values of acoustic and respiratory voice parameters of those artists with tobacco chewing habit did not significantly differ from those artists with tobacco chewing habit.

Chapter 5

Discussion

The present study was an investigation of the effect of Yakshagana performance on the characteristics of voice of Yakshagana artists, both Yakshagana dancing artists and Bhagavathars. The design of the study was like this: pre-performance assessment of voice characteristics not only to establish the base level of voice parameters, but also to understand the long-term effect of Yakshagana performance on voice. This was followed by two more evaluations of voice: once, 10-30 minutes after a performance and a second time, 10-12 hours after vocal rest following an Yakshagana play. A comparison of the pre-performance voice characteristics with those of first post performance evaluation would provide information on the short-term effect of Yakshagana performance on voice. A comparison of voice recorded after the performance with that of second evaluation following 10-12 hours of vocal rest after a play would throw light on the effect of voice rest. Also, comparison of voice characteristics of second post-performance with those of pre-performance would tell us if the changed voice characteristics following vocal rest have come back to their pre-performance level or not.

In addition, the relationship between years of Yakshagana practice, the habits of smoking, tobacco chewing and alcohol usage and the nature of complaints made by subjects in the experimental group about their voice was tested. A similar analysis was made between subject characteristics (habits) and the results of acoustic analysis of voice. All parameters of voice were combined to arrive at a voice index which is an overall indicator of the status of the voice of a given speaker.

5.1 Subjects

Sixty subjects, who were practitioners of Yakshagana, were included in the study. The subjects included 30 Yakshagana dancing artists in the age range of 21-49 years (mean age = 32.9 years) and 30 Yakshagana Bhagavathars in the age range of 24-48 years (mean age = 36.5 years). Similarly, a control group of 30 normal subjects in the age range of 21- 46 years (mean age = 31.4 years), matched for age and gender with those in the experimental group, constituted the control group. None of the subjects in the control group had any experience in Yakshagana, acting or singing. None of the artists had any formal or informal training or counseling on vocal hygiene except that they had been told about the importance of some home-made syrups - decoctions in 'maintaining' voice. Some were even drinking such decoctions.

There are two types of artists performing in Yakshagana - the dancing artists who sing, dance and act, and the singers (called Bhagavathars) who only sing. The nature of their vocal performance in Yakshagana is different. The dancing artists render dialogues, dance, act, and occasionally sing as well. They render dialogues/sing keeping their voice high above that of the background "chande", which is a percussion instrument emitting high frequency tones and which is played at high intensity levels. As the dancing artists also have to act and dance (often involving forceful, robust and vibrant movements), the combined effect of physical exertion (dancing and acting) and speaking/singing at high voice (frequency and intensity) can be presumed to be detrimental to their voice production. The chief role of the Bhagavathar is to sing. But, he also indulges in dialogue delivery, albeit occasionally. Most of the times, he would be doing so above the level of the sound created by the "chande".

Therefore, it can be expected that dancing artists and Bhagavathars may manifest different types of voice problems/characteristics. An effort was made to analyze the voice characteristics of both groups of artists separately in this study.

5.2 Assessment of Voice Parameters

A review of pertinent literature revealed that presence of voice problems in professional voice users was a reflection of improper voice usage, lack of knowledge about vocal hygiene techniques, poor breathing habits, poor postures, among others (Hixon and Hoffman, 1978; Mc Kinney, 1994; Brown, 1996). Based on this, it is suggested, to be experimentally confirmed or rejected, that there is a close association between the voice problems experienced by Yakshagana artists and the vocal behaviors that they exhibit during performance. Therefore, an assessment procedure was set up for identifying aspects of voice that were affected in both groups of Yakshagana artists. The vocal parameters that were analyzed and measured in Yakshagana artists were: (a) fundamental frequency (FO), (b) speaking fundamental frequency (SFO), (c) frequency range (FR), (d) speed of fluctuations in frequency (SFF), (e) extent of fluctuations in frequency (EFF), (f) jitter, (g) mean intensity (MI), (h) range of intensity (IR), (i) speed of fluctuations in intensity (SIF), (j) extent of fluctuations in intensity (EIF), (k) Shimmer, (1) harmonic to noise ratio (HNR), (m) Alpha, beta and gamma ratios of long-term average spectrum (LTAS), (n) open quotient (OQ), (0) speed quotient (SQ), (p) vital capacity (VC), (q) mean airflow rate (MAFR), (r) maximum phonation duration (MPD), and (s) S/Z ratio.

5.3 Voice Complaints by Yakshagana Artists

There does not seem to be a difference in the percentage of dancing artists and Bhagavathars complaining of voice problems. Both the dancing artists and Bhagavathars seem to experience voice or voice related problems to the same extent. However, in the present study, more number of Bhagavathars complained of a change in voice quality while more number of dancing actors complained of vocal fatigue. Bhagavathars are more likely to complain of change in voice quality because they have indulged in singing over a number of years, that too at higher octaves. Also, they may be primarily concerned in maintaining a good voice quality for singing and their concern may have led them to complain more frequently about voice quality. More number of dancing actors complained of vocal fatigue probably because they had to endure greater physical exhaustion caused by vigorous dance movements and also had to use voice at high levels of intensity and frequency to overcome the masking effect of background "chande". Perhaps, higher prevalence of smoking as well as alcohol habit in our sample of Yakshanaga dancing artists may also have contributed to greater complaints of vocal fatigue by these artists.

Phyland, Oates, and Greenwood (1999) noted similar findings in their study. They reported hoarseness, vocal fatigue, pain in throat and change in the pitch of speaking voice as the major voice symptoms in three types of singers (opera, theatre, and contemporary) which affected their performance and voice.

Shouting or loud talking seems to be the most mentioned voice damaging behavior (Sander and Ripich, 1983). There is general agreement to say that vocal fatigue is more related to loudness of speaking than speaking time (Hollbrook, 1977). It is also opined that some persons are more prone to vocal fatigue if increase in loudness is also accompanied by laryngeal strain (Boone, 1977; Sander and Ripich, 1983). The implication is that vocal fatigue can be prevented if intensity is regulated more by respiratory than by laryngeal muscle forces. The subjects of the present study have indulged in speaking at higher levels of intensity and frequency. The dancing artists of the present study did not show evidence of higher vital capacity while the vital capacity of Bhagavathars was significantly higher than that of both normals and dancing artists. Therefore, it is possible that the loud speaking/singing seen in dancing artists is associated with laryngeal strain (as they may not have breath support required for speaking continuously at higher intensity levels). This laryngeal strain coupled with the loudness level at which speaking was indulged in may have contributed to vocal fatigue, particularly in dancing artists.

5.4 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Nature of Voice Complaints by the Subjects

In the present study, the Yakshagana artists were classified into two groups based on the average years (14.8 years in this study) for which they practiced Yakshagana. The results indicated that years of Yakshagana practice did influence the nature of voice problems reported by these artists. Yakshagana artists who had > 14.8 years of experience in this field complained of problems like change in voice quality, irritation/ dryness of throat, voice breaks and loss of pitch range to a greater extent than artists who had < 14.8 years of experience in the field. Though we have taken 14.8 years as the cut off point for making two groups based on experience, it is not suggested that Yakshagana artists will not develop voice problems before 14.8 years. 14.8 years happened to be the 'average' number of years of Yakshagana performance that the subjects of this study had. It is for future research to find the minimum number of years of Yakshagana at which different types of Yakshagana artists are likely to develop voice problems.

One would have expected that the smokers among the Yakshagana artists would have complained of voice problems more than the non-smoking artists. The smoke they inhale will directly act on the mucosa of the vocal cords and the laryngeal systems, and when this happens persistently, there is a greater possibility of voice problems. However, the smoking Yakshagana artists in the sample of this study did not complain of voice problems to a greater extent than non-smoking artists, which is difficult to explain. Perhaps, none of the smoking artists in the present study smoked to an extent which would lead to voice problems. Perhaps, the frequency of smoking and the duration for which the artists were smoking are important factors to be considered here. However, Yakshagana artists with alcohol habit complained of vocal fatigue to a greater extent than those who did not have the habit of alcohol. Similarly, Yakshagana artists who were in the habit of chewing tobacco complained of voice fatigue and voice breaks to a greater extent than those artists who did not have the habit of tobacco chewing. Alcohol consumption as well as tobacco chewing would cause mucosal irritation and dryness of laryngeal mechanism which may be responsible for the voice problems reported by the artists.

5.5 Voice Characteristics of Different Groups of Subjects

Acoustic analysis of voice indicated significantly higher speaking fundamental frequency, intensity and intensity range in Yakshagana artists than in normals. This may be a function of number of years of experience in Yakshagana. It has repeatedly been said that both the Bhagavathars and the dancing artists have to sing or deliver dialogues at a higher frequency and intensity levels to project their voice above the level of noise in the open environment in which Yakshagana is enacted as well as to overcome the level of background music in the form of playing of "chande" and other percussion instruments. Perhaps, this habit is responsible for the observation that Yakshagana artists generally use a higher speaking frequency. Another reason for increased vocal pitch and loudness in Yakshagana artists could be that these artists want to adopt some compensatory strategies to overcome the effect of vocal strain. Increasing pitch level could be one such strategy as increasing pitch level takes the pressure off the larygnopharynx and alleviates vocal symptoms (Cooper, 1973). Another compensatory strategy could be elevation of larynx to achieve higher frequency and intensity levels to project voice which might have continued as a habit outside the Yakshagana play. Ship (1987) reported that his untrained singers used an increased FO, which they achieved by elevating larynx. When the larynx is raised upwards, stretching of tissues generates stiffening along the vocal fold margin in vertical direction thereby increasing FO.

Speaking pitch is usually cited as a factor in vocal fatigue and voice disorder. A most superficial reading of published electromyographic research suggests a rather straightforward relationship between voice fundamental frequency and the degree of longitudinal vocal fold tension: as pitch raises, the sum of thyroarytenoid and cricothyroid muscle activity increases. The inference is that producing high-pitched voice will be more fatiguing. Perhaps, the study of Stone and Sharf (1973) is the only one which has contributed experimental evidence relating pitch level to vocal fatigue. In their study, higher pitched phonations located at points 50% to 80% of each subject's total range produced earlier and greater voice change (vocal fatigue) than did a lower pitched voice production (similar to the modal conversational pitch of most persons) located at the 20% point. The subjects of the present study, particularly the dancing artists complained of vocal fatigue as their major problem. It is not that Bhagavathars did not complain of vocal fatigue, but they were more concerned with changes in their voice quality than fatigue. As we have repeatedly been telling, the Yakshagana artists have to speak and sing at a higher speaking pitch and intensity level in an Yakshagana play to be heard above the ambient noise. This practice perhaps leads to vocal fatigue which, in turn, may lead to further increase in the frequency and intensity level in speaking because of laryngeal force.

However, dancing artists and Bhagavathars perform different tasks in Yakshagana play. The Bhagavathars only sing while the dancing artists sing, deliver dialogues, and also enact. Also, the duration of performance in an Yakshagana play is different for dancing artists and Bhagavathars. In an Yakshagana play of 8 hours duration, the Bhagavathars may be singing for 75% of the time while a given dancing artist may perform for 10, 20 or 50% of the time depending on the role. Therefore, it can be expected that the nature and degree of voice problems may be different in dancing artists and Bhagavathars. Therefore, the nature of voice problems was analyzed separately for Bhagavathars and dancing artists. The results of separate analysis confirmed the results obtained for Yakshagana artists as a group on the usage of higher speaking fundamental frequency and intensity compared to normal subjects. However, the difference in mean speaking fundamental frequency and mean intensity was not significant between Yakshagana dancing artists and Bhagavathars.

The need for using higher frequency and higher intensity in dancing artists arises from two factors. First, these artists need to be heard over a long distance (most often without proper amplification system). Second, the male artists also play the female roles, and therefore, they have to speak at a higher frequency level. All these may have led the Yakshagana artists, both the Bhagavathars and the dancing artists, to develop the habit of speaking at a higher frequency and intensity level. Similar findings have been reported by Shipp (1987) in a study of trained and untrained Western opera style singers. The untrained singers in Shipp's (1987) study achieved higher frequency by increasing stiffness of the vocal cords and elevating larynx from its resting position. As the subjects of the present study, particularly the dancing artists, were also untrained in vocal hygiene and vocal techniques, it is possible that they achieve higher frequency and intensity by exertion of the laiyngeal system which may lead to vocal abuse in the long run.

There appears to be no direct relationship between vocal training and its influence on speech in a group of singers (Brown, Rothman and Sapienza, 2000). In other words, physiological and acoustical data provides no evidence to suggest that the speech of professionally trained singers is any different from that of a group of nonsingers. On the contrary, the results of the present study suggest that the speech of singers (some of them may not be professionally trained) is different from that of nonsingers in terms of higher speaking pitch and intensity. This is nothing but extension of the usage of higher pitch and intensity in Yakshagana play by these artists.

Perturbation measures reflect the stability of vocal fold vibration. Jitter, shimmer, and speed and extent of frequency and intensity fluctuations indicate the fine control that the speakers have on the vocal fold vibratory mechanism. It has been said earlier that both the dancing artists and Bhagavathars speak and sing at higher frequency and intensity levels for various reasons. When a set of speakers have to consistently perform at a higher level of frequency and intensity, they have to put in greater effort to achieve the desired level. The higher effort leads to tension of the vocal fold mechanism, and thus the fine control on vibration of vocal fold vibration can be lost. Also, both the Bhagavathars, and the dancing artists have to engage their vocal mechanism to deliver or sing long speech sequences, in a single breath. Reduced respiratory support, at the end of long speech sequences, puts further pressure on the vocal fold mechanism. The result is greater instability of the system leading to higher jitter, shimmer and other vocal perturbation measures. In addition, dancing artists have to use their vocal mechanism under more adverse circumstances (delivery of long sequences of speech, over a distance, and at high intensity levels to overcome the background noise) than Bhagavathars. This may explain the higher levels of jitter; shimmer and other perturbation measures in the voice of the dancing artists compared to Bhagavathers (However, only mean shimmer was significantly different between the two groups).

Hoffman-Ruddy, Lehman, Crandell, Ingram and Sapienza, (2001). expressed similar concerns in their study on the perturbation measures in three groups of high-risk performers (musical theater, choral ensemble, and street theater). Street theater artists exhibited higher jitter percent and shimmer percent followed by choral ensemble and musical theater group. However, there are many differences between the present study and that of Hoffman-Ruddy, Lehman, Crandell, Ingram and Sapienza, (2001) to warrant meaningful comparison. Perhaps, the only commonality between the two studies is that the experimental subjects in both the studies were engaged in some type of singing.

Whether or not vocal training or lack of it has any influence on the way the laryngeal system is used resulting in high perturbation needs to be investigated. Teachy. Kahane, and Beckford, (1991) analyzed the vocal mechanics in untrained, professional singers, and found abnormal levels of frequency perturbation and reduced phonation time reflecting deficient laryngeal valving or hard glottal attack. They attributed these changes to limited vocal training, lack of awareness or monitoring of vocally abusive speaking behaviors, and over participation in singing activities. Majority of the Yakshagana artists of the present study had no formal vocal training. Therefore, it is quite possible that they use their phonatory system in an unacceptable manner, to achieve higher levels of frequency and intensity in their singing or dialogue delivery.

The present study also analyzed the spectral measures - alpha, beta and gamma ratios - of long-term average spectrum and harmonic to noise ratio. Spectral measures reflect on the quality of voice. Yakshagana artists had significantly lower alpha and beta ratios compared to normals. Among the Yakshagana artists, Yakshagana dancing artists demonstrated significantly lower alpha and beta values compared to Bhagavathars while Yakshagana Bhagavathars demonstrated lower gamma values compared to Yakshagana dancing artists. Lower alpha, beta and gamma ratios mean that the energy level in the two regions of any band is nearer to each other. That is, energy level in 1 to 5 kHz region is nearer to that in the 0 to 1 kHz region as far as alpha ratio is concerned. In other words, there is almost equal spread of energy in the low and high frequency regions of a given band. There could be two explanations for the results reported above: (a) loss of energy in the low frequency region due to vocal fatigue, and (b) shift of spectral energy to higher frequency region, which would have helped the Yakshagana artists to project their voice over the loud background noise during performance. Bhagavathars indulge in singing at higher octaves which enhances energy concentration at high frequency ranges resulting in lowered gamma values than dancing artists.

Pinczower and Oates (2005) studied the long-term average spectral features of comfortable acting voice and maximal projection voice in thirteen professional male actors. The compared the acoustic energy between the higher (2-4 kHz) and the lower (0-2 kHz) regions of the spectrum in the voice samples of maximal projected condition and comfortable projected condition. LTAS analyses demonstrated increased acoustic energy in the higher part of the spectrum (2- 4 kHz) which was attributed to actor's formant (strong peak around 3.5 kHz). Actors formant was attributed to an efficient projection mechanism which was the result of training and experience.

Harmonic to noise ratio was reduced in the voice of Yakshagana artists compared to normals. Harmonic to noise ratio reduces when intensity of harmonics decreases or that of noise increases indicating vocal quality disturbances. Greater noise in the spectra of the voice of Yakshagana artists may have resulted in two ways: first, there may be a noise source at or near the vocal folds (for example, air rushing up against the vocal folds). The Yakshagana artists, particularly the dancing artists, evidenced higher open quotients which reflect improper adduction of vocal folds. Weakened vocal fold approximation (or improper) may lead to reduction in harmonic energy. Second, greater aperiodicity may show up in the form of increased level of noise in the spectrum. Both the groups of Yakshagana artists, Bhagavathars and dancing artists, evidenced higher level of jitter and shimmer than normals.

Results of electroglottographic analysis of vocal fold movement indicated significantly higher open quotients in Yakshagana dancing artists compared to normals and Bhagavathars. Higher open quotients imply that vocal folds take a longer time to adduct. Prolonged voice use can result in vocal fatigue. Such fatigue can be thought of as being associated with several forms of laryngeal reactions, particularly reduced vocal fold tonicity. Overuse of voice as well as improper use (speaking at higher levels of frequency and intensity), the effect accumulated over the years, may have led to vocal fatigue in the case of dancing artists preventing proper adduction of vocal folds resulting in higher open quotient (compared to Bhagavathars) in them. However, Bhagavathars had lower open quotient values than normals. This effect was unexpected and contrary to what we had anticipated. The increased respiratory support that the Bhagavathars displayed (significantly higher vital capacity) coupled with longer phonation time indicates that speaking at higher levels of frequency and intensity was achieved through respiratory maneuver than by laryngeal action.

Therefore, the vocal fold adductory pattern in Bhagavathars did not show any significant changes.

Speed quotient was significantly higher in Bhagavathars when compared to normals. Perhaps, changes in vocal fold approximation resulting from weakened vocalis muscles due to prolonged voice usage at high frequency and intensity levels in Yakshagana play have led to increased speed quotient in Bhagavathars. However, this is something that needs to be investigated in future.

Respiratory measures like vital capacity, mean airflow rate, maximum phonation duration and S/Z ratio were also measured to study the functioning of the respiratory system as well as the coordination between respiratory and laryngeal systems. Results indicated that Yakshagana artists, particularly Bhagavathars had significantly higher vital capacity, and maximum phonation duration than normals. These subjects presumably took advantage of the greater expiratory recoil pressures prevailing at higher lung volumes. Given that loud speech generally requires higher driving pressures, using high lung volumes would seem to be an efficient strategy for producing loud speech for long durations. However, both Bhagavathars and dancing artists exhibited higher mean airflow rate, and S/Z ratio than normals. The significance of this result is that Yakshagana artists, particularly dancing artists, have incomplete laryngeal valving (hypo adduction) as some portion of expiratory airflow escapes without being translated into vocal fold vibration due to vocal fatigue from long - term

Yakshagana performance. As we have seen earlier, higher open quotient in the spectrum of the voice of Yakshagana artists also reflects inadequate adductory movement of vocal folds.

5.6 Discriminant Analysis

Results of discriminant analysis indicated that the subjects could be reliably classified as belonging to their respective groups. The significance of the results of discriminant analysis is as follows: the Yakshagana dancing artists and Bhagavathars can be expected to manifest different voice characteristics compared to normals owing to the degree and nature of use of their vocal mechanism. The parameters analyzed and the mode of analysis in this study are sensitive enough to reliably tap these changes. Thus, the different subjects could be reliably classified into their respective groups.

5.7 Voice Index

Acoustic characteristics of voice, respiratory parameters and electroglottographic measures were analyzed in the present study. All these parameters have different measuring units - some in Hz, some in dB, some in cc, and so on. As can be expected, some of these parameters may be deviant in one group of subjects, some others in a second group, and so on. Therefore, drawing meaningful conclusions, particularly in a study like this which has looked into more than 20 parameters, is always complicated, and confusing to some extent. Therefore, an attempt was made to combine all these parameters into one index which may indicate the overall status of the voice of a given individual. The result was the "Voice index'.

Discriminant scores were obtained through discriminant analysis for each subject in normal, dancing artists and Bhagavathar groups. The linear combination of 17 parameters with discriminant scores as dependent variables was obtained using linear regression. The discriminant scores thus obtained can be considered as "Voice index".

The reliability of the voice index was tested for a sample of 30 normals, 30 dancing artists and 30 Bhagavathars. However, the true significance of this measure needs to be tested with different vocal pathologies and as a function of intervention procedure.

The voice index scores were higher in both the groups of Yakshagana artists, specifically in dancing artists, compared to Bhagavathars and normals. As the voice index scores for normal speakers were less than zero, scores moving away from zero, on the + side, indicates deviant voice. This is properly reflected in the higher scores obtained for dancing artists and Bhagavathars compared to normals. Higher scores in dancing artists and Bhagavathars may reflect the nature of the voice problems they have developed. This means that the multivariate linear regression used to develop voice index appeared useful as it included multiple voice parameters like acoustic, aerodynamic, and electroglottographic.

The reliability of voice index was "tested" by comparing voice parameters across three different conditions (condition 1: pre-performance, condition 2: post performance; condition 3: after vocal rest) in both groups of Yakshagana artists. We did not carry out any statistical analysis to understand the changes in voice index scores across the three conditions. However, a visual inspection of the '"Voice index" scores indicated voice deterioration after Yakshagana performance, and voice improvement after vocal rest. The change in voice index scores is as per the results of repeated measure ANOVA and Bonferroni's pair-wise multiple comparisons (Section 4.6 and 4.7), and therefore, it can be said that the voice index scores are valid. However, the usefulness of 'voice index' as a clinical tool needs further validation.

5.8 Short-Term Effect of Yakshagana Performance on Voice: Yakshagana Dancing Artists and Bhagavathars

The results have shown that following an episode of Yakshagana performance, the majority of Yakshagana dancing artists demonstrated deterioration in their voices. Increase in fundamental frequency, and jitter (and other frequency perturbation factors) reflect on the effort that the artists have to put in for phonation following a play. There is no doubt that the artists would be exhausted following the physical effort. Increase in open quotient, mean airflow rate and S/Z ratio; and reduced frequency range, harmonic to noise ratio, vital capacity, and maximum phonation duration reflect on the inadequate vocal cord closure following Yakshagana play. This may be because of both reduced respiratory support and vocal fatigue following singing and dancing at higher frequency and intensity levels.

The Bhagavathars showed similar results. In addition to the voice parameters which showed a change in the case of dancing artists, beta and gamma ratio also significantly decreased in the spectra of the voice of Bhagavathars following performance. Again these results point to the greater instability of the laryngeal systems brought about by vocal fatigue and reduced respiratory support.

There are no studies reported in the literature like the present study and therefore, comparison of the results of the present study with those from other performance studies will be inappropriate. Ryker, Roy and Bless, (2000) made their subjects (actors) to produce multiple repetitions of few emotionally charged vocal behaviors (grunt, groan, sob and shout) at stage volume. The post-performance acoustic signal was not significantly different from the pre-performance signal. The fact that it was only a simulated performance, and the duration for which they had to perform was short may explain why the actors post-performance voice was not significantly different from their pre-performance voice. Novak, Dlouha, Capkova, and Vohradnik, (1991) found a spectral tilt in the voice of theater artists, that is, there was increased spectral energy in the higher frequency region though the difference (between pre- and post performance) was not statistically significant. Novak, Dlouha, Capkova, and Vohradnik, (1991) attributed this spectral tilt to high vocal and physical effort (as well as emotional stress) on the part of theater artists.

Froschels (1939) was one of the earliest investigators to study the effect of performance on the voice of singers. Froschels viewed subject's larynges via mirror examination after a singing performance and reported that incomplete glottal closure was a common effect, mainly in singers who had poor vocal technique. However, as Froschels did not examine the singers before they performed, it is not possible to attribute his finding of incomplete glottal closure to performance.

Kitch, Oates and Greenwood (1996) studied the effect of performance on the voices of 10 choral tensors. They reported increased jitter and shimmer for comfortable pitched notes, and reduced pitch and amplitude ranges after post-performance. They attributed these changes to performance anxiety, performance experience, and voice use over the 24 hours before performance.

Welham and Maclagan (2004) studied the changes in vocal function across a solo-simulated vocal performance task in five trained singers. They were required to complete a 10-minute standard warm-up and sing for 40 minutes. They found increased habitual pitch and intensity levels in young untrained singers across a simulated solo performance. They attributed these changes to positive vocal adaptation.

However, it is apparent that all the studies quoted above differ from the present study in methodology and subject population. Therefore, it would be inappropriate to compare any of them with the present study.

In general, the results of the present study suggest that vigorous performance (acting or singing for long duration, speaking at higher level of intensity and frequency, and physical effort as in dancing) bring about a change in the voice of artists. However, the pre-post performance comparison to be meaningful, such variables as the duration for which a given artist has to perform in an Yakshagana play of 8 hours, the nature of his role, the amount of talking and singing that one has to do should be controlled. Data has been collapsed across the subjects here, and therefore, individual variations which may have been more meaningful, have been lost. Studies better controlled for these factors are warranted.

5.9 Effect of Short-Term Voice Rest on Voice: Yakshagana Dancing Artists and Bhagavathars

It is generally agreed that voice is temporarily adversely affected by fatigue and that resting of voice should restore normalcy. Deu Pree (1971) talked of a voice pattern of "tiring, resting and becoming rejuvenated in a continually overlapping pattern". On the other hand, fatigue may also be an important factor in further voice deterioration as the speaker struggles to cope with the difficulties by forcing his voice even more (Sander and Ripich, 1983).

Mean fundamental frequency, jitter, mean airflow rate, mean S/Z ratio decreased following vocal rest, while frequency range, harmonic to noise ratio, vital capacity and maximum phonation duration increased in dancing artists. Similarly, fundamental frequency, jitter and mean airflow rate decreased following vocal rest, while vital capacity, harmonic to noise ratio and maximum phonation duration increased in Yakshagana Bhagavathars. It may be recalled that generally these were the same parameters which had shown a change (or deterioration), following vigorous performance. These results overwhelmingly suggest that one can overcome the negative effects on voice by observing vocal rest. No doubt, the level of vocal parameters following voice rest was nearer to that of the pre-performance voice, but not quite so which indicates that 10-12 hours of vocal rest may not be adequate, to reverse the changes seen in voice following performance. This difference (difference between voice after vocal rest and pre-performance voice) is cumulative and that the effects of overuse of voice can be seen after many years. This signifies the need for training of these artists, especially those who are being 'initiated' into the art, on vocal hygiene and good vocal practice.

The status of voice prior to performance, following performance, and following voice rest provides indirect evidence to the utility of voice index computed in the present study. The voice of Yakshagana artists (pre-performance) was different from that of normals. The voice of these artists deteriorated following performance and improved following voice rest. All these are reflected in the voice index. Therefore, larger studies are warranted to establish the utility and validity of voice index in different vocal pathologies, as an indicator of severity of the problem, as an indicator of the efficacy of management programs etc.

5.10 Relationship Between Years of Practice of Yakshagana, Smoking, Alcohol Usage and Tobacco Chewing Habit, and Acoustic Characteristics of Voice

One-way ANOVA and Duncan's post hoc tests were employed to find the relationship, if any, between years of Yakshagana practice, habits like alcohol usage, tobacco chewing and smoking and voice and respiratory characteristics in Yakshagana artists. Contrary to subjective voice complaints by subjects, results revealed that number of years of Yakshagana practice did not have significant effect on voice characteristics. The mean values of different parameters of voice and respiratory effort were not significantly different between artists who had >14.8 years and artists with <14.8 years in Yakshagana. This is contrary to the complaints the two groups of artists made about their voice. However, the nature of subjective complaints made by the subjects is different from the parameters measured here. Therefore, a one-to-one relationship cannot be established between subjective complaints and acoustic parameters measured in the laboratory. However, artists with >14.8 years in Yakshagana complained of loss of pitch range while artists with <14.8 years in Yakshagana did not. Measured frequency range from voice samples shows that frequency range was significantly higher in the group of artists with >14.8 years Yakshagana experience than in artists with < 14.8 years of Yakshagana.

Jitter was significantly higher and vital capacity significantly lower in smoking artists than in non-smoking artists. The effects of smoking are primarily on the mucosa of the vocal folds leading to irritation which, in turn, may have led to higher jitter. Inhalation of smoke over a period of years is likely to clog the respiratory system leading to reduction in vital capacity. Chewing tobacco did not influence voice in any way as measured in the laboratory.

Usage or non-use of alcohol seemed to make a difference to the voice. Alcohol users had significantly higher jitter and shimmer (and related aspects), and significantly lower vital capacity and maximum phonation duration than nonusers of alcohol. Reduced respiratory support might lead to greater instability of their vibratory mechanisms resulting in higher jitter and shimmer. But, how usage of alcohol would affect respiratory mechanism is difficult to explain. Though there is no evidence in the literature on the direct effect of alcohol on voice parameters, the reasons for the increased frequency and intensity perturbations and poor respiratory support in alcohol users could be due to general muscle weakness as a result of alcohol usage. All in all, these results point to the need for education of the artists on vocal hygiene and usage.

There are no studies in the Indian context on the prevalence of voice problems in Yakshagana artists. Thus, this report is the first attempt to quantify voice characteristics, in terms of acoustic and respiratory correlates, in Indian singers and actors in the Indian context. The results of this study showed that majority of the voice parameters in Yakshagana Bhagavathars and dancing artists differed significantly from those of normals. However, only a few parameters (SIF, shimmer, beta ratio of LTAS, OQ and VC) showed significant difference between the two groups of Yakshagana artists. This may be related to the relatively different tasks that the two groups of artists have to perform in Yakshagana.

Chapter 6

Summary and Conclusions

Yakshagana artists are ever under pressure, like any other group of professional voice users, to maintain good vocal health. Poor vocal health may put their professional careers at risk, may lead them to compromise on their performance, and may also result in loss of income. Although the actual prevalence of voice disorders among Yakshagana artists is not known, professional impression is that it may be quite high considering the nature of the tasks performed by these artists. Informal training (learning through observation and imitation) being the order of the day in learning this art and taking it forward, coupled with lack of vocal education, particularly in the case of budding artists, puts these artists at high risk for developing vocal problems. The artists themselves, and others connected with this art form, are of the opinion that even those artists who are somewhat better trained are at high risk for developing voice problems in view of the long-hours of voice usage, often under adverse circumstances.

Information on the characteristics of voice of Yakshagana artists would be useful in designing a package of vocal education for them, and to counsel these artists on vocal hygiene. Also, information is needed to see if changes that occur in voice after a given performance are merely a reflection of normal vocal fatigue that subsides with brief voice rest, or is it a more serious change signifying vocal abuse. This information would help the professionals to institute a comprehensive training package for the benefit of these artists, and others of their kind.

The purpose of the present study was to

a) make a comparative analysis of the acoustic and respiratory characteristics of the voice of a group of normal speakers and Yakshagana artists, both the Bhagavathars and the dancing artists, to understand the long term effects of Yakshagana performance on the voice of its practitioners,

b) study the effect of a live Yakshagana performance on the voice of both the dancing artists and the Bhagavathars (short-term effect), by comparing their voice recorded prior to and following an Yakshagana performance,

c) analyze the effect of short voice rest, ranging from 10-12 hours, following an Yakshagana performance, on the voice of both groups of these artists,

d) find a relationship, if any, between years of Yakshagana performance, habits like smoking etc. of the artists and the nature of voice complaints made by these artists as well as results of acoustic analysis of voice, and

e) to arrive at a voice index which may reflect the overall status of the voice of a given speaker by combining different parameters of voice and respiratory effort which different units of measurement.

Normal subjects, Yakshagana dancing artists and Bhangavathars, 30 each, participated in the study. Yakshagana dancing artists and Bhangavathars were evaluated for their voice characteristics three times as shown below:

a) 30 minutes to one hour prior to Yakshagana performance

b) 10-30 minutes after Yakshagana performance

c) 10-12 hours after voice rest following an Yakshagana performance

The voice of subjects in the control group was evaluated only once. Comparison of the characteristics of voice of normal subjects with (a) above will give long-term effects of Yakshagana performance. Comparison between (a) and (b) above gives the short-term effects of Yakshagana performance while comparison between (b) and (c) above gives the effects of short vocal rest on voice.

The following characteristics of voice and respiratory effort were analyzed: fundamental frequency, speaking fundamental frequency, frequency rang, speed of fluctuations in frequency, extent of fluctuations in frequency, jitter, mean intensity, range of intensity, speed of fluctuations in intensity, extent of fluctuations in intensity, shimmer, harmonic-to-noise ratio, alpha, beta and gamma ratios of long-term average spectrum, open quotient, speed quotient, vital capacity, mean airflow rate, maximum phonation duration, and S/Z ratio.

Many studies have been conducted on the characteristics of voice of singers and theater actors (Teachy, Kahane and Beckford, 1991; Benninger, Jacobson, and Johnson, 1994; Mc Kinney, 1994; Bunch, 1995; Hogikyan, Appel, Guinn and Haxer, 1999; Murry and Rosen, 2000; Roy and Bless, 2000; Smith, Finnegan, and Kamell, 2005; and Pinczower and Oates, 2005). However, there are only the attempts of Novak, Dlouha, Capkova, and Vohradnik (1991), Kitch, Oates, and Greenwood (1996), and Welham and MacLagan (2003) on the effects of performance on voice. However, these studies have either analyzed voice only in the post-performance condition or have considered only simulated performance. There is a need for studies of the voice characteristics of Yakshagana artists for several reasons. First, though Yakshagana is a form of art unique to our country, there are virtually no studies on the voice characteristics of the practitioners of this art. Second, the art of Yakshagana presents an unique opportunity of studying two types of artists, namely, dancing artists and Bhagavathars, both of whom use their voice persistently, and for long periods, often under adverse circumstances. Third, there are no studies in the Indian context on the voice of actors and singers.

Voice parameters were analyzed from samples of sustained phonation of vowel /a/, continuous speech, samples of expiration, and samples of sustained production of /s/ and /z/. The major results of the study can be summarized as follows:

a) The voice of Bhagavathars and dancing actors was significantly different from that of normal speakers.

b) The voice of both Bhagavathars and dancing artists following an Yakshagana performance was different from their pre-performance voice.

c) Voice and respiratory parameters improved following vocal rest, but not quite to the pre-performance level.

d) Change in voice quality and vocal fatigue are the most predominant complaints made by the Yakshagana artists. Artists with more number of years of performance are more likely to complain of problems in their voice than those with less number of years. The personal habits of artists like smoking or alcohol consumption do not seem to have any effect on their voice except that smoking habit was associated with significantly higher mean value of jitter and lower value of vital capacity.

e) The subjects could be reliably classified into different groups (normals, dancing actors and Bhagavathars) based on an analysis of acoustic characteristics of voice and respiratory measures through discriminant function analysis. Extending this discriminant function analysis, a voice index could be computed combining parameters of voice and respiration with different units of measurement. The voice index developed appears to be a sensitive and reliable index of the overall status of the voice of a given individual.

It was presumed in the beginning of the study that the voice of Yakshagana dancing artists is more likely to get affected to a greater extent than the voice of Bhagavathars because of the excessive physical strain that they have to endure (physical movement as well as speaking at higher levels of frequency and intensity), but the results of the study have not supported this assumption.

Performance of Yakshagana perhaps alters the physiology of vocal mechanism of Yakshagana artists to some extent, and thus alters the characteristics of their voice. Even a single episode of Yakshagana performance can temporarily change the physiology of vocal mechanism due to overuse of voice in both groups of Yakshagana artists.

A period of 10-12 hours of voice rest brings about some recovery in their altered vocal mechanism thereby improving their voice characteristics to some extent. However, the voice rest period is not sufficient enough to return to the pre-performance level. This is true with both groups of Yakshagana artists. These minor changes perhaps get accumulated after every performance to alter the voices of Yakshagana artists in the long run.

All in all, the results suggest that some years of Yakshagana practice may not bring about adverse changes in the voice of its practitioners. Though the voice of Yakshagana artists (Bhagavathars and dancing artists) differed from the voice of normals (pre-performance comparison with normals), it should be remembered that the differences were within normal limits. The results, in general, point to the flexibility and adaptability of the vocal system of these practitioners which functions within normal limits even when it has to function under adverse circumstances for a long duration.

Limitations of the Study

Every effort was made to get as homogeneous a sample as possible. Subjects were matched for age, background, and habits, among others. But, these in themselves are not sufficient in a study of this nature. We had no control over such factors as nature of character portrayed by the artists, duration for which a given artist had to perform in a given play, whether there was any prolonged absence from acting in between etc. all of which are crucial variables. Subject variability, perhaps, was responsible for the high variance in the raw data (high standards deviations).

Another source of variability in data was perhaps the less than perfext setting/environment in which recordings were made. Though every attempt was made to record speech samples in the most ideal environments, the experimenter had to compromise on this issue considering the place and settings in which Yakshagana plays are performed. Therefore, in accepting the results of the present study, and their interpretations, considerations must be given to the sources of variability mentioned above.

Future Research

There is a need for a larger study with a more rigorous and controlled sampling to minimize sources of variability relating to subjects. Future studies should consider duration of performance in a play for a given character, whether it is a main role or a peripheral role, amount of talking and physical movement involved etc. in subject selection.

Other research projects can be initiated on the following:

a) Identification of factors relating to Yakshagana which lead to voice abuse and voice problems.

b) Identification of factors, whether subject related or Yakshagana performance related, which may help predict onset of voice problems in practitioners of the art of Yakshagana.

c) Underlying physiology of voice change because of Yakshagana performance and influence of vocal rest on vocal recovery.

d) Development of vocal hygiene programs and voice care tips based on the results of this study.

e) Validation of voice index on a larger population for future clinical use in the assessment of voice. Research is also warranted to make this voice index more comprehensive by amalgamating other dimensions related to diagnosis, evaluation and assessment of voice disorders like voice severity scale, voice handicap index, quality of life index etc. The utility of this voice index also needs to be examined to see if it reflects different pathological conditions that affect voice

References

Aronson, A. E. (1990). *Clinical voice disorders: An interdisciplinary approach.* New York: Thieme.

Baken, R. J. (1987). *Clinical measurements of speech and voice.* Boston: College-Hill press.

Benjamin, B., & Croxon, G. (1987). Vocal nodules in children. *Annals of Otology, Rhinology and Laryngology*, 96(5), 530-533.

Benninger, M. S., Jacobson, B. H., & Johnson, A. F. (1994). *Vocal arts medicine: The care and prevention of professional voice disorders.* New York: Thieme Medical Publishers.

Biever, D. M, & Bless, D. M. (1989). Vibratory characteristics of the vocal folds in young adults and geriatric women. *Journal of Voice,* 3 (2), 120-131.

Boone, D. R. (1977). *The voice and voice therapy.* Englewood Cliffs, NJ: Prentice-Hall.

Brodnitz, F. S. (1955). Post-operative vocal rehabilitation in benign lesions of the vocal cords. *Folia Phoniatrica,* 7, 193-200.

Brown, O. L. (1996). *Discover your voice.* San Diego, California: Singular Publishing Group.

Brown, W.S., Rothman, H.B., & Sapienza, CM. (2000). Perceptual and acoustic study of professionally trained versus untrained voices. *Journal of Voice,* 14, 301-309.

Bunch, M. (1995). *Dynamics of the singing voice.* Wien: Springer-Verlag.

Burzynski, C. M., & Titze, I. R. (1985). Assessment of vocal endurance in untrained singers. *Transcripts of the 14' Symposium Care of the Professional Voice, part I.* New York: Voice Foundation, 96-101.

Colton, R. H., & Casper, J. K. (1996). *Understanding voice problems.* Baltimore: Williams & Wilkins.

Cooper, M. (1973). *Modern techniques of vocal rehabilitation.* Sringfield: Charles C. Thomas.

Deary, I. J., Wilson, J. A., Cardig, P. N., & MacKenzie, K. J. (2003). The dysphonic voice heard by me, you and it: Differential associations with personality and psychological distress. *Clinical Otolaryngology,* 28, 374-378.

Deu Pree, (1971). The muscles of voice and speech, In L.E. Travis (Ed), *Handbook of Speech Pathology and Audiology.* Englewood Cliffs: Prentice Hall.

Doherty, E., & Shipp, T. (1988). Tape recorder effects on jitter and shimmer extraction. *Journal of Speech and Hearing Research,* 31,485-490.

Dworkin, J. P., & Meleca, R. J. (1997). *Vocal pathologies: diagnosis, treatment, and case studies.* San Diego: Singular Publishing co.

Eskanazi, L., Childers, D. G., & Hicks, D. H. (1990). Acoustic correlates of vocal quality. *Journal of Speech and Hearing Research,* 33, 298-306.

Fant, G. (1960). *Acoustic theory of speech production.* The Hague, Netherlands: Mouton.

Fisher, R. A. (1936). The use of multiple measurements in taxonomic problems. *Annals of Eugenics, 7,* 179-188.

Deary, I. J., Wilson, J. A., Cardig, P. N., & MacKenzie, K. J. (2003). The dysphonic voice heard by me, you and it: Differential associations with personality and psychological distress. *Clinical Otolaryngology,* 28, 374-378.

Deu Pree, (1971). The muscles of voice and speech, In L.E. Travis (Ed), *Handbook of Speech Pathology and Audiology.* Englewood Cliffs: Prentice Hall.

Doherty, E., & Shipp, T. (1988). Tape recorder effects on jitter and shimmer extraction. *Journal of Speech and Hearing Research,* 31,485-490.

Dworkin, J. P., & Meleca, R. J. (1997). *Vocal pathologies: diagnosis, treatment, and case studies.* San Diego: Singular Publishing co.

Eskanazi, L., Childers, D. G., & Hicks, D. H. (1990). Acoustic correlates of vocal quality. *Journal of Speech and Hearing Research,* 33, 298-306.

Fant, G. (1960). *Acoustic theory of speech production.* The Hague, Netherlands: Mouton.

Fisher, R. A. (1936). The use of multiple measurements in taxonomic problems. *Annals of Eugenics,* 7, 179—188.

Fisher, H. B. (1975). *Improving voice and articulation.* New York: Houghton, Mifflin.

Froeschels, E. (1939). *Twentieth century speech and voice correction.* NY: Philosophical Library.

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.

Gotaas, C, & Starr, C. D. (1993). Vocal fatigue among teachers. *Folia Phoniatrica*, 45, 120-129.

Greene, M. C. L., & Mathieson, L. (1989). *The voice and its disorders.* London: Whurr.

Gudykunst, W. B. (1986). *Intergroup Communication.* London: Edward Arnold.

Hill, S. D., Oates, J. M, Healey, J. E., & Russell, J. (1988). Effect of speaking over background noise on acoustic correlates of normal voice in adult. *Australian Journal of Human Communication Disorders,* 16: 23-27.

Fisher, H. B. (1975). *Improving voice and articulation.* New York: Houghton, Mifflin.

Froeschels, E. (1939). *Twentieth century speech and voice correction.* NY: Philosophical Library.

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.

Gotaas, C, & Starr, C. D. (1993). Vocal fatigue among teachers. *Folia Phoniatrica,* 45,120-129.

Greene, M. C. L., & Mathieson, L. (1989). *The voice and its disorders.* London: Whurr.

Gudykunst, W. B. (1986). *Intergroup Communication.* London: Edward Arnold.

Hill, S. D., Oates, J. M, Healey, J. E., & Russell, J. (1988). Effect of speaking over background noise on acoustic correlates of normal voice in adult. *Australian Journal of Human Communication Disorders,* 16: 23-27.

Hirano, M. (1981). Clinical examination of voice. In G. E. Arnold, F. Winckle, B. D. Wyke (Eds.), *Disorders of Human Communication* (pp.81-84). Vienna: Springer.

Hixon, T. J., & Hoffman, C. (1978). Chest wall shape in singing. In V. Lawrence (Ed). *Transcripts of the Seventh Symposium on Care of the Professional Voice, Part 1: Scientific Papers on phonological processes* (pp. 9-10). New York, NY: The Voice Foundation.

Hoffman - Ruddy, B. H., Lehman, J., Crandell, C, Ingram, D., & Sapienza, C. (2001). Laryngostroboscopic, acoustic, and environmental characteristics of high-risk vocal performers. *Journal of Voice*, 12 (4), 543-552.

Hogikyan, N. D., Appel, S., Guinn, L. W., & Haxer, M. J. (1999). Vocal folds nodules in adult singers: Regional opinions about etiologic factors, career impact and treatment. A survey of otolaryngologists, speech pathologists, and teachers of singing. *Journal of Voice*, 13, 128-142.

Holbrook, A. (1977). Instrumental analysis and control of vocal behavior. In M. Cooper, & M.H. Cooper (Eds), *Approaches to vocal rehabilitation* (pp.127-145). Springfield, Illinois: Charles C. Thomas.

Hollien, H., & Shipp, T. (1972). Speaking fundamental frequency and chronological age in males. *Journal of Speech and Hearing Research,* 15, 155-159.

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,* 66-70.

Johnson, A. (1994). Disorders of speaking in the professional voice user. In M. Benninger, B. Jacobson, A. Johnson (Eds.), *Vocal arts medicine: The care and prevention of professional voice disorders* (pp. 177-215). New York: Thieme.

Karnath, S. (1975). *Yakshagana,* Mysore : Institue of Kannada Studies.

Katrin, B. (2005). Transmission and transformation: Yakshagana of Coastal Karnataka. *Indian Folklife,* 20,7-11.

Kay, N. (1982). Vocal nodules in children - etiology and management. *Journal of Laryngology and Otology,* 96, 731-736.

Hollien, H., & Shipp, T. (1972). Speaking fundamental frequency and chronological age in males. *Journal of Speech and Hearing Research,* 15, 155-159.

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, 66-70.

Johnson, A. (1994). Disorders of speaking in the professional voice user. In M. Benninger, B. Jacobson, A. Johnson (Eds.), *Vocal arts medicine: The care and prevention of professional voice disorders* (pp. 177-215). New York: Thieme.

Karnath, S. (1975). *Yakshagana,* Mysore : Institue of Kannada Studies.

Katrin, B. (2005). Transmission and transformation: Yakshagana of Coastal Kamataka. *Indian Folklife,* 20,7-11.

Kay, N. (1982). Vocal nodules in children - etiology and management. *Journal of Laryngology and Otology,* 96, 731 -736.

Kitch, J. A., Oates, J., & Greenwood, K. (1996). Performance effects on the voice of 10 choral tenors: acoustic and perceptual findings. *Journal of Voice,* 10,217-227.

Kostyk, B. E., & Rochet, A. P. (1998). Laryngeal airway resistance in teachers with vocal fatigue: a preliminary study. *Journal of Voice,* 12,287-299.

Koufrnan, J. A., & Blalock, P. D. (1988). Vocal fatigue and dysphonia in the professional voice user: Bocart-Bacal syndrome. *Laryngoscope,* 98, 493-498.

Lancer, J. M., Snyder, O., Jones, A. S., & Le Boutillier, A. (1988). Vocal cord nodules: A review. *Clinical Otolaryngology,* 13,43-51.

Luschinger, R., & Arnold, G. E. (1965). *Voice—speech—language.* Belmont, California: Wadsworth.

Markel, N. N., Meisels, M., & Houck, J. (1964). Judging personality from voice quality. *Journal of Abnormal Social Psychology,* 69, 458-463.

McFarlane, S. C, & Watterson, T. L. (1990). Vocal nodules: Endoscopic study of their variations and treatment. *Seminars in Speech and Language,* 11(1), 47-59.

McGlone, R., & Hollien, H. (1963). Vocal pitch characteristics of aged women. *Journal of Speech and Hearing Research*, 6,164-170.

McKinney, J. (1994). Singing/acting young adult from a singing instruction perspective. *Journal of Voice*, 11, 153-155.

Murry, T., & Rosen, C. A. (2000). Vocal education for the professional voice user and singer. *Otolaryngologic Clinic of North America*, *33*, 967-82.

Neils, L. R., & Yairi, E. (1987). Effects of speaking in noise on vocal fatige and vocal recovery. *Folia phoniatrica et logo paediatrica*, 39,104-112.

Novak, A., Dlouha, O., Capkova, B., & Vohradnik, M. (1991). Voice fatigue after theater performance in actors. *Folia phoniatrica*, 43, 74-78.

Perkins, W. (1971). Vocal function: assessment and therapy. In L. E. Travis, (Ed.), *Handbook of speech pathology and audiology*. New York: Appleton-Century-Crafts.

Phyland, D. J., Oates, J., & Greenwood, K. M. (1999). Self reported voice problems among three groups of professional singers. *Journal of Voice*, 13,602-611.

McGlone, R., & Hollien, H. (1963). Vocal pitch characteristics of aged women. *Journal of Speech and Hearing Research,* 6, 164-170.

McKinney, J. (1994). Singing/acting young adult from a singing instruction perspective. *Journal of voice* , 11, 153-155.

Murry, T., & Rosen, C. A. (2000). Vocal education for the professional voice user and singer. *Otolaryngologic Clinic of North America, 33,* 967-82.

Neils, L. R., & Yairi, E. (1987). Effects of speaking in noise on vocal fatige and vocal recovery. *Folia phoniatrica et logo paediatrica,* 39, 104-112.

Novak, A., Dlouha, O., Capkova, B., & Vohradnik, M. (1991). Voice fatigue after theater performance in actors. *Folia phoniatrica,* 43, 74-78.

Perkins, W. (1971). Vocal function: assessment and therapy. In L. E. Travis, (Ed.), *Handbook of speech pathology and audiology.* New York: Appleton-Century-Crafts.

Phyland, D. J., Oates, J., & Greenwood, K. M. (1999). Self reported voice problems among three groups of professional singers. *Journal of Voice,* 13,602-611.

Piccirillo, J. F., Painter, C, Fuller, D., & Fredrickson, J. M. (1998). Multivanate analysis of objective vocal function. *Annals of Otology, Rhinology, and Laryngology*, 107, 107-112.

Pinczower, R., & Oates, J. (2005). Vocal projection in actors: the long-term average spectral features that distinguish comfortable acting voice from voicing with maximal projection in male actors. Journal of Voice, 19(3), 450-453.

Rantala, L., Paavola, L., Korkko, P., & Vilkman, E. (1998). Working-day effects on the spectral characteristics of teaching voice. *Folia Phoniatrica et logopaedica*, 50 (4):205-l 1.

Rantala, L., Vilkman, E., & Bloigu, R. (2002). Voice changes during work: Subjective complaints and objective measurements for female primary and secondary school teachers. *Journal of Voice*, 16, 344-355.

Raphael, B. N., & Scherer, R. C. (1983). Repertory actors' perceptions of the voice in relation to various professional conditions. In V. L. Lawerence, (Ed.), *Twelfth symposium: Care of the professional voice* (pp. 25-31). New York: The Voice Foundation.

Raphael, B. N., & Scherer, R. C. (1987). Voice modification of stage actors: Acoustic analysis. *Journal of Voice*, 1, 83-87.

Rosen, C. A., & Murry, T. (2000). Voice handicap index in Singers. *Journal of Voice*, 14, 370-37.

Roy, N. & Bless, D. M. (2000). Personality traits and psychological factors in voice pathology: A foundation for future research. *Journal of Speech, Language, and Hearing Research*, 43, 73 7-748.

Ryker, K. S., Roy. N., & Bless, D. M. (2000). Vocal violence in actors: An investigation into its acoustic consequences and the effects of hygienic laryngeal release training. *Journal of Voice*, 14, 215-30.

Sander, E. K., & Ripich, D. E. (1983). Vocal fatigue. *Annals of Otology, Rhinolgy, and Laryngology, 92,* 142-145.

Sapir, S. (1993). Vocal attrition in voice students: Survey findings. *Journal of Voice,* 7, 69-74.

Sapir, S., Atias, J., & Shahar, A. (1990). Symptoms of vocal attrition in women army instructors and new recruits: Results from a survey. *Laryngoscope,* 100,991-994.

Stemple, J. C, Stanley, J., & Lee, L. (1995). Objective measures of voice production in normal subjects follovving prolonged voice use. *Journal of Voice, 9*, 127-133.

Stone, R., & Sharf, D. (1973). Vocal change associated with the use of atypical pitch and intensity levels. *Folia Phoniatrica (Basel),* 25, 91-103.

Street, R., & Hopper, R. (1982). A model of speech style evaluation. In E. Ryan & H. Giles (Eds.), *Attitudes towards language variation* (pp. 175-188). London: Edward Arnold.

Sundberg, J. (1987). *The Science of the singing voice.* Dekalb: Northern Illinois University Press.

Sundberg, J., Elliot, N., Gramming, P., & Nord, L. (1993). Short - term variation of subglottal pressure for expressive purposes in singing and stage speech: A preliminary investigation. *Journal of Voice*, 7, 227-234.

Teachy, J. C, Kahane, J. C, & Beckford, N. S. (1991). Vocal mechanisms in untrained professional singers. *Journal of Voice, 5*, 51-56.

Titze, I. R. (1994). *Principles of voice production.* Englewood cliffs, NJ: Prentice Hall.

Vilkman, E., Lauri, E. R., Alku, P., Sala, E., & Sihvo, M. (1999). Effects of prolonged oral reading on FO, SPL, subglottal pressure and amplitude characteristics of glottal flow waveforms. *Journal of Voice*, 13, 303-315.

Watson, P., & Hixon, T. (1985). Respiratory kinematics in classical (opera) singers. *Journal of Speech and Hearing Research*, 28, 104-122.

Welham, N. V., & Maclagan, M. A. (2003). Vocal Fatigue: Current knowledge and future directions, *Journal of Voice,* 17(1), 21 -30.

Welham, N. V., & Maclagan, M. A. (2004). Vocal fatigue in young trained singers across a solo performance. *Logopedics, Phoniatrics, Vocology*, 29(1): 3-12.

Wuyts, F. L., De Bodt, M. S., Molenberghs, G., Remade, M., Heylen, L., Millet, B., Van Lierde, K., Jan Raes, & Van de Heyning, P. H. (2000). The dysphonia severity index: An objective measure of vocal quality based on a multiparameter approach. *Journal of Speech, Language, and Hearing Research*, 43,796-809.

Zemlin, W. R. (1998). *Speech and hearing science: Anatomy and physiology.* Massachuettes: Allyn & Bacon.