RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY OF VOICE AND 'ADHARA SHRUTHI' IN CARNATIC VOCAL MUSIC

Register No. M9904

A Dissertation submitted in part fulfillment for the
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To

my Nanaji

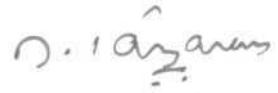
&

papa, mummu& bhaiya

who Introduced me to the world of music

CERTIFICATE

This is to certify that the dissertation entitled **"RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY OF VOICE AND 'ADHARA SHRUTHF IN CARNATIC VOCAL MUSIC"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with register number M9904.



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CERTIFICATE

This is to certify that the dissertation entitled **"RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY OF VOICE AND 'ADHARA SHRUTHI' IN CARNATIC VOCAL MUSIC"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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DECLARATION

This dissertation entitled "RELATIONSHIP BETWEEN THE FUNDAMENTAL FREQUENCY OF VOICE AND 'ADHARA SHRUTHP IN CARNATIC VOCAL MUSIC" is the result of my own study under the guidance of Dr. M. JAY ARAM, Director, AIISH, Mysore and has not been submitted at any other university for the award of any Diploma or Degree.

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CONTENTS

CHAPTER 1

INTRODUCTION

Sangita-jndnamanu Brahma
dnanda-sagarami'dani
dehamu bhiimari-bhdramu

The body that does not revel
in the ocean of bliss that music is,
is a burden unto the Earth

- *TYAGARAJA*

When we listen to the murmur of a running brook or the rustle of the southern breeze, or the notes of a thrust, our mind is filled with a certain tenderness and joy. This joy comes due to the music hidden in these sounds. It is the evocative power of certain sounds and their combinations which is the basis of all music, from drums and trumpets of the primitive tribes to the modern chamber music and concerts.

Indian music is one of the most ancient and most difficult art forms. The music of India ranges from the grunts and shrieks of Nagas in the far East and the Todas in the Southern hills to the most sophisticated concert raagas and talas of the classical stream.

INDIAN SYSTEMS OF MUSIC

Present day Indian music has two schools - the Hindustani and the Caraatic. In general, they have the same basis, being melodic and governed by rules of raaga and taala structure. The Carnatic system is the art form of Southern India (Tamil Nadu,

Kerala, Andhra Pradesh, Karnataka), but not necessarily restricted to this region. In general, the rest of India follows the Hindustani stream. The Carnatic school claims to have maintained and developed the orthodox traditional style while the Hindustani school is said to have experienced considerable changes and developments through the Moghul period upto the present time (Sambamurthi, 1982).

Indian classical music is expressed in terms of raagas. The term "Raaga" (Sanskrit) means 'affection, happy feelings, colour, mode, mood'. In music, it means a set of notes arranged in ascending and descending order within the octave. This systematic arrangement of notes forms the basis of all Indian melodies. The ascending order is called 'arohana' (ascension) and the descending order is called 'avarohana' (descension) in Sanskrit. I

Basic Tones of Indian Music

The basic notes in Indian system of music are seven in number as shown below:

Sa	Sadja
Re	Risabha
Ga	Gandhara
Ma	Madhyama
Pa	Panchama
Da	Dhaivata
Ni	Nisada

These basic notes cover a range of one octave. Except the two notes of 'Sa' and 'Pa' which are characterized as 'achala' (constant, stationary), the other five notes in the above series have, broadly speaking, two variations - the low pitched and the high pitched variations in tone. \

Shruthi

'Shruthi' means 'to hear' or that which is heard. Musically, it points to the interval between notes which can be just perceived auditorily. Musically viable pitches in an octave are literally infinite.

However, all the vibrations within an octave are not considered musical tones. Only a limited number of vibrations in an octave (from 'Sa' to 'Sa' in the arohana or avrohana) are perceived as musical notes. In fact, the total number of the shruthis taken into account in the present musicometrical calculations is 43. Shruthi-locations have been accepted to be 43 while the Shruthi-zones have been taken to be only 22. Shruthis locationally are of unequal lengths, but zonally are of equal lengths (Verma, 1973).

Melodic points when silently located on the pitch-series of the octave are called 'Shruthis' and when they are sounded as specific points of punctuation in a melodic mode, they become 'Svaras'. In other words, shruthis are theoretical possibilities of svaras while svaras are practical manifestations of shruthis (Verma, 1973).

In Indian classical music, the base note - 'Sa' or the 'adhara shruthi' is not of a constant pitch unlike the 'C in European music which is a pitch of a fixed number of vibrations/sec (240 Hz). The pitch of 'Sa' chosen, in Indian music, varies widely depending upon the singer, and many factors intrinsic to any given singer. It may also depend, though very rare, on the chief instrument in a concert. Such a scenario is usually seen in the enactment of mythological dramas. Hence, the remaining notes of the octaves vary in their vibrational values according to that of the "adhara shruthi' as they are all relative and not fixed.

REQUIREMENTS OF VOICE IN SINGERS

VThe singer is quiet vulnerable to criticism regarding his pitch. Pitch to a singer is the perception of tone colour. Winkel (1967) states that pitch and tone colour are same dimensions. If at all different, then tone colour can be seen as a large area of which pitch is one division.

Each individual has a unique natural frequency which depends upon his age, sex, size of vocal organs, etc. During a concert, a vocalist not only has to have a good and appealing voice, but also, has to compete with the other accompanying instruments. Achievement of loudness with minimal vocal effort is of paramount concern for the professional vocalist whose livelihood depends on maintenance of a healthy voice under the most stressful conditions (Perkins, 1978).

In Indian classical music, as mentioned earlier, each raaga is composed of a different set of tones. Some have more notes in the lower and middle octave while some have more in the higher octave. While singing, vocalist needs to be careful in selecting his 'adhara shruthi' as the shruthi so selected should enable him to comfortably cover all the notes in the raaga.

The twin needs of a singer to have a good and appealing voice, and an ability to traverse all the notes in a 'raaga' without much difficulty, basically determine his/her selection of 'adhara shruthi'. Generally, most singers have their shruthi at the initial note of the mid register (mid octave). From this level, most singers can easily travel upto 'Pa' in the higher register (ascending scale), but achieving tones in the lower register may not be easily accomplished. Therefore, it may not be incorrect to say that 'adhara shruthi' is selected on a trial and error basis with a singer stabilizing at that shruthi level which facilitates him to traverse into the high and low octaves (generally up to the 'Pa' note) in the higher and lower registers easily.

It is our clinical observation that many singers stabilize their 'shruthis' at a slightly higher or lower frequency in relation to their natural fundamental frequency of voice (habitual frequency). Majority of the singers tend to keep a higher shruthi, so that intoning lower tones would be facilitated.

Initiation into classical music, at least in this country, is generally done very early in life. It is not uncommon to see pupils of 3 years in most music schools. At that

young age children will not have a conscious option to select any particular level of shruthi, and invariably are guided by their teacher. However, as the children continue their music lessons and are introduced to more raagas, they become aware of the tonal structure of the raagas and the range they have to traverse up and down the scale. This may necessitate readjustment of their shruthi level. It is not known, at this point of time, whether such adjustments in shruthi are indeed necessary and made? If yes, at what age such adjustments are made, and whether the number of years of training is a factor influencing their readjustment is also not known. The present study also addressed this question with the data available, but in a limited way.

PURPOSE OF THE STUDY

Therefore, the purpose of this study was to analyze the frequency levels of the 'adhara shruthi ' in a group of singers and to investigate the relationship of this level to the natural fundamental frequency of their voice (habitual frequency).

OBJECTIVES

The objectives of this study were to determine

a) the 'adhara shruthi' levels in a group of female singers,
b) investigate the relationship between frequency level of 'shruthi', on the one hand, and fundamental frequency of voice in phonation and speaking, on the other hand, and

c) to carryout an analysis of the relationship between fundamental frequency of voice and 'adhara shruthi' levels as a function of the number of years of training in music.

A secondary objective was to analyze whether or not the 22 notes in the mid register were embedded within an octave range. This was carried out as data was available.

IMPLICATIONS OF THE STUDY

Music to be pleasing to the ears of the listeners requires that the singers are not only able to intone the different tones of a raaga, but also that they employ a natural voice. A singer who places much emphasis on traversing across the musical registers may have to compromise on the selection of the 'shruthi' and thereby the quality of his voice. The result of this study will help us to educate the singers as well as the teachers of singing. This is especially very important in the Indian scene as a majority of the budding singers start their music lessons very early in their life, much before the age of puberty and much before their voice has stabilized. Such young trainee singers will have to make further adjustments in their voice after the age of puberty.

Singers who may be using a shruthi which is different from their natural fundamental frequency of voice may also be compromising on the quality of their voice. Their voice may not sound resonant or they may find it difficult to project their voice and singing, leaving everyone dissatisfied. The results of this study will help in the vocal education of the singers.

Singing involves a more prolonged and sustained voice production compared to speech. Singing undoubtedly involves a more sophisticated and controlled production of voice. It follows, therefore, that singers, particularly those who have not had received good vocal education or training, are particularly susceptible to voice problems. Long hours of voice usage in both rehearsals and performance coupled with improper breathing techniques and inappropriate usage of frequency of voice may lead to many voice problems in the singer. Hoarseness, vocal fatigue (inability to sing for extended periods of time without a change in voice quality or control) and an inability to produce high or low tones with the same facility as before are some of the voice problems reported by the singers. Though employment of inappropriate frequency levels of voice may not be solely responsible for the many voice problems faced by singers, it could be a major precipitating factor of voice problems in them. The results of this study may throw valuable information to guide the singers in their vocal practice.

CHAPTER 2

REVIEW OF LITERATURE

The importance of human voice in the modern society cannot be overstated. It is said that voice is the primary instrument through which most of us try to project our personalities and influence our compatriots (Sataloff, 1991).

Voice is the musical sound produced by the vibration of the vocal cords driven by air from the lungs. Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible and coherent which are essential qualities to efficient communication through spoken word (Green, 1964). The act of speaking is a very specialized way of using the vocal mechanism. The act of singing is even more so. Speaking and singing demand a combination or interaction of the mechanism of respiration, phonation, resonance and speech articulation (Boone, 1983).

SPEAKING AND SINGING

Society is formed because of communication. Man has used speech and song to communicate his ideas and feelings for long. There are theories which state that "human speech took origin from song" (Critchley, 1975) and others like Proctor (1960) and Bunch (1982) believe that singing is specialization over speech. Bunch (1982) described singing as a sensory motor phenomenon **that** requires particular motor skills. It is said that in ancient times, Sanskrit was in the form of poetry, as also the dramas of

those times (Sharma,1968). From this a possible conclusion is that, at onetime, everyone could sing while only a small group has maintained this ability today.

Butenschon and Borchgrevink (1982) have contended that

(i) in principle, there is no difference between the sounds of speech and of singing,

(ii) singing employs continuous flow of vocal sound for consonants as against that in speech, and

(iii) singing also demands considerable resonance and articulation.

Fujisaki (1981) delineated differences in fundamental frequencies (FO) between speech and singing :

(i) In classical music, a singer is expected to sustain the mean fundamental frequency at a constant value over the time interval of a note while a speaker is never expected to do so during an utterance in speech,

(ii) There is no FO-declination within a note while FO declination is quite common in speech,

(iii) A singer is asked to control the rate of FO-transition from one note to another according to the specified manner of performance while the rate is never consciously controlled in speech.

Sundberg (1977) opines that there is a major difference between the way the formant frequencies are chosen in speech and the way they are chosen for singing.

In singing, vowels are prolonged, because they are especially suited to carry melody (Luchsinger and Arnold, 1965). It follows that the rhythmical, dynamic and melodic qualities of speaking and singing differ with regard to both quantity and quality.

L The rhythmic progression from sound to sound and use of vowels in music accounts for another difference. Singing makes some poor habits difficult or impossible for singers (Bunch, 1982). A good breathing habit, good control of subglottic pressure, proper shaping of supraglottic air spaces and active use of articulators are sine qua non of good music .

In addition to the above, Greene (1972) draws our attention to another aspect of music; singing requires a complete mastery of techniques, the control, not merely of the mechanics of singing, but of the fine shades of tone colour. Tone colour is abstract and defies analysis, but it conveys the emotional message of the passage as compared to the act of speaking. \

The main differences between speech and singing can be summarized as follows:

(i) Isochronism of vibration of vocal fold is not much stressed in speech as it is in singing.

(ii) More controlled breathing is seen in singing,

(iii) Greater vocal range is used in singing as compared to speech.

(iv) Vibrato-singer's formants are used by singers.

(v) Vocal apparatus is under greater stress during singing than in speech.

PARAMETERS OF VOICE

Production of voice requires the concerted action of the following three basic components :

a) the respiratory system which provides the required air pressure of air in the lungs,

b) the vocal folds which chop the air stream from the lungs into a sequence of periodic air pulses, and

c) the vocal tract which gives each sound its final characteristic spectral shape and thus its timberal identity. These three components are referred to as respiration, phonation and resonance respectively (Sundberg, 1979).

Perceptual correlates of the above three systems are loudness, pitch and quality of the voice, respectively. Deviation or disturbance in any one of the aspects will affect the voice as a whole in a given speaker.

Pitch

Pitch, as mentioned above is the psychological correlate of the physical dimension of frequency of vocal fold vibration (Case, 1991). Human voice is a complex tone of many frequencies. The listener perceives the lowest frequency, the FO as the speakers's pitch (Borden and Harris, 1980). The FO is the number of glottal openings per second (Borden and Harris, 1980).

The FO of a voice is determined by vocal fold length, tension and mass of the vocal folds in combination with subglottic pressure (Greene and Mathaison, 1995). The frequency of vocal fold vibration directly determines the FO of the voice.

Till date, several studies, have reported on the speaking frequency level of normal Caucasian adults. Fitch and Holbrook (1970) evaluated the " middle 55 words of the Rainbow Passage" as read by 100 men (age 18 to 25.2 years) and 100 women (age 17.75 to 23.5years). They found the average speaking F0 for men to be 116.65 Hz with a range of 85-155 and for women, it was 217 Hz with a range of 165-255 Hz.

Case (1991) defined habitual pitch as the modal or average level heard in a continuing sample of speech, the level around which normal pitch inflections occur. In other words, it is the central tendency of the pitch.

On average, the habitual pitch, which is variable according to the individual and circumstances, is estimated to be roughly as follows (Boone, 1977):

Men	128 Hz
Women	225 Hz
Children	265 Hz

The question of possible racial differences in speaking F0 has been addressed by several investigators. Hollien and Malchik (1962) and Holien, Malchik and Hollien (1965) have found a slightly lower speaking F0 in young black males as compared to

their Caucasian counterparts. Hudson and Holbrook (1981, 1982) found that modal speaking FO was somewhat greater than mean speaking FO range. None of these differences, however was large enough to be clinically meaningful.

VLuchsinger and Arnold (1965) estimate that a child's and a small woman's (i.e. soparono) modal speaking FO will be in the region of 300 Hz whereas a bass will be in the range of 100 Hz. They gave the following estimates:

1. Men : Median speaking range.

Bass	96-110 Hz
Baritone	117- 133 Hz
Tenor	147-165 Hz.

2. Women : Median speaking range (one octave higher than men)

Contralto	220 Hz
Mezzo-Soprano	226 Hz
Soprano	262 Hz

*

In singing, the pitch range is much more extensive although there is some disparity between the measurements given by various investigators. The disparity probably arises from different assessment methods, j

Selection of an appropriate frequency is a very crucial decision for a singer. During selection of FO he needs to consider the natural mechanism of his voice box, the accompanying instruments, the singing environment and of course to achieve an appealing tone colour in the voice.

i Luchsinger and Arnold (1965) suggest a singing range of 147 - 349 Hz for men and 249 - 698 Hz for women while Perkins and Kent (1986) recommended ranges of 80 - 700 Hz and 140 - 1000 Hz for men and women, respectively!)

_The artistically acceptable range for most singers is two to two-and-a-half octaves although they produce notes of higher and lower pitch (Bunch, 1962).

Physiologically, range of pitch is determined by the length and shape of the singer's vocal folds and their ability to coordinate the vocal muscles. The voice quality, as distinct from pitch of the voice, is in part determined by the inherent shape of the vocal tract and the ability to modify this by muscular activity (Bunch, 1980);

Loudness I Intensity

Change in loudness is brought about by changing the subglottal pressure : higher the subglottal pressure, louder the sound (Sundberg, 1990). Variation of subglottal pressure is required not only for changing loudness, but also for pitch changes (Cleveland and Sundberg, 1963). This is because the vocal folds become stiffer as they

are stretched for rising pitch, and the stiffer folds need more driving pressure (Titze, 1989). Thus, higher subglottal pressures usually increase the pitch levels.

In singing, well-controlled patterns of subglottal pressure are required. Subglottal pressure must be adjusted quite accurately; otherwise, pitch errors occur (Sundberg, 1990).

Singers obviously use their voices in very special ways, influenced by and creating aesthetic values. Singers' voice seems to be special and different and general conclusions regarding voice are hard to infer from the way they use their voices.

INDIAN SYSTEM OF MUSIC

Indian music is distinguished from other musical systems in terms of its origin and its implication. Music is considered as a gift of God and part of fourfold goals of life. This theocentric or sociocentric view has its wide spread effect. Till today, Indian classical music in all its forms is used to worship, praise or hail the glory of the formless (Satynarayana, 1983); so much so even raagas and notes have their own Gods. The basic conceptual material is from vedas. No other musical system has such a definite and strong background as Indian music (Satyanarayan, 1983).

There are certain peculiarities of Indian music. Musical progression is in terms of single note. That is, at any given time only one note or its shadow is acting. Thus it is

called homophonic or sometimes loosely as melodic music. Western music, on the other hand, is heterophonic or harmonic system. That is, progression is in terms of harmony and calls for several sounds simultaneously. There are other systems which are homophonic, but Indian system is the only one which has seven notes in an octave and the melodic content divided into 12 semitones which are further divided into 22 positions in a scale called shruthi.

TERMINOLOGY

1. **Nada** : Musicologists refer to any melodious tone as 'nada'. It is the basic component of music. Nada can be basically of two types (a) Anahata (b) Ahata.

Anahata refers to sounds of nature, i.e. sounds produced without human effort. Sounds produced by body metabolism fall in to this realm. Ahata refers to sounds produced by conscious effort of man. Ahata is divided into 6 subtypes depending on the origin of the sound.

The six subtypes are as follows:

a) Sariraja - Sound emanting from human voice.
b) Nakhaja - Sound produced by plucked instruments. Ex. Veena.
c) Dhanuraja - Sound produced by bowed instruments. Ex. Violin.
d) Vayuja -Sound produced by wind instruments. Ex. Flute.
e) Charmaja - Sound produced by skin covered instruments. Ex. Drums

0 Lohaja -Sound produced by metallic instruments. Ex. Cymbals.

This study concerns itself only with the "sariraja".

2. **Shruthi** : Shruthi may be defined as the tones with perceptible difference of pitch that is free from resonance and is pleasant. It is the interval between the notes which can be just perceived. In an octave nada can be many, but shruthis are only 22 in number. The allocation of shruthis from 'Sa' to 'Sa' according toDatta et al (1983) are:

Sa	4
Re	3
Ga	2
Ma	4
Pa	4
Da	3
Ni	2

3. Swaras : are pitch related entities akin to the letters in the alphabet. The seven notes are Sa, Re, Ga, Ma, Pa, Da, Ni, Sa.

Among the seven swaras 'Sa' and 'Pa' are called Achala (invariant) swaras while the remaining five notes, namely, Ri, Ga, Ma, Da, Ni, have a "komal" or low note and a "tivra" or a high note. There are 12 notes including the variables as given below:

Basic Notes	Name of variety	Denoted as
Sa	Shadja	Sa
Re	Shuddha Rishabha	**R1**
	Chatusshruti Rishabha	R_2
Ga	Sadharana Gandhara	G_2
	Anthara gandhara	G_3
Ma	Shudha Madhyama	**M1**
	Prati Madhyama	$\mathbf{M_2}$
Pa	Panchama	**Pa**
Da	Shudda Dhaivata	**Da1**
	Chatusshruti Dhaivata	Da_2
Ni	Kaisiki Nishada	N_2
	Kakali Nishada	N_3

As can be noticed 'Ga' and 'Ni' do not enlist a shudda note. This is actually due to overlap with the immediate preceeding note that is

Shudda Ga = Chatusshuti Re

Shudda Ni = Chatusshruti Dha

Shuddha refers to the lowest pitch or the earliest variety of each note in the ascending scale

4. **Raaga** : Raaga can be termed as a melodic mode or matrix in which few tonal notes are brought together in a definite organization. Each raga has individuality; a distinct personality. Variation can be seen in the same raaga when sung by different singers depending upon situation, his attitude, his impression of aesthetic content, but yet the morphology of raaga is maintained. The notes have to be of definite nature (scale); they are to be in a certain order of tonal syntax, with emphasis on determined note.

In India, oral tradition has significantly influenced the education, performance, creation, appreciation as well as propagation of music. Although, notation is employed to document basics like the composition skeleton, note exercises etc., oral tradition continues as the chief mode of knowledge transfer. Indian music has the choice to choose any comfortable pitch as key-note called 'adhara shruti'.

PROBLEMS FACED BY SINGERS

The universality of human voice, as an instrument, is its greatest joy as well as its major disadvantage (Bunch, 1982). Almost everyone can sing and make musically acceptable vocal sounds, but few people can become true artists. The complexities of the vocal mechanism and the high degree of coordination and the amount of energy necessary for artistic musical performance are often overlooked, taken for granted, or not understood by a majority. .

The human voice offers fewer constraints to its users, than any other musical instrument. All other instruments contain at least fixed resonances and several also offer the player only a restricted choice of FO and an ensemble of present degrees of loudness. In human voice, by contrast, resonances, oscillator characteristics, and loudness can all be continuously varied. This puts exceptionally high demands on the control of these parameters on the part of the singer (Sundberg et al., 1995).

One of the aspects of relevance to the aesthetic quality of singing is control of FO. As listeners of music, we all seem to have very precise demands as to the singer's matching target pitch. Singers also need to develop a precise control over the subglottal pressure to control pitch change (Sundberg, et al.1995).

A singer should begin a sound with prior thought and a proper attack, and at the same time be able to maintain a tone of constant loudness and pitch (Kirchner, 1970).

The control of vocal intensity, pitch, subglottic air pressure and rates of airflow involves a highly complex coordination of mechanism operating within the larynx and the rest of the respiratory system. If coordination of these forces is not precise, then vocal problems ensue (Bunch, 1982).

Each individual has a distinct pitch or natural frequency which suits his system the best. Singers needs to be very careful in choosing their pitch for singing; a mistake may cause the singer to sing in a pitch range that is inappropriate to her/his vocal folds

and vocal tract which may lead to lack of success and even voice problems (Berndtsson and Sundberg, 1994).

In singing, it is common for untrained but professional singer to attempt to use tones at the extreme limits of their range, either too high or too low which leads to damage to the vocal structures in the long run (Proctor, 1980).

Though, other factors like correct posture, breathing pattern and articulatory factors also play a role, pitch has been found to be one of the major determining factors that decide how effectively the singing voice is projected; and the wrong usage of which is most prominent.

INDIAN STUDIES

Considerable research has been carried out in the Sangeeta Research Academy, Calcutta on Hindustani Music. Carnatic Music still has not been studied much.

(Rao and Atre (1989) carried out experiments to analyse the 'aalap' section of raaga 'Bhimpalasi' sung by two well known singers. They observed that (a) the descending movements of notes were much smoother and direct when compared to their ascending movements, (b) notes perceived to be steady by a trained listener showed significant fluctuations in frequency, and (c) melodic contours of a given note varied with a change in melodic context and with application of different embellishments, consonants or vowels.

Suvarnalatha and Biswas (1993) studied the consistency of intonation in Raaga 'Yaman'. They found that factors like element of improvisation, individual style and school etc. tend to induce an element of variability in the raaga exposition. Results showed that in a performance of a given raaga, musicians do conform to particular pitch values. The basic tenets comprising the rigid core structure of the raaga remains unchanged while the variant factors operate at a peripheral level without disturbing the core structure.

A few studies in Carnatic music have been carried out at AIISH.

Sheela (1974) compared vocal parameter of trained and untrained singers. She compared the optimum frequency, the FO of speaking and singing voices for phonation, pitch range and vital capacity. Singing FO was acquired by asking the singers to phonate the vowel /a/ in their singing pitch. She concluded that trained singers use their optimum frequency whereas non-singers do not while speaking. Trained singers do not use optimum frequency while singing.

Gupta (1984) studied the off-pitch phenomenon in Carnatic music. He found that most of the trained singers go off-pitch at the highest and above octave range and at the lowest and below octave range. He also concluded that the tendency to go off-pitch does not decrease or increase either with age or the number of years of training.

Ragini (1984) carried out acoustical analysis of singing voice. Sample included reading, recitation and singing of a poem. She studied range of FO, FO segment duration and vowel duration. She did not find any significant difference between the FO and FO range for the above three conditions.

Sujatha (1987) studied singing voice for different acoustical parameters and she reported of significant difference in mean FO between reading, singing octave range and singing song among trained singers. Singers tended to use higher FO for singing than for reading.

Vijaya (1992) evaluated the FO selection of seven notes of Carnatic music and reported that human vocal system is capable of producing notes which bear complex ratios with one another.

An analysis of the studies in Indian music show that there are still areas where information is lacking. Though different aspects of speaking, singing and reading have been compared for FO, there are no studies which have investigated the FO level of shruthi which is 'adhara' for all singers.

'Adhara shruthi ' is the fundamental note around which all music resolves. The logic adopted by singers in selecting 'shruthi' is not known, but, we believe that singers would select that level which would enable them to freely traverse to the upper and

lower notes of the raaga in their level. It is our clinical experience that singers who have been coming to voice clinic with voice problems have all tended to use level of 'adhara shruthi' which is higher than FO or habitual frequency expected for their age level. Improper selection of 'adhara shruthi' might be one of the factors in these singers which has led to voice problems. Therefore, the purpose of this study was to investigate the level of 'adhara shruthi' in a group of singers and to compare that-with age related norms. Also, the correspondence between FO of phonation of isolated vowels, speaking FO and level was investigated in two groups of singers controlled for number of years of formal training in music.

CHAPTER 3

METHOD

The purpose of this study was to compare the frequency level of 'adhara shruthi' in a group of vocalists practicing Carnatic system of music, with their speaking and phonation fundamental frequency. Another aim was to compare the phonation fundamental frequency of the singers with that of non-singers.

SUBJECTS

A group of 22 trained singers, of whom 7 were below 13 years of age and 15 were above 13 years, participated in the study. Singers, below the age of 13 years had a mean age of 12.23 years (range : 11 to 13 years) while those above 13 years had a mean age of 27.26 years (range : 14 to 47 years). The mean age of the entire group was 22.5 years (range : 11 - 47 years). When singers were classified in terms of number of years of training, there were 9 with less than 6 years of training and 13 with greater than 6 years of training.

A further criterion for the selection of singers in the study a was that they should have had at least 3 years of formal training in the Carnatic music. The singers selected had, on an average, 10 years of formal training in music.

Along with this, a group of nonsingers (who have had no training in music or those was were not even interested in music), numbering 54, also participated in the study. Though, we had well-formed age and gender matched nonsinger population, between-group comparisons (for example, singers aged less than 13 years with nonsingers aged less than 13 years) were not carried out.

Subject Selection Criteria

Only those subjects who had no history of any vocal pathology, hearing loss or any pathology of upper respiratory tract at the time of recording and who had a minimum of 3 years of training in Carnatic classical vocal music were selected for the study. A criterion for selection of nonsingers was that they should not have had any training in music. All subjects selected were females, as male and female singers will have different FO.

MATERIAL

a) *Spontaneous Speech*

A sample of spontaneous speech of 3 minutes duration was recorded from all the subjects. The topic of speech was kept the same for all the subjects to maintain uniformity in the sample.

b) Phonation

Phonation of /a/, in isolation, of at least 5 seconds was recorded thrice.

c) Singing

Singers were asked to render the ascending and descending notes of the raaga "Shankarabharana" in their voice which they use for their concerts and practice. The notes of this raaga are as follows:

Sa Ri_2 Ga_3 Mai Pa Da_2 Ni_3 Sa

Sa Ni_3 Da_2 Pa Mai Ga_3 Ri_2 Sa

The choice of the raaga "Shankarabharana" was made because it is the most common of the raagas in Carnatic music. Otherwise, it is not of any significance because 'adhara shruthi' which is usually the first note in the mid register is the same, irrespective of the raagas.

PROCEDURE

Samples were recorded in a quiet set-up with minimal noise and recorded on a portable mini disc recorder (Sony MZ-R3) with the AIWA stereo microphone. The singers were encouraged to speak about themselves and their music training. In this manner, a sample of at least 3 minutes duration was recorded. The singers were asked to phonate the vowel /a/ three times. They were asked to sing the ascending and descending notes of the raaga 'Shankarabharana'.

Similarly, the non-singers were asked to phonate the vowel /a/ three times and, for a sample of spontaneous speech, was asked to speak about themselves and their studies for at least three minutes. Microphone was kept at a uniform distance of about 6 - 8 cms. from the mouth for all the subjects.

The subjects were not told about the purpose of the study. Recording order of different types of samples was counterbalanced for each group of subjects (Singers and non-singers). A qualified singer with 25 years of experience in Carnatic music later attested the correctness or otherwise of the intoning of the notes of the raaga 'shankarabharana' by all the subjects.

ACOUSTIC ANALYSIS

The recorded voice samples of speech, phonation and singing of notes were directly fed from the digital recorder to the Dr. Speech Clinic Software (Huang, 1988) for analysis of voice and speech on a Pentium ID PC. The required speech sample was highlighted and selected on the window and FO for a direct extraction of FO. The FO of 'Sa' at the beginning and the end of the scale of the arohana was noted. The middle sample of the phonation of vowel /a/, in isolation, was always selected for acoustic analysis. The analysis set-up parameters for FO extraction were as follows:

Sampling frequency	11025 Hz
Pitch analysis setting- Low limit	65 Hz
- High limit	1200 Hz
Low pass filter	7
Spectral analysis - FFT (points)	1024

STATISTICAL ANALYSES

All statistical analyses was carried out on the SPSS statistical package version 7.5 on a Pentium IE. Basically, significance of difference of means at the 5% confidence level was computed for the following :

a) Difference in mean Fo for phonation and frequency level of 'adhara shruthi' in singers as a whole group.
b) Significance of difference of mean FO for phonation and frequency level of 'adhara shruthi' in the two groups of singers (< 13 years and >13 years), separately (within-group).
c) Significance of difference of mean FO for phonation and frequency level of 'adhara shruthi' in the two groups of singers (< 6 years of traning and > 6 years of training), separately (within- group).
d) Similar analysis as in (a) to (c) above with singers, but with respect to speaking FO and 'adhara shruthi'.
e) The significance of difference of means between'adhara shruthi' and the 'Sa' at the end of arohana. For example, if the 'adhara shruthi' was 205 Hz and the 'Sa' at the end of the register was 415 Hz, then the comparison was between 'adhara shruthi' and ['Sa' at the end of the arohana - 'Adhara shruthi']. In the above example, 205 Hz and 210 Hz (415 Hz - 205 Hz).
f) Significance of difference in mean FO of phonation between singers and nonsingers.
g) Significance of difference in mean speaking FO between singers and nonsingers.

CHAPTER 4

RESULTS

The study aimed at investigating whether Indian classical music vocalists use their habitual frequency as their 'adhara shruthi'. Also the relationship between speaking FO and 'adhara shruthi' level was investigated. These comparisons were made taking singers as a group. A further comparison between two groups of singers controlled for number of years of formal training in music was also carried out.

SINGERS AS A GROUP

(i) Phonation FO and 'Adhara shruthi'

Paired sample statistics were applied. The results of the analysis are given in Table 1 which showed that the phonation FO and frequency level of 'adhara shruthi' were significantly different at the 0.05 confidence level. The results in Table 1 show that the singers, all females here, as a group employed a lower shruthi level compared to their phonation FO.

	N	Mean	SD	t	p
Phonation FO in Hz	22	216.61	24.03	3.32	0.001
Adhara Shruti in Hz	22	197.54	9.82		

Table 1 : Mean, standard deviation (SD) and the results of the test for significance of difference of means, between phonation F0 and level of 'Adhara shruthi'in singers as a group.

(ii) Speaking FO and Adhara Shruthi

The mean speaking; FO and the mean frequency of adhara shruthi were significantly different (Table 2) for singers as a whole. The difference in means was statistically significant at 0.05 level with the singers employing a lower FO for their shruthi compared to speaking FO.

	N	Mean	SD	t	p
Phonation FO in Hz	22	226.81	24.03	5.21	0.001
Adhara Shruti in Hz	22	197.54	9.82		

Table 2 : Mean, standard deviation(SD) and the results of the test for significance of difference of means, between speaking F0 and level of 'Adhara shruthi' in singers as a group.

(iii Singers with Varying Durations of Training

Two groups of singers, one group of 9 singers with less than 6 years of training in music and another group of 13 singers with training of more than 6 years were compared for phonation F0, speaking F0 and levels of adhara shruthi. The results of the comparison are shown in Table 3

	N	Mean	SD	t	P
A. Singers with less than 6 years of training					
Speaking FO	9	240.11	22.80	6.40	0.001
Adhara Shruti	9	194.11	11.46		
Phonation FO	9	214.88	26.52	2.10	NS
Adhara Shruti	9	194.11	11.46		
B. Singers with greater than 6 years of training					
Speaking FO	13	217.61	24.13	2.71	0.01
Adhara Shruti	13	199.92	8.13		
Phonation FO	13	218.15	23.16	2.47	0.01
Adhara Shruti	13	199.92	8.13		

Table 3 : Mean, standard deviation (SD) and the results of the test for significance of difference of means, between phonation F0 and level of 'Adhara shruthi' speaking F0 and 'adhara shruthi' in singers based **on number** of years of training.

The results in Table 3 indicated that both groups of singers employed a lower level of adhara shruthi compared to speaking F0 and the difference was statistically significant at 0.001 confidence level. However, while the singers with less than 6 years of training did not show a significant difference between the mean F0 for phonation and adhara shruthi ($t = 2.101$; $p>0.05$), the singers with greater than 6 years of training showed a statistically significant difference ($t=2.257$; $p<0.05$) between F0 for phonation and 'adhara shruthi'.

SINGERS GROUPED FOR AGE

As the singes selected in this study range in age from 11 to 47 years, and as we know that, at the time of puberty, the frequency of voice falls by about a note even in females, a comparison was carried out to find out if chronological age is a factor in the relationship between phonation FO and frequency of 'adhara shruthi'. The singers were classified into two groups, one group with singers aged 13 years or less (roughly the age of puberty) and the other group with singers older than 13 years. The results of the comparison are given in Table 4.

	N	Mean	SD	t	P
A. Subjects aged less thanl3 years					
Speaking FO	7	240.88	17.64	-8.04	0.001
Adhara Shruti	7	195.85	11.43		
Phonation FO	7	216.00	26.16	1.672	NS
Adhara Shruti	7	195.85	11.43		
B. Subjects aged greater thanl3 years					
Speaking FO	15	222.53	26.87	-3.102	0.001
Adhara Shruti	15	198.85	9.30		
Phonation FO	15	217.20	23.92	2.814	0.001
Adhara Shruti	15	198.85	9.30		

Table 4: Mean, standard deviation(SD) and the results of the test for significance of difference of means between phonation F0 and adhara shruthi, speaking F0 and 'adhara shruthi' in singers based on chronological age.

The results in Table 4 showed that singers les than 13 years have their 'adhara shruthi' at the same level as that of their phonation FO (t = 1.672, p>0.05). However, difference between mean speaking FO and 'adhara shruthi' for the group was significantly different (t = -8.04, p<0.001). In the case of singers aged more than 13 years, the difference in mean phonation FO and 'adhara shruthi' as well as between mean speaking FO and 'adhara shruthi' was statistically significant. The frequency level of 'adhara shruthi' was lower compared to their speaking and phonation FO.

SINGERS AND NONSINGERS

Singers were compared to nonsingers for speaking FO and phonation FO. The results of the comparison are shown in Table 5. The results indicated that singers had a lower speaking as well as phonation FO compared to nonsingers. This difference in means with respect to both speaking and phonation FO was statistically significant (P<0.001). One-sample statistics was used to compute 't'- values.

	N	Mean	SD	t	p
Speaking FO					
Singers	22	226.81	25.67	4.45	0.001
Nonsingers	54	255.61	30.75		
Phonation F0					
Singers	22	216.81	24.03	4.10	0.001
Nonsingers	54	236.55	21.82		

Table 5 : Mean standard deviation (SD) and the results of the t-test for significance of difference of means between singers and nonsingers with respect to phonation and speaking F0.

Octave Range

As a secondary objective, whether or not the singers traverse an octave from their 'adhara shruthi' to the higher 'Sa' at the end of the aarohana was investigated. The results of 't' score analysis for the significance of difference of mean frequency levels of adhara shruthi and the higher 'Sa' are given in Table 6. The 'sa' to 'Sa' mean frequency of 191.09 corresponds to the mean of

Frequency of the highest 'Sa' in arohana - Frequency of adhara shruthi

	N	Mean	SD	t	P
Adhara shruthi	22	197.54	9.82	2.075	0.05
S a - Sa	22	191.09	17.77		

Table 6: Mean, standard deviation and the results of the test for significance difference of means between adhara shruthi and (Sa - Sa)

The results indicated that singers as a group do not exactly cover an octave from shruthi to highest 'Sa' and the difference was statistically significant at 0.05 level (t = 2.075). Generally, the singers end up traversing less than an octave from their shruthi.

CHAPTER 5

DISCUSSION

This study was carried out with the aim of comparing the 'adhara shruthi' and the speaking and phonation Fo of the singers. In other words, the aim was to see if the vocalists of Carnatic music employ their habitual FO as the level of 'adhara shruthi'. The speaking and phonation FO of singers was also compared to that of non-singers.

As a secondary goal, we investigated if the vocalists cover an entire octave when rendering the arohana of a raaga (between the base 'Sa' or 'adhara shruthi' and upper 'Sa') in the mid register.

Singers as **a Group**

For both the conditions, that is, when speaking FO was compared to 'adhara shruthi' and when phonation FO was compared to 'adhara shruthi', it was found that 'adhara shruthi' was different and considerably lower than the other two as shown in Tables 1 and 2. This could be because, in most of the raagas, vocalists need to sing more in the higher range than in the lower range. Even if they have to sing the lower notes it would be for a lesser extent when compared to the frequency and duration of higher notes. In other words, a female singer, by keeping their 'adhara shruthi' at a lower level in relation to their natural phonation FO, would be able to intone the notes of the higher frequency with some facility. It would seem correct to say that starting at a lower 'adhara shruthi' (say 200 Hz), singers would find it easier to sing the higher 'Sa' at the

end of mid register at 400 Hz and then to intone 'Pa' in the high register at 450 Hz or so. On other hand, if female singers keep their 'adhara shruthi' at the level of their habitual (phonation FO) frequency (say around 230Hz), then singing higher 'Sa' in the mid register at 460 Hz and the higher 'Pa' in high register around 510 Hz would be very difficult. Singers are usually expected to cover about 2 octaves from 'Pa' in the low register to the 'Pa' in the high register in their singing of different raagas.

A fact that should also be recognised is that singers may consciously adopt low level of shruthi because, in their perception, it would facilitate them to intone higher notes. However, they may find it more difficult to intone notes below the shruthi from their already low level of shruthi. Either way, singers may develop voice related problems sometimes in the career.

The observation that FO of 'adhara shruthi' in singers was significantly lower than their speaking FO is not much of significance in itself. Speech is complex and it encompasses a whole array of frequencies and its mean FO is bound to be high.

There are really no studies of this nature in Indian music to attempt a comparison of results. Ragini (1986) compared the mean FO levels in reading, reciting and singing tasks in a group of trained singers while Sujatha (1989) compared the mean FO levels during reading, singing in an octave range, and singing a song.

In Indian music, oral tradition significantly influences the education, performance, creation, appreciation as well as propagation of music. Pupils of Indian music are highly influenced by their teachers irrespective of the age at which they start their music lessons. Another variable playing a role in the selection of 'adhara shruthi' could be the model 'adhara shruthi' given by their music teachers.

In the Indian tradition, music lessons are started at a very young age. It is not uncommon to see young children of even 3 to 4 years being initiated into classical music. It may not be entirely correct to say so, but, more often than not the frequency level of 'adhara shruthi', particularly young children, are modelled by the teacher in the Indian tradition. It may be a slightly different scenario with respect to music pupils of an older age, particularly, those were initiated into music after the age of 13 or 14 years, or in their young adulthood.

During the course of analysis, it was noticed, that singers even below the age of 13 years had a mean FO of 'adhara shruthi' as 195 Hz whereas their speaking FO was around 240 Hz. This clearly supports the view that teachers play a major role in the selection of the 'adhara shruthi' of their pupil.

Another reason why a female vocalist may select a lower 'adhara shruthi' could be that classical music demands a well projected loud voice. It may be the perception of a female vocalist that she may achieve this by selecting a slightly lower 'adhara shruthi' than her natural / habitual FO. It is recognised here that the explanations given here are

highly hypothetical and that there is no direct evidence for the reasoning put forward. But, it is probable.

The habitual FO of singers those below 13 years and above 13 years, was significantly less than their nonsinging counterparts. It is indicates that somehow singers or singer trainees tune their vocal mechanism for a voice with slightly lower frequency, and that it is necessiated by their singing.

It is well known that singers constitute one of the major groups among the professional voice users, that is, those individuals who are directly dependent on their vocal communication for their livelihood. In fact, Koutman and Issason (1997) classified singers as 'elite performers'. Singing involves a more prolonged and sustained production of voice than in speech which is a series of transient sounds. Singing undoubtedly involves a more sophisticated and controlled production of voice. It follows, therefore, that singers particularly those who have not received a sound vocal education, are more susceptible to voice problems. Singers who in their singing use a voice which is not natural to their mechanism or which is not their habitual voice, run the risk of developing a voice problem. It is in this context that the results of this study are useful in educating the singers.

Singers with Varying Duration of Training

Analysis of singers with varying durations of training was carried out in order to investigate whether number of years of training is a variable in the selection of 'adhara

shruthi'. It was found that irrespective of the number of years of formal training in classical music, the 'adhara shruthi' remained lower than the speaking FO. However, while the 'adhara shruthi' was significantly lower than phonation FO in the case of singers with more than 6 years of training, there was no difference between FO for phonation and 'adhara shruthi' levels in the case of singers with less than 6 years of training. This result implies that in the beginning of the training, the singers use only one level voice, but, as their training continues and they become more and more aware of the nuances of music (perhaps), they start making slight adjustments in their voice to meet the new requirements.

The observation that there was no significant difference between mean phonation FO and mean 'adhara shruthi' can also be explained as follows :

It was observed by the experimentor that pupils with less than 6 years of training, when asked to phonate the vowel /a/, tended to phonate it at the level of their 'adhara shruthi' unconsciously, where as this was not much noticed with singers who had undergone a greater number of years of training. From this observation it may inferred that as the vocalists undergo more and more years of training, they attain more control on their pitch mechanism.

Singers and Nonsingers

Speaking FO and phonation FO of singers and nonsingers was compared. Both the groups were age matched. It was found that singers have a lower speaking and phonation FO when compared to nonsinger groups. This difference in means was significant at 0.01 confidence level.

This result implies that singers tend to use a lower FO for speech. As the subject groups were controlled and matched for a host of factors which may have an impact on vocal behaviour, and as the only aspect that was different between the groups was singing, it can be surmised that the factor of singing was somehow responsible for the difference between the groups in speaking and phonation FO. Whether or not the difference in the size of the samples (nonsingers = 54; singers = 22) had any effect on the final results needs to be considered in interpreting these results.

Octave Range

As the data was available, we investigated if a vocalist truly covers a range of one octave between the lower 'Sa' and a higher 'Sa' in the arohana of a raaga.

The mean of the difference between the lower 'Sa' and upper 'Sa' was compared with the mean frequency of 'adhara shruthi'. A statistically significant difference was found indicating that, most of the time, singers do not cover an entire octave range. Sometimes, they cover less, sometimes more. The standard deviation for higher 'Sa' was very high indicating high variability.

There is one study (Vijaya, 1994) which reported indirectly on the octave frequency levels. (Vijaya, 1994) Two female singers in the study failed to cover an octave from their 'adhara shruthi'. In general, they fell short. However, the subjects in the study of Vijaya (1994) were not singing the notes of a raaga 'Shankarabharana' like here, but were singing the different notes in the low, mid and high registers.

A plausible explanation for this is that an ability to cover an octave from shruthi depends on the number of years of training that a musician has had. However, examination of the data reveals that it is not a valid explanation. It may be mentioned here that singers selected in the study had training ranging from 3 to 37 years. A visual inspection and comparison of the data pertaining to vocalists with lesser number of years of training and vocalists with more number of years of training did not reveal any perceivable difference among the two groups of vocalists. In other words, inability to sing an octave in a raaga, from the 'adhara shruthi' level was a common feature for all the singers, and that it was not a function of number of years of training. It may be noted that inability to hit a particular level of frequency in a given note, in relation to the 'adhara shruthi', will be immediately perceived by the musicians to be an 'apaswara' (swara-melodic and appropriate; apaswara - swaras not appropriate in the given raaga). Such singers who are unable to achieve given levels of a note face the danger of being branded as 'bad' vocalists.

This finding may be attributed, again highly hypothetical, but supported by personal experience, to the artistic variations brought about by the vocalist during

singing which enhances the appeal of the piece of music. It is widely recognised than among musicians that vocalists sometimes compromise on the rules of music for the beauty of music, and it is accepted by the music fraternity. Thankfully, musicians who may not be able to cover an octave from their 'adhara shruthi' in a raaga which requires it are not immediately branded as 'bad' singers.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Indian music is a melodious system in which, in contrast to western style of music, singers have a choice in selecting their base pitch for singing. This base pitch is also called 'adhara shruthi'.

When singing, vocalists have to be careful in the selection of their 'adhara shruthi'. The 'adhara shruthi' will, to a large extent, determine the range as well as the facility with which they can cover the notes in the upper and lower octaves. Each raaga in Indian music has a different arrangement and set of notes, but with a different personality. During a performance, an Indian classical vocalist needs to fulfil the demands of each raaga successfully with the same 'adhara shruthi'. Singers face, in addition, the demand of maintaining a good, appealing, projecting and efficient voice for different raagas sung in a single performance.

This study, one of the preliminary attempts at providing empirical data on Carnatic music, aimed at studying the relationship between the 'adhara shruthi' and the speaking and phonation FO in singers who are practioners of Carnatic music. Whether the relationship between speaking FO and phonation FO, on the one hand, to 'adhara shruthi', on the other hand, differs with respect to the number of years of training or with respect to the chronological age was also investigated. A third aim of the study was to compare the speaking and phonation FO of singers to that of nonsingers. As a

secondary aim, the question of whether or not the singers cover a complete octave between the base 'Sa' ('adhara shruthi') and the 'Sa' at the end of the arohana of a raaga was sought to be answered.

A group of 22 trained singers and 54 nonsingers participated in the study. Out of the 22 trained singers, 7 were below the age of 13 years and 15 were above the age of 13 years (13 years roughly corresponds to the age of puberty). On the basis of the number of years of training, 9 subjects had less than 6 years of training and 13 had more than 6 years of training. In the nonsinger group, 21 subjects were 13 years or less while 33 were above 13 years age.

A sample of spontaneous speech and phonation of vowel /a/ was collected for both singers and nonsingers. In addition, the singers rendered the notes of the arohana of the raaga 'Shankarabharana'. The recorded speech samples were analysed using the Dr. Speech Clinic software.

The results of the study indicated that 'adhara shruthi' in singers did not match their speaking or phonation FO. Statistically, the 'adhara shruthi' level was lower compared to phonation and speaking FO. However, when separate analysis was made on groups of singers classified according to number of years of training they had, or their chronological age, the results were slightly different. Phonation FO and 'adhara shruthi' were the same in singers with less than 6 years of training, but different in singers with more than 6 years of training. Speaking FO and 'adhara shruthi' were significantly

different in both the groups. The phonation FO was significantly different in the group of singers compared to nonsingers (lower in the singers).

The observed result that singers employ a lower 'adhara shruthi' compared to their phonation FO has been explained as follows: somehow the singers perceive that starting at a lower 'adhara shruthi' will enable them to intone higher notes easily. There is evidence to show that the model given by the music teachers is a very powerful influencing factor in the selection of 'adhara shruthi' by the singer trainees. It was also found that though, theoretically, a singer is supposed to cover a range of an octave between the base 'Sa' and the upper 'Sa' during the arohana or avrohana of a raaga, singers seldom achieve this. They tend to exceed the octave range sometimes or fail to reach the octave target sometimes. It was observed that this tendency was more common in the case of experienced singers compared to singers with less than 6 years of training. It may be that the experienced singers in the process of incorporating their style and enhancing the appeal of song may be compromising with the theoretical bounds. However, the extent of difference around the octave cannot be totally explained as something related to only the singers style.

Singing pitch is the essence of the song. A wrong pitch selection not only ruins the song and the music concert, but its continued use may ruin the singers voice too.

In Indian culture, where music is considered as equivalent to worshiping God, children at young age are sent for vocal training. Most of the time, the 'adhara shruthi'

selected by their music teacher itself becomes the pupil's 'adhara shruthi'. This selected pitch may or may not be suitable to the pupil. The present study indicates that irrespective of the age of the pupil, they use a low 'adhara shruthi' which is not suitable for his/her system. Continued usage of this pitch may result in voice problems later in life.

The results of the present study provide empirical support to the often observed difference in the pitch employed by singers in singing compared to their habitual or phonation FO. They also provide a basis for the proper vocal education of singers.

Our interaction and experience with singers suggested to us that the female singers adopt a lower 'adhara shruthi' compared to their natural or habitual FO. The results of the present study provides empirical support to the above postulation. Similarly, it is our observation that male singers employ a slightly higher 'adhara shruthi' in relation to their habitual frequency which needs to be experimentally verified.

It has also been observed by many that once 'adhara shruthi' is fixed, at any age, it will continue to be followed throughout singing career. Male singers who are 50 or 60 years old and whose habitual frequency has increased with age, continue to sing at the same level of 'adhara shruthi' which they adopted at the young age. This not only needs to be verified experimentally, but also the long term repercussions, both on their singing and vocal mechanism, needs to be studied. However, many singers do report that they change their 'adhara shruthi' with passing years, but systematic experiments are to be conducted to verify their assertion.

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