COMPARISION OF DYSPHONIA SEVERITY INDEX (DSI) IN TRANIED CARNATIC CLASSICAL SINGERS AND NONSINGERS

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Certificate

This is to certify that this dissertation entitled **"Comparison of Dysphonia Severity Index (DSI) in Trained Carnatic Classical Singers and Nonsingers"** is a bonafide work in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 11SLP018). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This dissertation entitled **"Comparison of Dysphonia Severity Index (DSI) in Trained Carnatic Classical Singers and Nonsingers"** is the result of my own study under the guidance of Dr. M. Santosh, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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Dedicated to Almighty God, Appa, Amma & Loving sisters.

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"Trust in the lord with all your heart and lean not on your own understanding; in all your ways acknowledge him, and he will make your paths straight".

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CHAPTER I

INTRODUCTION

Like any other professional voice users, singers also experience voice problems. Voice problems in singers can be in terms of changes in their pitch, loudness and voice quality. Voice problems in singers can adversely affect their career because slight changes in voice quality can get noticed while singing. Moreover, because of voice problem, singers may not be able to reach their upper or lower end of singing scale. Hence, voice problems in singers need to be identified early and appropriate management needs to be initiated before the voice problem affects the career of singer.

Assessment of voice can be conducted using different approaches. Previously, perceptual analysis of voice was used extensively and was considered as the gold standard for the measurement of voice. This is because perceptual analysis provided the global evaluation of voice of the person (Orlikoff, Dejonckere, Dembowski, Fitch, Gelfer, Geratt, et al, 1999). However, because of its poor reliability, problems in scale validity, and problems with the credibility of the assessment, this procedure was not used alone. Other additional measures such as acoustical analysis of voice have added accountability to the measurement of voice. Acoustic analysis is a non-invasive procedure, which can be used both for voice assessment and for assessing treatment efficacy. Over the years, different multiparametric acoustic analysis procedures have been developed for the quantification of voice (Awan & Roy, 2005; Awan & Roy, 2006; Awan & Roy, 2009; Callan, Kent, Roy, & Tasko, 1999; Frolich, Michaelis, Stube, & Kruse, 2000; Michaelis, Gramss, & Strube, 1997). Dysphonia Severity Index (DSI) is one such widely used measure.

Dysphonia Severity Index (DSI) (Wuyts, De Bodt, Molenberghs, Remacle, Heylen, Millet et al., 2000) is an objective and quantitative measure of voice quality. It has been reported that DSI correlates with the perceived voice quality and is very sensitive to slight change in the voice quality and vocal function (Wuyts et al., 2000). The DSI parameters are relatively easy and quick to be obtained. The Dysphonia Severity Index calculates 4 voice parameters: highest frequency (F0-High in Hz), lowest intensity (I-Low in dB), maximum phonation time (MPT in seconds), and jitter (%). These parameters are measured based on sustain vowel /a/. The values of 4 parameters are obtained and DSI is calculated using the following formula,

DSI = 0.13xMPT (seconds) + 0.0053xFo high (Hz) – 0.26xI low (dB) – 1.18xjitter (%) +12.4

The values of DSI may range from +5 (indicating normal voice) to -5 (indicating severe dysphonia). DSI has been used as a tool to differentiate normal versus disordered voice (Wuyts et al., 2000), to identify the effect of age and gender (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2006), and to document to effect of specific management (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2008) for voice problems. Although DSI has been found to significantly correlate with GRBAS scale (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2008), there was no significant correlation between voice handicapped Index (VHI) and DSI (Wuyts et al., 2000; Hakkesteegt, Brocaar, & Wieringa, 2010).

Hakkesteegt et al. (2006) suggest that extended normative data needs to be established to specific population while comparing DSI values of disordered population with normative data. Jayakumar and Savithri, (2010) provided corroborative evidence for this suggestion. They investigated the effect of geographical and ethnic variation on DSI and found difference in MPT, F0-High, and DSI values for Indian population. Males had higher MPT, lower high F0 compared to females. The MPT was found to be less in Indian population compared to western population. DSI values were less in males compared to females. They also found significant difference in the DSI scores in Indian and European population.

Similarly, separate normative data for specific type of professional voice users, such as singers also need to be established. This is necessary because singers may have better respiratory capacities than nonsingers (Gould, 1977; Large, 1971; Watson & Hixon, 1985), greater F0 range (Troup, 1982; Awan, 1991; Titze, 1994), greater dynamic range (Awan, 1991, Murbe, Sundberg, Iwarsson, & Pabst, 1996) and better breath control (Sulter, Schutte, & Miller, 1995) than nonsingers, Several studies have compared trained and untrained singers using DSI measure (Awan & Ensslen, 2009; Prakup, 2011). Awan and Ensslen (2009) found that trained singers have increased vocal and respiratory capacities and different respiratory patterns compared to nonsingers. Further, trained singers had greater F0 range and greater dynamic range capabilities. Trained singers produced longer maximum phonation duration, greater mean F0, lower intensity and lower jitter compared to the untrained singers. The overall DSI score was found to be more in trained singers. Similarly, Prakup (2011) reported that trained singers voice was perceived to be younger voice compared to untrained singers. DSI was used to measure the trained and untrained singers and found that singers had less jitter and greater intensity measure in DSI compared to untrained singers. However, no statistically significant differences were found between singers and nonsingers regarding F0 or shimmer parameters.

Indian classical singing can be mainly classified into carnatic and Hindustani styles of singing. Among this, carnatic singing is a very complex system that requires much thought, both artistically and technically. Carnatic singing is mainly concerned with the southern part of India. Carnatic music is mainly sung through compositions, called kirtanams. Carnatic singing mainly depends on two aspects 1) Raga i.e. Melody, 2) Tala i.e. Rhythm.

Like Western classical singers, carnatic singers undergo regular training and practice to achieve proficiency in singing. Like any other professional voice users, carnatic singers also experience voice problems. However, because of their increased vocal capabilities, their DSI values may fall within the normal ranges of nonsingers. Hence, there is a need to compare DSI values for trained carnatic singers with nonsingers. For this purpose, present study was planned. The **aim of present study** was t**o compare Dysphonia Severity Index scores in trained classical singers and nonsingers**.

CHAPTER II

REVIEW OF LITERATURE

Singing is an art of producing musical sounds with voice. Singing is a unique way of communicating ideas. Singing is done for different purpose like for pleasure, comfort, ritual, education and profit. For a person to be a good singer they require time, dedication and regular practice toward singing. **Singing is defined as a sensory motor phenomenon that requires particular balanced physical skills (Bunch, 1982).** Singing and Speech are most closely connected as both involve similar ways of voice production. In speech, words are considered, and in singing, lyrics are considered. The principles of good voice production are same in speaking and singing. Many people believe that singing voice is considered as good speaking voice with more prosody and stress patterns in it (Sataloff, 1991).

Even though singing and speech are considered similar yet they differ in terms of their prosodic features (i.e. Para-linguistic acoustic features such as pitch movements, duration, rhythm, etc). While singing singers require more breathe support, quicker inhalation, and longer period of exhalation when compared to speech. Singers follow particular strategies to achieve optimum control of breath, influencing tonal quality, range and dynamics.

Classical singing is an art that a person develops after vigorous training and practice. Singers produce musical sounds known as songs. The vocal characteristics can express different emotions of the song rendered by the trained singers. Singers have a way of combining concept, melody, and text and stage movement and are hence considered artists in the true essence. They are specially trained and can vary their voice including pitch and loudness compared to untrained singers. In general, classical singers undergo regular practice to achieve proficiency in singing and obtain good voice quality. Due to the regular practice, singer's voice quality was reported to be better when compared to nonsingers (Hollien, 1993).

Singers undergo years of training and practice to achieve good singing. Beautiful singing needs seven or more years of arduous practice (Greene, 1972). In the literature, few studies are done to find out whether singing training has any effect on the singers voice quality. Few selected studies are discussed below.

Mendes, Brown, Rothman, and Sapienza (2003), studied the effect of singing training on the speaking voice. They included 14 singing students (12 females, 4 males in the age range of 17-20 yrs) in the study. The participants were students from the University of Florida. Participants were taken from each semester of four groups. The participants were made to phonate vowel /a/ for some duration and then read the Rainbow passage. The acoustic measures which were included are speaking fundamental frequency (SFF) and sound pressure level (SPL). The Perturbation measures included were jitter, shimmer, and harmonic-to-noise ratio. Temporal measures included were sentence, consonant, and diphthong durations. The result of this study indicated that, as the number of duration of training increases, the SFF increases, while jitter and shimmer parameters were slightly decreased. Repeated measure analysis was done which, indicated that none of the acoustic, temporal, or perturbation parameters were statistically significant. The results indicated that singing training has more effect on the singing voice compared to speaking voice. The authors concluded that the duration of singing training has more effect on the voice quality of singers.

Ranjini (2010) investigated the effect of training on the voice of the carnatic classical singers. She compared the voice of 20 trained carnatic and 20 beginning carnatic singers in the study. The trained singers had more than 10years of experience and the beginning singers had less than 2years of experience. The acoustic parameters considered were phonation duration, habitual frequency, and frequency range in phonation, speaking and singing. The MPD, habitual frequency and wide range of frequency in phonation were observed to be higher in the singers group with more than 10years of training. The study concluded that there is an effect of singing training on the voice of the singers in few parameters.

Awan (1991), used phonetogram profile to find out the difference between the trained and untrained singers. In the study 20 trained and 20 untrained young singers were considered. The subjects were asked to phonate the vowel /a/ to obtain the acoustic parameters. The findings of the study showed that trained subjects' phonetogram has large peak in dynamic range. It was also found that the trained singers showed increased capability in terms of fundamental frequency range, minimum, maximum and comfortable SPL production compared to the untrained singers on phonetogram profiles. On the phonetogram, trained singers had greater dynamic range in each of the frequency level and the overall vocal areas were also high compared to untrained singers. The authors noted that trained singers had increased vocal capabilities compared to the untrained singers in the phonetogram profile.

Even though during speaking both singer and nonsingers group use same physiological measures like resonatory, articulatory and respiratory systems but in terms of singing it differs from both the groups. Brown, Hunt, and Williams, (1988) studied physiological differences between trained and untrained singers' singing and speaking voice. Study included 10 professionally trained females with singing experience ranging from 2 to 30yrs and 10 untrained females without any singing experience. The subjects were in the age range of 18-44years. Tasks like intraoral air pressure discrimination and intraoral steady state tasks were carried out. In the results there was no significant difference found between the trained and untrained group in their ability to discriminate or control constant breath pressure. Based on these results the authors came to the conclusion that the professional singer is not physiologically endowed or special gifted power with the voice but they might be higher in the voice parameters due to the effective singing training.

Singing requires certain capacities from the voice source, even though there is good voluntary control over the phonation and music. These capacities can be a desirable range of sound intensity and frequency, which can be measured and represented in a phonetogram. Sulter, Schutte, and Miller (1995) conducted a study to find out differences in phonetogram features between male and female subjects with and without vocal training. They included 224 subjects for the study which included both singers and nonsingers group. Subject's voice samples were analyzed using phonetogram. The results showed that trained singers had larger enclosed area of the phonetogram, which can be due to the soft voice capabilities in males and females. There was significantly larger frequency range in trained female singers. The authors concluded that there is difference between the trained and untrained singers this can be due to greater natural capacities in trained singers or it can be superior learned control over the voice mechanism which is directly related to the measured dynamic and frequency ranges.

Sundberg (1990) aimed to find out whether there is any difference in breathing, phonation and articulation of singers and nonsingers. Six singers and nonsingers were included in the study. The results indicated that there is significant difference in the breathing, phonation and articulation measures between singers and nonsingers. Based on the results, Sundberg (1990) stated that there are great differences in the demands on subglottal pressure control in speech and singing. There is variation in the subglottal pressure produced by singers during singing which causes increased loudness and pitch. In speech, subglottal pressure is used mainly for loudness control, whereas in singing subglottal pressure is required in regard to both pitch and loudness. The singers were able to control both loudness and pitch whereas nonsingers were not able to control pitch. The singers have developed greater independence between the various phonatory parameters. There was a difference between the nonsingers and singers in loud phonation. Many nonsingers were tend to produce reduced peak flow amplitude with increasing fundamental frequency, whereas the singers maintained high peak flow amplitude with increasing fundamental frequency. The study indicated that singers have a higher level of the singer's formant compared to untrained singers. In singers the level of formants increases with loudness, while in nonsingers it does not increase with the loudness. The authors concluded that singers have independent control over breathing, phonation, and articulation. This indicates that singer ideally has capacity to changes those aspects of the tone which are supposed to be changed. Singers and nonsingers differ from each other with respect to their use of voice.

Sheela (1974) studied vocal parameters of the trained and untrained singers. The vocal parameters included were optimum frequency, fundamental frequency in singing and speaking voice, pitch range, phonation time and vital capacity in trained and untrained singers. The study was done on thirty trained and thirty untrained singers in the age range of 19-57years. The results showed significant difference between the trained and untrained singers in the above mentioned vocal parameters. Results indicated that only trained singers tend to use their optimum frequency while speaking compared to untrained singers. Both the groups did not use their optimum frequency while singing. Pitch range was found to be significantly greater in singers than untrained singers. There was no significant difference found in the phonation time and vital capacity between the singers and nonsingers group. Low correlation was observed between the phonation time and vital capacity between the groups.

To summarize, several studies have showed differences between the trained singers and nonsingers in selected voice measures. These results support the point that singers are different from nonsingers in voice measures which can due to their effect of training and also the way that the singers manipulate/control their voice during singing.

Like any other professional voice users, singers may also experience voice problems. Voice problems in singers may cause changes in their pitch, loudness and voice quality. Even though the voice problems of singers are not noticed during speaking, their voice problem may get noticed during singing. Some singers may not be able to reach their upper or lower end of singing scale. This can cause changes in their singing behavior. This voice problem has to be noticed early because it can affect their singing career. However, even though singers experience voice problems, in some instances, it may come between the normal ranges of the untrained singers. Hence, we need to consider voice problem of singers. The voice problem in singers should be noticed early so that their voice problem can be prevented. Voice problem in singers can be assessed using different procedures to find out which voice parameters are affected.

Assessment of voice can be conducted using different approaches. According to European Laryngeal Society, the assessment procedures of voice disorder patients should include Laryngostroboscopy, perceptual voice assessment, acoustic analysis, aerodynamic measurements and subjective self evaluation of voice (Dejoncjer et al 2001; Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2006). Previously, perceptual analysis of voice was used extensively and was considered as the gold standard for the measurement of voice. Perceptual evaluation is the simplest form of description of the sound of voice. This is because perceptual analysis was easy and it provided the global evaluation of voice of the person (Orlikoff, et al, 1999). The perceptual evaluation is the simplest form of description of sound of the voice/voice quality. It provides a global measure of voice quality. Each individual has own internal standard to compare the perceived voice quality (Wuyts, et al., 2000). Although perceptual analysis approach is widely used, the perceptual ratings may vary between the individuals. To reduce the variability between individuals, and to increase the reliability, various rating scales have been created to determine specific aspects of voice quality. Among them one such scale is GRBAS scale.

The 'GRBAS scale' was introduced by Isshiki, Okamura, Tanabe, and Morimoto, (1969); Hirano, (1981). This scale was developed as an effort to explain the psychoacoustic phenomenon of hoarseness utilizing the Osgood semantic differential technique (Wirz, 1995; Hirano, 1981). This scale evaluates five aspects of voice quality G= Grade, Degree of abnormality, R= Rough, irregularity of vocal fold vibration, B= Breathy, Air leakage in the glottis, A= Aesthinic, lack of power, S= Strained, hyper functional state. Here for each parameter a four point scale is used to address the severity ranging from 0 to 3 regarding the severity of each parameter. 0= Normal, 1= Mild, 2= Moderate, 3= Severe.

GRBAS scale is the most widely used scale. Kreiman, Gerratt, Kempster, Erman, and Berke (1993) reviewed 57 different papers selected from the literature that used various approaches to auditory perceptual analysis of voice. Among these approaches, the GRBAS scale has been widely used for judging the disordered voice quality.

Even though perceptual evaluation of voice is important there are several limitations associated with this assessment method which influences the clinical utility. When this procedure is used alone, the limitations include problems with scale validity and reliability, poorly defined/shifting definitions of severity; credibility of the assessment (Awan, & Ensslen, 2009; Orlikoff, et al, 1999). These limitations attempt to explain the voice quality via a temporary auditory impression of the acoustic signal i.e perceptual analysis. Due to these limitations, for the accountability of voice measurement, clinicians and researchers have included perceptual assessment of voice quality with other additional objective measures.

Objective measurements frequently involve instrumentation to quantify the voice quality. They are regarded as less subjective and more reliable method to document the voice characteristics. For objective evaluation of the voice quality several acoustic and aerodynamic measurements like jitter, shimmer, frequency range, harmonics to noise ration and maximum phonation time etc, are used. It is not surprising to find the extensive literature identifying which instrument measures correlate best with perceptual assessment, with the intention of replacing perceptual evaluation to objective evaluation. It is found that multi-parametric measurements which combine several other objective parameters are better to assess the voice quality than the single parameter measurements (Wuyts, De Bodt & Molenberghs, et al, 2000; Yu, Revis, Wuyts, Zanaret & Giovanni, 2002). The multiparametric approach includes different instrumental voice measures, through which there is an ease of differentiating the perceptual severity level of voice (Wuyts, et al., 2000). Recently, researchers have developed different multiparametric acoustic analysis procedures for the quantification of voice (Awan & Roy, 2005; Awan & Roy, 2006; Awan & Roy, 2009; Callan, Kent, Roy, & Tasko, 1999; Frolich, Michaelis, Strube, & Kruse, 2000; Michaelis, Gramss, & Strube, 1997). Dysphonia Severity Index (DSI) is one such widely used objective measure.

Dysphonia Severity Index (DSI) (Wuyts, De Bodt, Molenberghs, Remacle, Heylen, & Millet, et al., 2000) is an objective and quantitative measure of voice quality. It has been reported that DSI correlates with the perceived voice quality and is very sensitive to slight change in the voice quality and vocal function (Wuyts et al., 2000). The DSI parameters are relatively easy and quick to be obtained. The Dysphonia Severity Index calculates 4 voice parameters:

- Highest frequency (F0-High in Hz),
- Lowest intensity (I-Low in dB),
- Maximum phonation time (MPT in seconds),

- Jitter (%).

These parameters are measured based on sustain vowel /a/. The components of DSI form a specific combination of acoustic voice measures that aid in characterizing the various type of vocal dysfunction. The values of 4 parameters are obtained and DSI is calculated using the following formula,

DSI = 0.13xMPT (seconds) + 0.0053xFo high (Hz) – 0.26xI low (dB) – 1.18xjitter (%) +12.4

Each of the parameter in DSI describes the anatomy of the voice production. The first parameter, highest phonation frequency gives information regarding the structural changes of true vocal folds. The second parameter, lowest intensity determines the vocal intensity, in case of vocal fold pathology this will be affected and disturbance in the periodicity of phonation is observed. The third parameter, jitter determines the measure of short term instability which quantifies cycle to cycle variations and has been used to assess the degree of perturbations in the voice quality. The forth parameter is MPT which is a general measure of Phonatory abilities. It reflects the function of several mechanisms necessary for voice production, such as respiratory capacity and control, subglottic pressure, airflow resistance and closure of the vocal folds. This relation between voice characters and DSI was correlated by Wuyts et al (2000).

DSI has been used as a tool to differentiate normal versus disordered voice (Wuyts et al., 2000), to identify the effect of age and gender (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2006), and to document to effect of specific management (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2008) for voice problems. Although DSI has been found to significantly correlate with GRBAS scale (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2008), there was no significant correlation between voice handicapped Index (VHI) and DSI scores (Hakkesteegt, Brocaar, Wieringa, 2010; Wuyts et al., 2000).

Wuyts et al, (2000) first described and validated DSI. They used various acoustic and aerodynamic measurements on 387 subjects in the age range of 18 to 80 years. In addition, each patient's voice was perceptually rated using the GRBAS scale. The DSI was obtained using multiple regression analysis and consists of four weighted variables in the equation. The results indicated an inverse relationship between the DSI and overall severity of Dysphonia. The more negative this DSI is for a patient, the more his or her voice can be regarded as dysphonic. The values of DSI may range from +5 (indicating normal voice) to -5 (indicating severe dysphonia). These authors also noted that DSI is not necessarily restricted to +5 to -5 range.

Hakkesteegt, Brocaar, Wieringa, and Feenstra (2006) investigated the effect of the usefulness of Dysphonia Severity Index (DSI) as an objective multiparametric measurement in assessing Dysphonia. DSI was compared with the score on Grade of the GRBAS scale. They investigated that whether the DSI has capacity to differentiate between a group of patients with voice pathologies and control group. A total of 294 patients with different voice disorders were included in the study. The control group consisted of 118 volunteers without any voice problem. The voices of all participants were perceptually evaluated on Grade, and the DSI was measured. The disordered group with voice complaints had a lower DSI and higher scores on GRBAS scale compared to the control group. The DSI was significantly lower when the score on Grade was higher. The results suggested that the DSI can discriminate between patients with nonorganic voice disorders, vocal fold mass lesions, and vocal fold paresis/paralysis. The authors concluded that DSI is a useful instrument to objectively measure the severity of Dysphonia.

It is well known that voice may change along with the age. Ageing has effect on all the voice parameters. So, studies have been done to see the influence of age and gender on the DSI parameters. Hakkesteegt, Brocaar, Wieringa, and Feenstra, (2006) investigated the age and gender effect on the DSI. The DSI of 118 non smoking adults (69 females, 49 males with age range of 20-70 years) without voice complaints were measured. They concluded that age has significant effect on DSI and its parameters like highest frequency and lowest intensity only in females. There was no significant effect of gender on DSI although it had a significant effect on the parameters like highest frequency and maximum phonation time. The study provided normative data for the male and female groups, separately according to the age and it helps in distinguish between the effects of normal aging and voice disorder conditions.

Jayakumar and Savithri (2010) investigated the effect of geographical and ethnic variation on DSI and evaluated the DSI in Indian population. 120 participants (60 males and 60 females with age range of 18-25yrs) who had G0 on the GRBAS scale participated in the study. The authors compared their results with the previous study by Hakkesteegt, Brocaar, Wieringa, and Feenstra, (2006) and Wuyts et al (2000) on the parameters of DSI. Results showed significant difference between Indian and European population on MPT, highest frequency and DSI values. They explained that reduction of the MPT values lead to the decrease in the overall values of DSI in both the genders. They also found gender difference on DSI with females having higher DSI compared to males. This was in contradiction with the previous study done by Hakkesteegt et al (2006). The results of the study also cautioned voice professionals to reinvestigate and establish their own norms for their geographical and ethnics group.

Neelanjana (2011) Compared DSI and Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) in individuals with voice disorders in Indian population. 50 voice disordered subjects were included in the study. The subjects were in the age range of 20-60 years. Objective evaluation was done using DSI and subjective evaluation was done using CAPE-V. In the results, the mean DSI value for voice disordered subjects in Indian population was found to be -3.52. There was no significant age and gender effect on DSI and CAPE-V measures. The older group was found to be affected more on voice parameters compared to younger group and only jitter showed significant difference between the genders. The results also indicated that DSI (objective measure) and its parameters have good correlation with the CAPE-V (subjective measure) measures. The DSI was found to be lower with higher perceptual score of overall severity of CAPE-V scale in Indian population. It was concluded that DSI can be clinically useful in quantifying dysphonic severity.

Aichinger, Feichter, Aichstill, Bigenzahn, and Schneider-Stickler, (2012) evaluated the reliability of the DSI measurements. They considered 30 subjects (18female and 12 males) in the age range of 19-61years. Among the subjects 12 were without any voice problem and other 18 subjects were with voice problem. Their voice was perceptually rated using GRBAS scale by a speech language pathologist. Voice range profiles of the subjects were measured using two instruments i.e. Ling waves and DIVAS for measuring DSI. The subjects were made to phonate /a/ for the measurements. Results showed that there was great difference between the DSI scores obtained from both the devices. For 95% of the cases the DSI ranged from +2.93 to -2.82 indicating that the difference from both the devices range in between these values. The DSI values obtained in this study were not matching with the Wuyts et al (200) original data. The DSI values obtained from both the devices showed systematic and random errors. Based on this, the authors found that there was disagreement between the DSI obtained from the two devices. They concluded that the DSI measurements were reliable for the calculation of the voice disordered population.

The DSI is also used as an effective tool in management options (Hakkesteegt, Brocaar, Wieringa, & Feenstra, 2008). These authors used DSI and Voice Handicap Index (VHI) as an effective tool to compare pre and post surgery and voice therapy in voice disordered population. They included 171 patients with voice disorders, who had undergone surgery and therapy. The voice quality was measured objectively using DSI. The perceived voice was measured with the help of VHI. Results of the study indicated that DSI and VHI scores improved for those who had undergone voice therapy and surgery. Using DSI the authors observed improvement in the voice parameters. The effectiveness of the voice therapy was measured using DSI and VHI. Thus, DSI and VHI can be used to determine the significant intrasubject result of intervention. The DSI and VHI measure each different aspects of the voice its measurements. Thus, the authors concluded that DSI is applicable in clinical practice for objective evaluation of the voice quality and the VHI for subjective evaluation of the perceived voice quality of the patient itself.

Prakup (2011) studied acoustic measures of the voices of older singers and nonsingers and correlation between acoustic measures and listener judgment of the speaker's age. The study was conducted on 30 (15 male & female) singer group and 30 (15male & female) nonsingers group in the age range of 65-80 years. The task was to sustain the vowel production. Ten speech-language pathology graduate students were selected as listener participants to estimate the age of speakers from the recorded vowel sounds. Results revealed that male and female singer's voice are perceived to be younger compared to the non singers. Between the two groups the difference in the DSI parameters in singers, they had less jitter and greater intensity compared to nonsingers. There was no significant difference found between the singers and nonsingers regarding F0 or shimmer. The perceived age was found to be related to jitter in male singers and nonsingers and female singers. Perceived age was found to be related to intensity in female nonsingers.

Based on all the studies DSI has been considered as a good diagnostic tool to quantify the normal and the disordered population. Few studies have also investigated the effect of age and gender on DSI. However, studies related to effect of singing training on DSI are limited. There is no accurate DSI value for the singers to measure their normal and abnormal voice quality because singer's voice problem may come into normal range of DSI even, if there is voice problem. This is mainly because of their wider frequency range, maximum lung capacity (Awan & Roy, 2005). Awan and Ensslen (2009) compared the trained and untrained singers using DSI measure and also contribute normative DSI data for the trained singers. The study included 30 singers (15male, 15 female) and 36 untrained (12 male and 21 female) participants in the age range of 18-30 years. Results revealed significant differences between trained and untrained groups for three of the four components of the DSI (F0 high; I low; jitter). Trained singers produced longer maximum phonation duration, greater mean F0, lower intensity and lower jitter compared to the untrained singers. The overall DSI score was found to be more in trained singers.

The aim of present study is to compare Dysphonia Severity Index in female trained carnatic singers and nonsingers. Carnatic singing is one of the traditional cultures of Indian classical singing. It is mainly concerned with the southern part of India. Carnatic singing is a very complex system which requires much thought, both artistically and technically. Carnatic music is mainly sung through compositions, called **kirtanam**. Carnatic singing mainly depends on two aspects 1) **Raga** i.e. Melody, 2) **Tala** i.e. Rhythm. These Raga and Tala offers aesthetic and emotional value to the song. As Carnatic classical singers undergo similar training in pitch and loudness gliding, singing at pitch (musical) scales, we can hypothesize that their DSI values will be different from nonsingers.

CHAPTER III

METHOD

Participants

Thirty female carnatic singers in the age range of 18 – 50yrs (mean= 29.35 SD= 10.48) were considered for this study. The selected participants had minimum of 10 yrs or more number of training in carnatic singing. The number of years of training ranged from 10 to 40 (mean=29.33, SD=9.20) years. The singers were actively involved in the vocal training. The mean duration of practice per day was 2.6 hours (SD, 1.66). The mean body mass index for singers was 23.27(S.D, 2.63).Thirty age and gender matched nonsingers were taken as the control group (mean= 29.35 SD= 10.48). The nonsingers had no formal singing/training practice. The mean BMI for non-singer group was 22.38(S.D., 2.56).

Table 1 shows the demographic data of individual singers. Table 2 shows the demographic data for individual non-singers.

Participants in both the groups were assessed for any, speech, hearing, or neurological problems by taking detailed demographic history from them. Only those participants without any speech, hearing or neurological problems were taken for this study. Further, to check for any voice problem, their voice quality was rated perceptually using the GRBAS scale (Hirano, 1981). GRBAS scale is a four point rating scale which is used for the perceptual evaluation of voice quality. On GRBAS scale the parameters are G=grade, R=roughness, B=breathy, A=asthenic, S=strained. The voice quality is rated from 0 to 3 ranging from normal to severe dysphonic voice. The participant's phonation and reading sample were recorded through the Ling Waves instrument

(WEVOSYS). Participant's phonation samples were recorded by asking them to phonate /a/ and they were also asked to read a passage in English. A qualified speech language pathologist rated the voice quality for phonation and reading samples. Only those participants who got score of G0 on GRBAS scale (indicating normal voice quality) were considered for the study. The selected participants were made to fill a questionnaire which contains demographic details, information regarding vocal training and experience, and medical history. Once the questionnaire was filled by the participants they were explained about the need for the study and also about the task.

Table 1

Demographic details of individual singers

Singers	Age	Training	Practice/day	Medical history	Profession	BMI
1	31	23	2	nil	Music teacher	24.1
2	32	30	1	nil	Researcher	23
3	23	20	1	nil	Student	26.2
4	20	16	2	nil	student	22.5
5	24	20	1	nil	House Wife	19.5
6	22	15	5	nil	student	19.9
7	19	14	2	nil	Student	18.1
8	19	16	1	nil	Student	21.7
9	20	15	1	nil	Singer	23.7
10	24	18	2	nil	Student	23.4
11	18	11	2	nil	Student	21.3
12	19	14	1	nil	student	21.5
13	20	14	1	nil	student	23.8
14	23	12	2	asthma	Working	20.4
15	34	18	1	nil	student	21.7
16	48	40	8	h/o FC	Music teacher	23.9
17	35	20	1	nil	Singer	24.5
18	34	27	2	nil	Singer	23.7
19	22	10	2	nil	Student	22.7
20	21	15	1	h/o FC	Student	23.8
21	41	33	2	nil	Artist	21.9
22	45	44	5	nil	Music teacher	23.8
23	43	33	2	B.P	Singer	27.1
24	47	40	6	diabetic	Music teacher	25.7
25	48	20	2	cold	House wife	29.6
26	22	12	2	nil	Student	22
27	20	17	2	nil	Student	20.2
28	47	25	1	nil	Student	27.4
29	24	14	2	Cold	Student	22.9
30	35	18	2	nil	Teacher	28.2

Table 2

Demographic details of individual non-singers

Nonsingers	Age	Medical history	Occupation	BMI
1	31	Nil	House wife	23.1
2	32	Nil	Working	23
3	23	Nil	Student	19.8
4	20	Nil	Student	23.4
5	24	H/o cold	Student	20.8
6	22	Nil	Student	19.9
7	19	Nil	Student	18.6
8	19	Nil	Student	21.1
9	20	Nil	Student	20.7
10	24	Nil	Student	21.1
11	18	Nil	Student	21.9
12	19	Nil	Student	21.5
13	20	Nil	Student	19.4
14	23	Nil	Student	20.2
15	34	Nil	Student	20.2
16	48	H/o Cough	Working	22.7
17	35	Nil	Student	22.8
18	34	Nil	House wife	23.7
19	22	Nil	Student	22.9
20	21	Nil	Student	23.8
21	41	Nil	House wife	21.2
22	45	Nil	Working	26.2
23	43	Nil	House wife	26.1
24	47	Nil	House wife	23.7
25	48	H/o B.P	House wife	27.3
26	22	Nil	Student	19.6
27	20	Nil	Student	20.2
28	47	H/o B.P	House wife	27.4
29	24	Nil	Student	20.9
30	35	Nil	House wife	28.2

Instrumentation and Recording Procedure

The data collection was done using Ling Waves instrument (WEVOSYS). The Ling Waves is high quality software hardware unit which analyses human voice. The Ling waves has sound level meter (SLM) with a microphone attached to it. This SLM was placed on a tripod stand, through this stand, the SLM can be adjusted to the patient's mouth level. The Ling Waves software is a combined analysis tool for the measurement of the quantitative (singing/voice range profile) and qualitative voice parameters. It consists of different modules. It has a separate module for the calculation of the DSI parameters.

The recording was carried out in a sound treated room. The noise level inside the room was less than 30 dBSPL. The participants were made to stand and do the task as recommended by WEVOSYS. The microphone was adjusted according to the height of the participant. A distance of 30cm was maintained between the microphone and the participant's mouth to avoid any distortions during recording. The participants were explained about the task and a recorded sample of the task was played back to the participants. The participants were given three trials for each of the task and the average was taken for the calculation of the Dysphonia Severity Index. The following tasks were considered and recorded from each participant.

Tasks

Highest phonation frequency (HF0):

The participants were asked to phonate vowel /a/ from low pitch to high pitch. They were made to phonate at the highest pitch level possible without losing control of the voice, or pitch breaks in between the task. They were also instructed not to use the false voice during the phonation. The highest phonation frequency was recorded in this way. Three trials were given for the task and the average of these trials was taken as the mean value of highest phonation frequency.

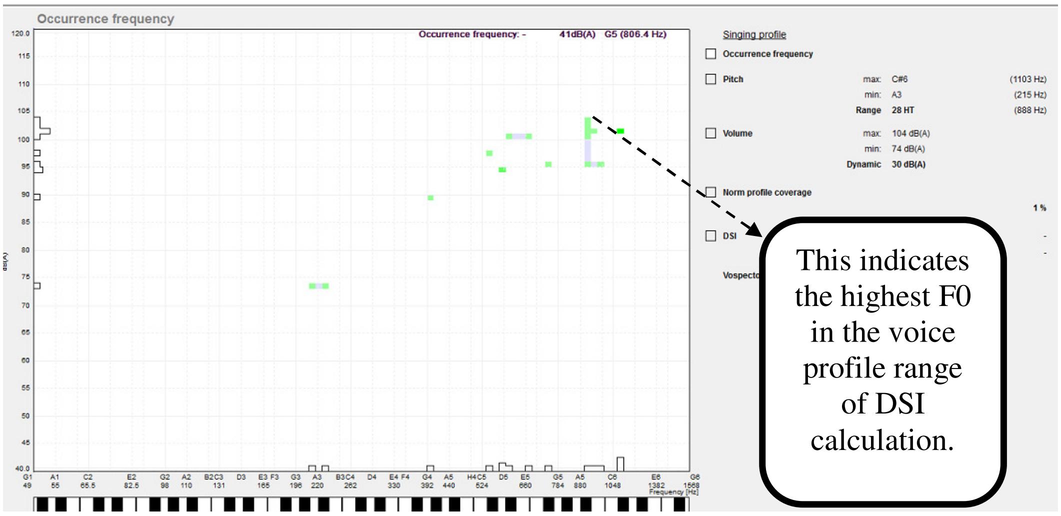

Figure 1, *Picture shows the Highest Fundamental Frequency in DSI calculation.*

Lowest intensity level (I low):

The participants were asked to sustain the vowel /a/ at a comfortable pitch from the softest loudness to the maximum loudness possible. In this way the lowest loudness level was measured. In other way the participant can start phonating at comfortable loudness, pitch and then slowly decrease the loudness level to the softest loud they can go. Three trials were given for the task and the average of these trials was taken as the mean value of lowest intensity level.

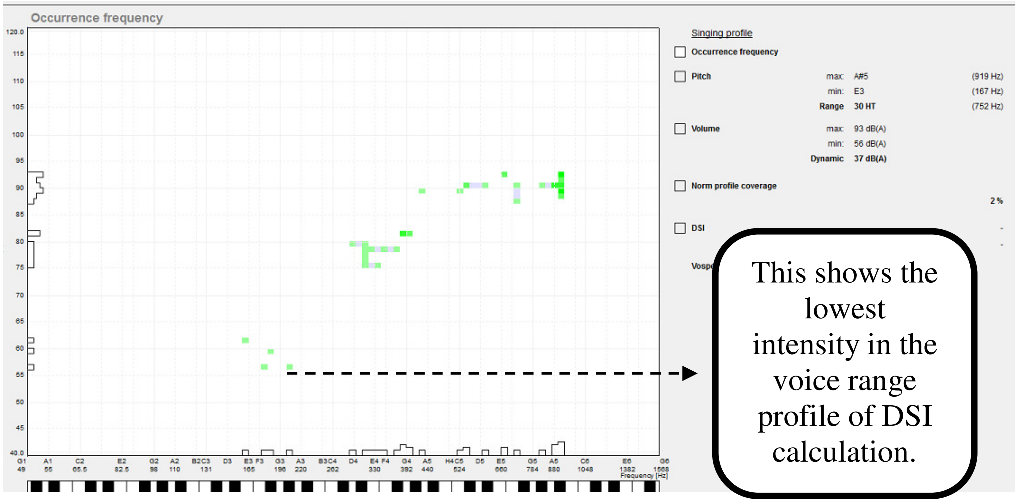

Figure 2, *Picture shows the calculation of lowest intensity in the DSI calculation.*

Jitter:

The participants were instructed to produce sustained phonation of the vowel /a/ at a comfortable pitch and loudness for 2-3 seconds. The selected portion (2-3 seconds) of phonation was used for the jitter calculation. They were instructed not to change the voice in between the task and had to produce it without any pitch breaks. Three trials were given for the task and the average of these trials was taken as the mean value of jitter.

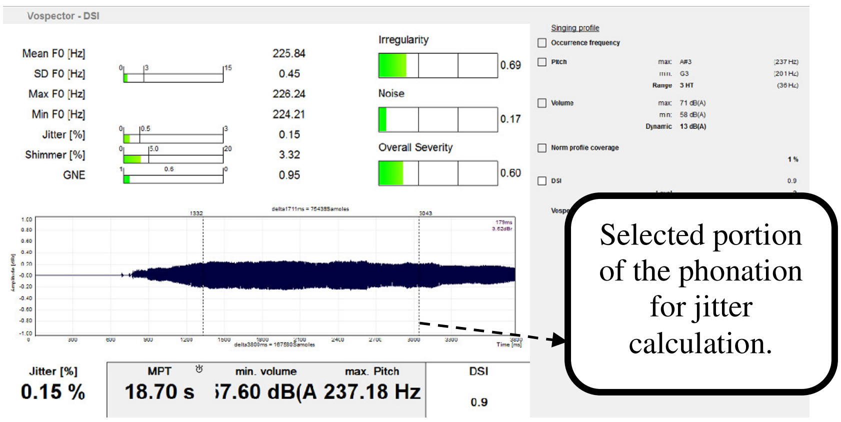

Figure 3, *Picture shows calculation of jitter in DSI calculation.*

Maximum phonation time:

The participants were instructed to take a deep breath/inhale deeply and sustain vowel /a/ as long as possible at a comfortable pitch and loudness. The participants were instructed utilize the maximum amount the air from their lung capacity. They were also instructed not to take breaks in between while phonating. This way the maximum phonation duration was measured. Three trials were given for this task and the average of these trials was taken as the mean value of maximum phonation time.

Using these four parameters the Dysphonia Severity Index is calculated using the following formula.

DSI = 0.13xMPT (seconds) + 0.0053xFo high (Hz) – 0.26xI low (dB) – 1.18xjitter (%) +12.4

Figure 4, *Picture shows the overall calculation of the DSI using its four parameters.*

Statistical analysis

Statistical analysis was carried out using SPSS software (version 17.0). An independent t test was carried out to compare the DSI and its parameters between the singers and the nonsingers group.

CHAPTER IV

RESULTS

The purpose of the present study was to compare DSI and its parameters between the singers and nonsingers. The results of the present study are presented separately for five parameters as mentioned in the method.

Highest fundamental frequency (HF0):

The highest F0 was found to be significantly higher in singers (M=736.5, S.D=192.13) group compared to nonsingers group (M=433.94, S.D=93.72). An independent test was done to find the possible difference between the two groups. The results showed significant ($t\ (58) = 7.753$, $p<0.05$) difference between singers and nonsingers groups. Figure 5 shows the comparison of highest F0 and the range between singers and nonsingers.

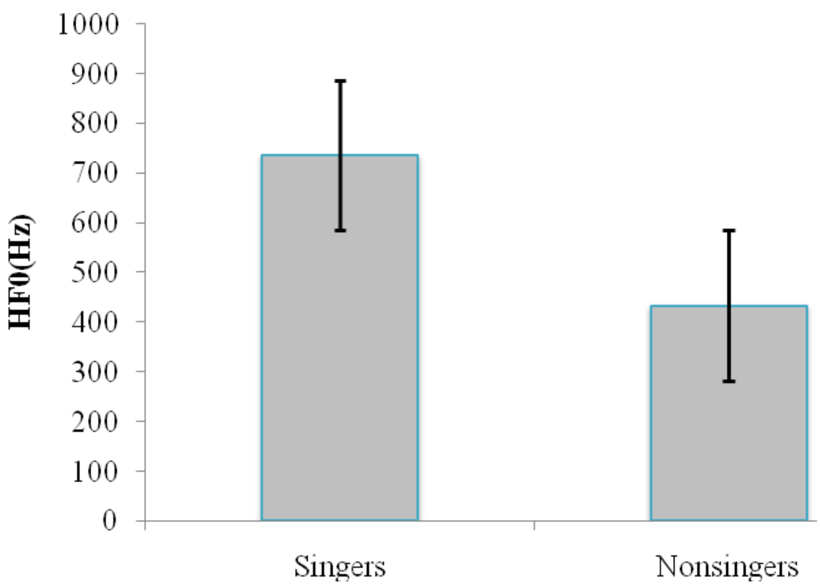

Figure 5, *Comparison of highest F0 (Hz) and the range between singers and nonsingers. In the figure error bars indicate S.D values.*

Lowest Intensity (I-Low):

The mean lowest intensity value was found to be slightly higher in the nonsingers group (M=58.03, S.D=5.56) compared to singers group (M=57.03, S.D=5.68). The results of independent t test showed no significant (t (58) = -0.691, P>0.5) difference between the two groups. Figure 6 shows the comparison of I-Low values between singers and nonsingers.

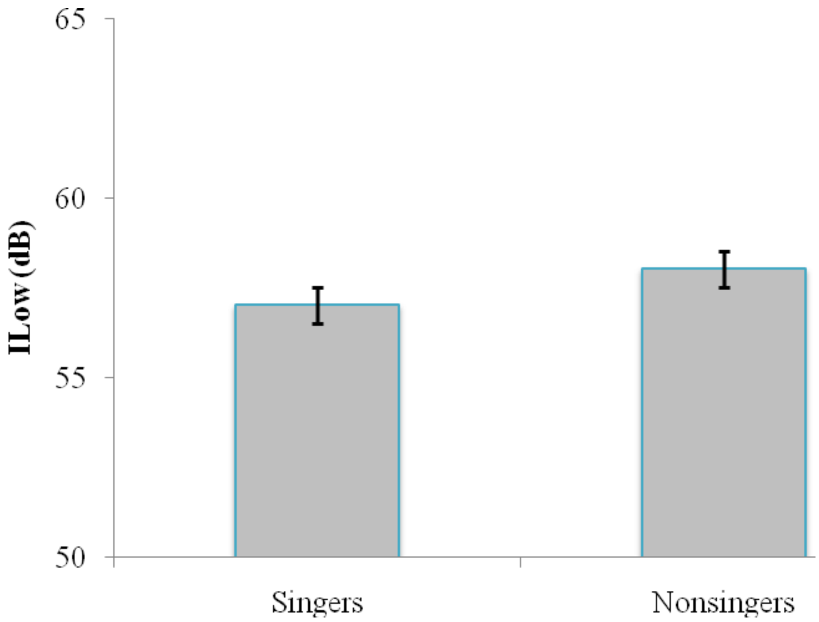

Figure 6, *Comparison of I-Low values between singers and nonsingers. In the figure error bars indicate S.D values.*

Jitter (%):

The mean jitter percent value was found to be slightly higher in the nonsingers group (M=0.1810, S.D=0.318) compared to singers (M=0.1623, S.D=0.0478) group. The results of independent t test showed no significant difference (t (58) = -1.779, P>0.5) between the singers and nonsingers groups. Figure 7 shows comparison of jitter between the singers and nonsingers.

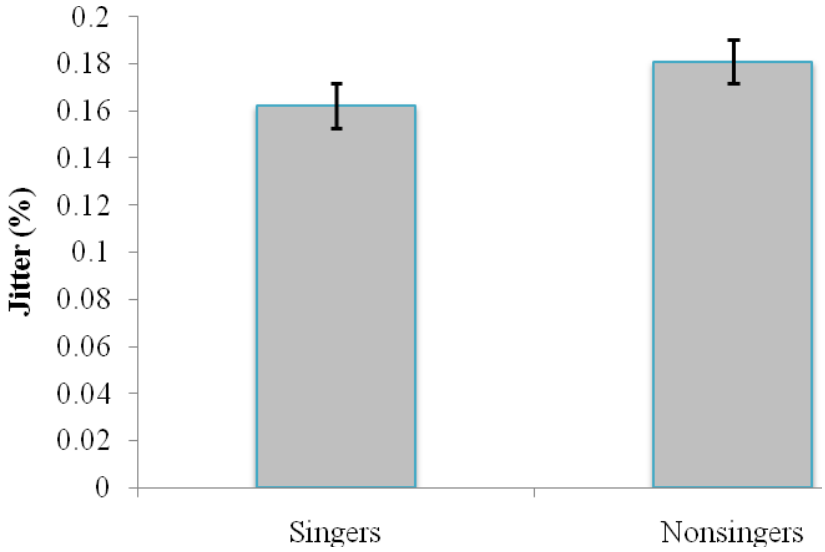

Figure 7, *Comparison of jitter between the singers and nonsingers. In the figure error bars indicate S.D values.*

Maximum Phonation Duration (Seconds):

The mean value of MPD was found to be higher in the singers group (M=15.28, S.D=4.04) compared to the non singers (M=12.87, S.D=1.977) group. The results of independent t test showed significant (t (58) = 2.926, P<0.5) difference between the two groups. Figure 8 shows the comparison of maximum phonation duration (MPD) between singers and nonsingers.

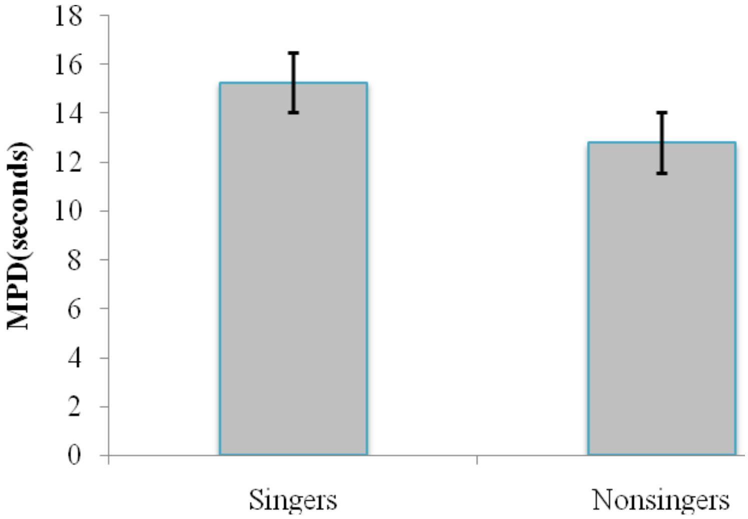

Figure 8, *Comparison of maximum phonation duration (MPD) between singers and nonsingers. In the figure error bars indicate S.D values.*

Dysphonia Severity Index (DSI):

The mean DSI value was significantly higher in singers (M=3.53, S.D=1.68) group compared to nonsingers (M=1.56, S.D=0.9754) group. The results of independent t test showed significant difference ($t(58) = 5.541$, $p < 0.05$) between the singers and nonsingers group.

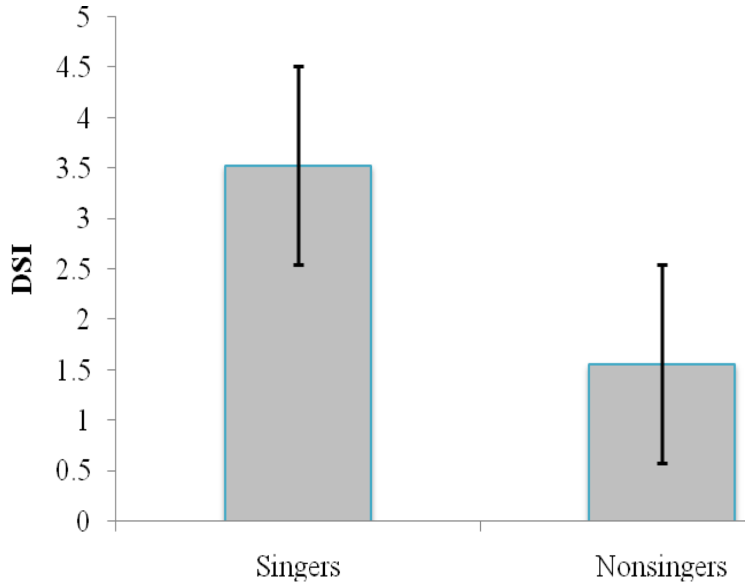

Figure 9, *Comparison of DSI values between singers and nonsingers. In the figure error bars indicate S.D values.*

CHAPTER V

DISCUSSION

The aim of the present study was to compare trained Carnatic classical singers and nonsingers on Dysphonia Severity Index (DSI). The results revealed several points of interest. First, the **mean highest fundamental frequency (HF0) values were significantly higher in singers compared to nonsingers.** Similar results are reported in Western Classical singers. Awan and Ensslen (2009), in their study also they found highest F0 to be greater in both trained male and female singers compared to the untrained male and females. Another study by Awan (1991), also reported higher HF0 in singers using phonetogram. The results showed that trained singers had increased fundamental frequency range compared to untrained singers. The reason for the increased highest F0 in singers can be attributed to the effect of singing training. In Carnatic classing singing training, like Western classical singing, singers go through training for pitch matching, pitch gliding, singing at different pitch (musical) scales. Due to this, singers are able to produce greater frequency ranges and maximum frequencies than nonsingers. In the present study, HF0 values were lower compared to western singers, (Awan & Ensslen, 2009). In Awan and Ensslen study, the mean HF0 value for female trained singers was 942 Hz, whereas in the present study the mean HF0 was 736 Hz. The mean HF0 value for nonsingers was also lower than Jaya Kumar and Savithri (2010) study done Indian population. In Jayakumar and Savithri (2010) study the mean HF0 for nonsingers was 967 Hz. In the present study the mean, HF0 for female nonsingers was 433 Hz. The reason for this variation could be due to differences in the ethnic and physical characteristics of the subjects and also the variation in the recording procedures and the instruments used in the study.

Second, **there was no significant difference between trained singers and nonsingers for minimum intensity (I low) productions**. The mean value of minimum intensity in untrained singers was 58.03dB when compared to the trained singers who had 57.03dB. The present results are in contrast to previous findings reported in the literature (Awan & Ensslen, 2009; Sulter & Meijer, 1996; Awan, 1991; LeBorgne & Weinrich, 2002). These studies have found significantly lower minimum intensity in Western singers compared to nonsingers. The reason for significantly lower minimum intensity in singers compared to nonsingers has been attributed to the effect of vocal training. With vocal training singers develop better abdominal support and greater control over their loudness ranges. Hence, they are able to produce vocal intensities at low levels. The present results suggest that even though Carnatic singers had slightly lower intensities, they were similar to nonsingers. Further studies need to be done to corroborate present findings.

Third, there was **no significant difference between the trained and untrained singers in Jitter (%) parameter.** Present results are in contrast to Awan and Ensslen (2009) results. Awan and Ensslen (2009) found that untrained singers had significantly higher jitter compared to trained singers.

Fourth, **carnatic singers had significantly higher MPD** (15.28sec) **compared to nonsingers** (12.8sec). Caroll, Sataloff, Heuer, Spiegel, Radionoff, & Cohn, (1996) also reported classically trained singers had longer MPD (13.98sec) compared to normals. Ranjini (2010) found singers above 10 years of training had longer MPD (14.10sec) compared to those with less than 2years of training (10.30sec). In contrast Sheela (1974) found no difference between the trained and untrained singers in maximum phonation time. Present results suggest with vocal training singers would have greater respiratory capacity. All the singers in the present study had atleast 10 years of vocal training in Carnatic style of singing. Due to this they have better control over their respiratory capacity, subglottic pressure, airflow resistance and closure of the vocal folds.

The mean MPD values of both groups in present study are significantly lower than those reported in the Western speakers. According to Hirano (1981), MPD in normal males should be 34.6secs and in females 25.7secs. In Indian context this values can vary due to geographic and physical condition of the individuals. Jayakumar and Savithri (2010) found difference in the MPD between the Indian and European population. They found 17.6sec for males and 13.8sec for females. This difference is due to difference in the physical structure (i.e. Body Mass Index) between the groups. Indians vital capacities and lung capacities are reduced compared to Europeans. In India the MPD values again varies between the singers and nonsingers group.

Fifth, the **mean DSI values were significantly higher** (3.53) **compared to** nonsingers (1.56). The results of the study are in support with the study done by Awan and Ensslen (2009). They reported that the DSI to be significantly higher in the trained vocalist group (6.35) compared to the untrained group (4.69). Timmerman, De Bodt, Wuyts and Heyning, (2004) also found that the DSI value was increased in the vocally trained group compared to the untrained group. (Timmerman, De Bodt, Wuyts & Heynin, 2005) Further there was an effect of duration of training on the DSI values, and mean DSI values increased from 9 months to 18 months of singing training. The higher DSI values in trained singers was majorly due to increased highest fundamental frequency (HF0) and longer maximum phonation duration (MPD) which contributed to the overall increase in the DSI value of the present study. The results of the present study have shown that there is difference in the DSI and its parameters between the trained and untrained singers group.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The objective of the present study was to **compare the Dysphonia Severity Index in trained and untrained carnatic singers.** In the present study 30 female trained carnatic singers and age matched 30 nonsingers in the age range of 18 to 50 (mean= 29.35 SD= 10.48) were considered. The singers had minimum of 10 years of singing training and were actively involved in classical singing. The nonsingers had no formal singing practice. Participant's phonation of /a/ and reading samples were recorded and played to speech language pathologist for perceptual evaluation using the GRBAS scale. Those who got G0 on GRBAS indicating normal voice quality were considered for the study. The data recording was done in sound treated room with noise level less than 30dB. The data recording was done using Ling waves software (WEVOSYS). There were four tasks in the study.

- **Highest phonation frequency (F0 high)**
- **Lowest intensity level (I low)**
- **Jitter**
- **Maximum phonation time**

In each of these tasks, three trials were recorded and the average was taken for each task which was used for calculation of the DSI. The results of the present study showed that there was overall increase in the DSI scores in the singers (M=3.53, S.D=1.68) compared to nonsingers (M=1.56, S.D=0.9754). In the specific DSI parameters, there was statistically significant difference for highest fundamental frequency and Maximum phonation time between the singers and nonsingers group. HF0 was significantly higher in singers (M=736.5, S.D=192.13) compared to nonsingers (M=433.94, S.D=93.72). There was no significant difference between the two groups for I-low and Jitter parameters. However, the MPD was found to be significantly increased in the singers (M=15.28, S.D=4.04) compared to nonsingers (M=12.87, S.D=1.977). The present results confirm that there is an effect of Carnatic classical singing training on DSI parameters.

Clinical Implication of the study

- The results of the present study provided normative DSI values for the trained carnatic female singers which can help in assessing voice problems in singers.
- Using DSI it can found that which parameters related to voice quality are affected.

Future direction

- This study can be compared between the male and female singers.
- This also can be done across different age groups of singers.

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