DYSPHONIA SEVERITY INDEX IN PHONONORMIC YOUNG ADULTS USING THE *PRAAT* PROGRAM

Kuncham Celestial Lydia

Register Number: 17SLP020

A Dissertation submitted in part fulfilment of degree of

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University of Mysore, Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI

MYSURU – 570006

MAY 2019

CERTIFICATE

This is to certify that this dissertation entitled "***Dysphonia Severity Index in Phononormic Young Adults using the Praat Program***" is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 17SLP020. 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.

Mysuru

May 2019

Dr. M. Pushpavathi

Director

All India Institute of Speech and Hearing

Manasagangothri, Mysuru-570006

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Mysuru
May 2019

Guide
Dr. Pebbili Gopikishore
Assistant Professor in Speech Pathology
All India Institute of Speech and Hearing
Manasagangothri, Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled "***Dysphonia Severity Index in Phononormic Young Adults using the Praat Program*** " is the result of my own study under the guidance of Dr. Pebbili Gopikishore, Assistant Professor in Speech Pathology, Department of Speech Language Pathology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Registration Number: 17SLP020

Mysuru

May 2019

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CHAPTER I

INTRODUCTION

Assessment of voice can be done using different procedures. The most commonly used procedure reflects a listener's auditory impression on the quality of voice based on a set of listener rating scales (Kreiman & Gerratt, 2010). As perceptual analysis provides global evaluation of voice (Orlikoff, Dejonckere, Dembowski, Fitch, Gelfer, Geratt, Haskell, Kreiman, Metz, Schiavetti, Watson & Wolfe, 1999), it was considered as the 'gold standard' (Kempster, Erma & Berke, 1994; Bodt, Heyning, Wuyts & Lambrechts, 1996; Kent, 1996; Ma & Yiu, 2006; Oates, 2009). However, because of its poor reliability and validity, Orlicoff et al. (1999); Hillman, Montgomery and Zeitels (1997); Ma and Yiu (2006); Oates (2009) have recommended to incorporate both subjective and instrumental measures of clinical voice evaluation. Therefore, complimentary to perceptual evaluation, the objective measures such as acoustic, aerodynamic and imaging techniques add credibility to voice assessment.

A non-invasive procedure, acoustic analysis serves two purposes. During evaluation, it provides indirect evidence of severity of voice problem and at follow-up, it helps to evaluate the effects of rehabilitation plan (Garrett & Healey, 1987; Karnell, 1991; Bielamowicz, Kreiman, Gerratt, Dauer, & Berke, 1993; Titze, 1994; Scherer, Vail, & Guo, 1995). Despite of its usefulness, Awan and Roy (2006) stated that single parametric measures like cepstral and spectral based measures have limited validity for diagnostic outcomes. Felippe, Grillo and Grechi (2006) studied 20 men and 20 women with no signs and symptoms of voice problem to establish a normative for acoustic analysis. They reported that the parameter Harmonics-Noise Ratio (HNR) is not sensitive in differentiating dysphonia from normal voice.

Considering the limited efficacy of the acoustic measures in unison, researchers verified the accuracy of combination of these acoustic measures for assessment of voice. They reported that the use of multiparametric measures are better than the single parameteric measures in evaluating the quality of voice (Michaelis, Frohlich & Strube, 1998; Ouaknine, Ravis & Giovanni, 2001; Hartl, Hans, Vaissiere & Brasnu, 2003). Dysphonia Severity Index (Wuyts, Bodt, Molenberghs, Remacle, Heylen, Millet & Heyning, 2000), Acoustic Voice Quality Index (Maryn, Bodt & Roy, 2010), Cepstral Spectral Index of Dysphonia (ADSV model 5109, Kay PENTAX. Montvale, NJ), etc have been introduced and have proved to be useful in voice research.

Dysphonia Severity Index (DSI) was introduced as a multiparametric measure to establish an objective and quantitative correlate for perceived quality of voice. It has been reported that DSI is susceptible to minimal variations in voice quality and vocal function (Wuyts et al., 2000). The DSI parameters are easy and quickly obtained. A regression equation is developed from the weighted combination of four single parameters namely highest frequency (Hz), lowest intensity (dB), maximum phonation time (seconds) and jitter (percent). The values of the parameters are obtained by calculating using the following formula, $DSI = 0.13 \times MPT + 0.0053 \times F0High - 0.26 \times ILow - 1.18 \times Jitt + 12.4$.

The values of DSI range from +5 (indicating normal voice) to -5 (indicating severe dysphonia). The fact that the DSI is based on voice range, acoustic and aerodynamic measurements makes it a multidimensional, robust, and objective outcome measure for assessing vocal quality. DSI has been used as an instrument to differentiate normal voice from pathological voice (Wuyts et al., 2000), to identify the effect of gender and age (Hakkesteegt, Brocaar, Wieringa & Feenstra, 2006), and to document the effect of specific management (Lierde, Claeys, Bodt & Cauwenberge, 2007; Hakkesteegt, Wieringa, Brocaar, Mulder & Feenstra, 2008). Hence, it would serve as a productive tool for both research as well as clinical practice.

A study done by Rzepakowska, Sielska, Osuch & Niemczyk (2018) revealed a considerable difference between DSI results, acoustic and aerodynamic measures, and the perceptual assessment. Factors such as instrumentation, age and gender were reported to influence the DSI value (Awan, Miesemer & Nicolia, 2012; Jayakumar & Savithri, 2012). Aichinger, Feichter, Aichstill, Bigenzahn & Schneider (2012) measured the inter-device reliability of DSI in dysphonic and non-dysphonic subjects using two devices. A strong disagreement was observed among the two results. In agreement with Aichinger et al. (2012), Rzepakowska et al. (2018) recommended for an initiation of improvements to measure the DSI intended for its common applicability in routine clinical examination.

DSI requires sophisticated and expensive instrumentation which is one of the major drawbacks for using it in day to day clinical practice. Attempts have been made by Maryn, Morsomme and Bodt (2017) to deduce the DSI using the freely available *Praat* (Boersma, 2002) program, in which they reported that DSI can be measured in *Praat* by using DSI formula $\mathrm{DSI}_{\mathrm{BETA}} = -0.14 + 0.140 \times MPT + 0.00450 \times F_0Max - 0.0329 \times IMin - 4.530 \times Jitt_{PPQ}$.

Need for the study

The DSI has been explored on several procedural aspects since its initial publication. Several studies had consistently indicated the efficacy and robustness of the DSI in documenting the quality of voice objectively. Nevertheless, for a generalized application, carrying out the DSI in a high-standard yet freely available program such as *Praat* would benefit all the voice clinicians. In this context, the present study was taken with the aim of documenting the DSI in phononormic young adults obtained using *Praat* program.

Aim of the study

The present study was aimed at establishing the preliminary normative data for the DSI in phononormic young adults obtained using the *Praat* program.

Objectives of the study

1. To document the DSI in phononormic young adults in the age range of 18-34 years obtained using the *Praat* program.
2. To verify test-retest reliability of the DSI obtained using the *Praat* program.

CHAPTER II

REVIEW OF LITERATURE

Voice is an important aspect of communication in the present world. Therefore, any impairment in voice will have greater impact on daily routine and social activities of individuals (Hakkesteegt, 2009). The study of vocal quality was observed since ages (Kreiman & Gerratt, 2010). Voice disorders/ deviance in normal voice can be evaluated subjectively (self rating scales, perceptual scales like CAPE-V, GRBAS, etc. & laryngeal imaging procedures) and objectively (aerodynamic and acoustic measures).

Subjective evaluation of voice

The most frequently used method to measure the quality of voice reflects the listener's auditory impression on a set of rating scales (Kreiman & Gerratt, 2010). Over the years several rating scales for evaluation of quality of voice have been proposed. For instance, the GRBAS protocol (Hirano, 1981) assesses voice for grade (equivalent to overall severity), roughness, breathiness, astheny (weakness) and strain using a four-point rating scale. CAPE-V (Consensus Auditory Perceptual Evaluation - Voice) protocol (Kempster, Gerratt, Abbott, Barkmeier & Hillman, 2009) is another popularly used rating scale for assessing voice. It has a 100-millimeter line forming a visual analog scale for overall severity, roughness, breathiness, strain, pitch, loudness and the presence of other attributes can be indicated under "additional features".

Easy availability and lack of sophisticated instrumentation makes perceptual evaluation feasible to use in the clinical setup. However, the application of the perceptual evaluation is confined to a listener's ability to judge, experience and expertise in the area which makes it susceptible to the variability. Further, the task factors such as phonation/ reading/ spontaneous speech or the conversation also influence the perceptual ratings. For instance, based on variability in sources, the GRBAS scale has drawbacks in professional background and experience of the judges (Bodt, Wuyts, Heyning & Croux, 1997), examiner bias due to knowledge of the patient's history (Wuyts, Bodt, Heyning, Lambrechts & Abeele, 1998) and the type of sample such as running speech versus sustained vowel (Revis, Giovanni, Wuyts & Triglia, 1997, 1999).

The laryngeal imaging provides visible evidence for the users to make visual and perceptual judgements about the appearance, movement and vibratory pattern of the vocal fold and their effect on the production of voice (Hirano & Bless, 1993; Colton, Woo, Brewer, Griffin & Casper, 1995). It gives more information about the severity and possible etiology of the voice disorder. From flexible or rigid endoscopes the clinicians can observe and document the images of the larynx displayed on a monitor in a finer and brighter view. Techniques like Stroboscopy, Kymography, and High speed imaging are used to assess voice disorders. Each device has different advantages and disadvantages (Bless, 1991; Hicks, 1991; Hirano, 1981; Hirano & Bless, 1993). Adequacy and accuracy of the image is dependent on the contribution of factors such as lighting, colour, focus of lens and angle, lens-to-object distance and system resolution (Hibi, Bless, Hirano & Yoshida, 1988). Subject variability is large, so there is critical learning curve to the understanding of what 'normal' looks like. Interpretation of the image involves visual perceptual judgements, which pose threats of bias and poor reliability when correlated with perceptual measures. Not every patient will be able to sustain a task for longer duration. Limitations such as anatomical abnormalities, gag reflex, dysphonia severity, result in lack of task compliance (Hirano & Bless, 1993).

Objective evaluation of voice

Despite the significant role of perceptual and laryngeal imaging in diagnosing vocal pathologies, they lack in providing sensitive and quantifiable objective values which can be compared across the treatment sessions. Objective evaluation uses various instruments and procedures which maybe invasive or non-invasive to measure the voice. It gives an accurate, precise and quantitative measure of voice (Hillman, Montgomery & Zeitels, 1997). As it is considered as less subjective and more reliable technique to record vocal dysfunction, they offer uniformity in diagnostic formulation with respect to different clinicians and different clinical settings. But, objective evaluation requires a financial outlay, frequently accessible only in specialized voice centres and it is a time consuming process. A number of aerodynamic and acoustic measures have been developed to overcome the limitations of perceptual evaluations and to substantiate the subjective findings (Hirano, Hibi, Terasawa & Fujiu, 1986).

Aerodynamic measurements such as subglottic pressure and transglottal airflow assess the physiologic vocal function indirectly and non-invasively. It reveals information about the glottal power, laryngeal resistance, vocal efficiency, laryngeal valving mechanism and others based on the exchange of pressure and flow (Rothenberg, 1973; Hirano, 1981; Bless, 1991; Hicks, 1991; Titze, 1994; Baken, 2000) during vocal fold vibration in a single mathematic ratio (Hirano, 1981; Smitheran & Hixon, 1981; Melcon, Hoit & Hixon, 1989; Titze, 1994). These help to discriminate the normal and disordered vocal function, assess disorder severity and even indicate the etiology of dysphonia. A real-time visual display provided by these measures can be used as primary feedback tools in behavioural voice therapy. It allows comparison across instruments and clinical sites (Holmberg, Hillman & Perkell, 1988; Miller & Daniloff, 1993; Schutte, 1992; Weinrich, Salz & Hughes, 2005). Aerodynamic measures require regular calibration of the instrument due to varying atmospheric pressure and temperature. Even these measures are subject to constraints such as technological error, intra-subject variability and difficulty comparing similar measures collected using diverse recording protocols (Holmberg et al., 1988; Miller & Daniloff, 1993; Scherer, 1991; Weinrich et al., 2005).

There are large and ever-increasing number of acoustic measures. These measures involve procedures such as inverse filtering, auto correlation, spectrum, cepstrum to extract the frequency related measures (eg. fundamental frequency, its range and standard deviation), amplitude related measures (eg. habitual intensity and extent of its fluctuation), perturbation related measures (eg. jitter and shimmer), noise/ harmonic related measures (eg. harmonics to noise ratio) and measure of voice continuity (Hibi et al., 1988; Wolfe, Fitch & Cornell, 1995; Dejonckere & Lebacq, 1996; Picirillo, Fuller, Painter & Fredrickson, 1998). The acoustic parameters serve two purposes. During evaluation, it provides indirect evidence of severity of voice problem and at follow-up, it helps to evaluate the effects of rehabilitation plan (Garrett & Healey, 1987; Karnell, 1991; Bielamowicz et al., 1993; Titze, 1993; Scherer, Vail & Guo, 1995).

Despite its usefulness, these acoustic measures cannot pinpoint the specific etiologies or pathologies (Stemple, Glaze & Klaben, 2010). Lack of clinical and technical standards has also limited the utility of acoustic measures due to variations in elicitation techniques, recording tasks, speech sample lengths and number of samples needed for reliability (Brockmann & Drinnan, 2011). Investigations done by

Karnell, Hall and Landanl (1995) revealed that the fundamental frequency and perturbation measurements when measured using three different analysis system were found to be more consistent when compared to jitter and shimmer measurements. Bough, Heuer, Sataloff, Hills and Cater (1996) reported poor to moderate correlation on investigating inter-device reliability in perturbation measures. Felippe, Grillo and Grechi (2006) reported that the parameter Harmonics-Noise Ratio (HNR) is not sensitive in differentiating dysphonia from normal voice. It is difficult to use the acoustic measures to document the therapeutic and surgical outcomes when a poor correlation with the perceptual measures is observed. Hence, a reliable parameter that correlates well with the perceptual severity of dysphonia is essential. Further, Awan and Roy (2006) stated that single parametric measures like cepstral and spectral based measures have limited validity for diagnostic outcomes.

Considering the limitations of the acoustic parameters reported in the literature, researchers had verified the accuracy of combination of these acoustic measures in evaluating the voice quality objectively. Various studies observed the use of multiparametric measures better than the single parameteric measures in evaluating the quality of voice (Michaelis, Frohlich & Strube, 1998; Hartl, Hans, Vaissiere & Brasnu, 2003). Several multiparametric measures such as Dysphonia Severity Index (DSI), Acoustic Voice Quality Index (AVQI), Cepstral Spectral Index of Dysphonia (CSID), etc have been introduced and proved to be useful in voice research.

Development of Dysphonia Severity Index (DSI)

Wuyts et al., (2000), introduced Dysphonia Severity Index (DSI) as a multiparametric measure to establish an objective and quantitative correlate of the perceived vocal quality from multivariate analysis of 387 subjects. It was established as a mathematical model with a merged acoustic and aerodynamic voice assessment, which had 98.4% accuracy to the ‘Grade’ of GRBAS in the evaluation of the severity of dysphonia. They have assumed this perceptual rating scale as an indicator for the classification. This is because the relationship between pathology and dysphonia is not evident, because a severe pathology does not always strictly imply a severely dysphonic voice and vice versa. Based on the correlations of each of the acoustic-aerodynamic parameters with perceptual rating, these authors developed a regression equation from the weighted combination of four single parameters namely highest frequency (Hz), lowest intensity (dB), maximum phonation time (seconds) and jitter (percent). This regression equation was named as ‘Dysphonia Severity Index’ and the values of DSI ranges from +5 (indicating normal voice) to -5 (indicating severe dysphonia).

The above mentioned four parameters were chosen based on the stepwise logistic regression procedure. Logically the highest frequency (F_0-High) is chosen because, more than 50% of the dysphonic patients have excess mass distributed on their vocal cords which hampers the higher vibratory rates, thereby, reflecting a decreased F_0-High. Consequently, an increased glottal resistance is observed. As greater pressure is required to begin and sustain the vibrations of the vocal cord, an increase in lowest intensity (I-Low) will be seen in these dysphonic patients. Similar effects for F_0-High and I-Low were found in VRP studies of children with vocal nodules (Heyning, Remacle, Cauwenberge, Bodt, Heylen, Raes,... & Pattyn, 1998). A perceived dysphonia will have irregularity in the degree of vibration of vocal cords. The jitter (Jitt) was intended to assess these irregularities as it is likely that a perceived dysphonia will result in an increased perturbation measure. Maximum

Phonation Time (MPT) can be regarded as a phonatory ability measure (Hirano, 1981) that reveals the competence of a number of means essential for the production of voice, such as airflow resistance, closure of the vocal folds, subglottic pressure and so forth. Hence, it has been selected as a parameter of DSI.

Relationship between Dysphonia Severity Index with perceptual and self rating measures

Several studies reported that DSI is a good correlate of the perceptual dysphonia severity (Wuyts et al., 2000; Hakkesteegt, Brocaar, Wieringa & Feenstra, 2006; Neelanjana, 2011). Moreover, high correlation with Voice Handicap Index (VHI) indicates that the DSI reflects not only the vocal quality of the patient but also reflects the extent of handicap perceived by the patient (Kent, 1996). In the study done by Hakkesteegt, Brocaar and Wieringa (2010), the voice quality of 171 individuals with voice disorders was measured and analysed before and after intervention. As an objective measure DSI was used and VHI was used to measure perceived voice handicap. It was observed that 63% of the population had the results in concordance. A relation between G-level of GRBAS and DSI was found in a study by Wuyts et al. (2000) in which they compared DSI and CAPE-V to assess normals and individuals with vocal pathology/ dysphonia. Jayakumar and Savithri (2009) compared the voice quality of 20 monozygotic twins (age range 18-25years) using CAPE-V as a qualitative measure and DSI as quantitative measure. They concluded that the voice quality was similar in many of the parameters in both CAPE-V and DSI. Similarly, Neelanjana (2011) reported a significant correlation between CAPE-V and the DSI. The fact that the DSI is based on, acoustic, voice range and aerodynamic measurements, makes it a multidimensional, robust and objective outcome measure for the assessment of vocal quality.

Application of Dysphonia Severity Index in voice diagnostics and as an outcome measure

According to Wuyts et al. (2000), the daily clinical use of the DSI for 18 months had shown that the DSI was a practical tool to describe voice quality in a well-balanced way. Hakkesteegt, Brocaar & Wieringa (2010) conducted a study to investigate the applicability of DSI in evaluating the effects of intervention (voice therapy, phonosurgery and no intervention) in 171 patients with voice disorders. Significant better scores were obtained after intervention (voice therapy and phonosurgery). This difference in different voice disorder groups make DSI a practical tool for objective assessment of voice quality. The successful applicability of DSI in documenting the outcomes of surgical as well as therapeutic management of voice disorders have been accounted in several other studies (Hakkesteegt et al., 2006; Lierde et al., 2007). DSI plays a valuable part in the global assessment of a dysphonic patient. In 2011, Awan conducted a study on 30 female smokers and 30 female non-smokers to investigate if DSI can measure the variations in the vocal ability among the groups. The results indicated a significant difference in the DSI score among both the groups. Hence, DSI could prove valuable to both research and daily clinical practice.

Factors affecting the Dysphonia Severity Index

The DSI estimates dysphonia severity using only the sustained vowel task which does not give information about the speaker's habitual speaking voice. However, studies indicated that the connected speech task is more valid compared to sustained vowel task for acoustic analysis of voice quality (Halberstam, 2004). Aichinger et al. (2012) measured the inter-device (LingWAVES and DiVAS) reliability of DSI in dysphonic and non-dysphonic individuals and reported strong discrepancy of results in the two devices when used to measure the DSI values. In agreement with Aichinger et al., Rzepakowska et al., recommended for an initiation of improvements to measure the DSI intended for its common applicability in routine clinical examination. Awan, Miesemer and Nicolia (2012) reported the intra-subject variability on the DSI in which the two parameters of DSI (I-Low and Jitt) showed higher variability among its four constituent parameters. Similarly, Jayakumar and Savithri (2012) reported the significant control of geographical and cultural variations on DSI, particularly on its constituent parameters F_0-High and MPT. Factors such as instrumentation, ages and gender were reported to influence the DSI value. As the DSI involves jitter as one of its constituent parameters, the variations in jitter could influence its overall value. Measuring DSI requires sophisticated instruments for precise measurements of constituent parameters, particularly the I-Low. According to a study done on 151 individuals undergoing microlaryngeal surgery by Rzepakowska, et al. (2018), the task for DSI evaluation is considered quite difficult to execute for those with severe dysphonia. In few individuals, they reported a considerable difference between DSI results and the acoustic and aerodynamic measures and perceptual assessment.

Measuring Dysphonia Severity Index using *Praat* program

To overcome one of the drawbacks of DSI that it requires sophisticated and expensive instrumentation, attempts have been made in the recent past by Maryn, Morsomme and Bodt (2017) to deduce the DSI using the *Praat* program. A script named as 'DSI_{BETA}' has been developed to measure the DSI values obtained in *Praat* program and to evaluate these outputs with their counterparts (DSI_{ALPHA}). In this study, a group of 49 individuals (age range 18-82) diagnosed with voice disorders were considered. The DSI scores of this population were documented by conducting the two versions (DSI_{ALPHA} and DSI_{BETA}) of administration. Both the values were analysed statistically. It was reported that DSI can be measured in *Praat* by using DSI formula $DSI_{BETA} = -0.14 + 0.140 \times MPT + 0.00450 \times F_0Max - 0.0329 \times IMin - 4.530 \times Jitt_{PPQ}$. The beta measures for Jitter included $Jitt_{LOC}$, $Jitt_{ABS}$, $Jitt_{RAP}$ and $Jitt_{PPQ}$, which were further subjected to statistical analysis. Amongst the above mentioned, $Jitt_{PPQ}$ was selected as it had a strong correlation ($r_P = 0.617$, $P = 0.000$) with 38.1% of variance with 'Jitt' (measure of original study by Wuyts et al., 2000). The F_0-High and I-Low are interchanged with F_0Max and IMin.

Though the number of participants considered were relatively few in number, the strengths are explained as follows; a) since the data considered was obtained from diverse environmental acoustics and vaguely different recording equipment, it was hypothesized that the developed script is more generalizable and b) the DSI values were determined by following the methods and materials described by Wuyts et al., (2000).

In summary, the literature on the acoustic analysis of voice indicates that the multiparametric weighted equations have been superior and better correlates to the perceptual voice quality or dysphonia severity. Among the multiparametric measures, the DSI is a well documented robust measure that can be obtained through the freely available *Praat* program. Therefore, it is essential to establish norm referenced data, and to investigate the efficacy of DSI obtained using *Praat* program in various clinical conditions. Hence, the present study would be a preliminary attempt to document the reference data for DSI using *Praat* program in phononormic young adults.

CHAPTER III

METHOD

Participants

A total of eighty participants including 40 males and 40 females in the age range of 18-34 years participated in the study. They were selected randomly from Mysuru city.

Inclusionary criteria

The following criteria were considered to include the participant for the study.

- Individuals with no complaint or history of voice problems.
- Individuals with perceptually normal voice as examined by a Speech Language Pathologist.

Exclusionary criteria

- Individuals with high vocal loading and the professional voice users with active participation were excluded from the study.
- Individuals with infections related to vocal tract on the day of testing, history of asthma, chronic obstructive pulmonary disorder or any other pulmonary anomalies were excluded.
- Individuals with any associated conditions such as hearing loss, neurological impairment were excluded.

Stimuli: The current study included the recording of the phonation of vowel /a/ at highest pitch, lowest intensity and the longest possible /a/ in a single breath.

Procedure

Samples were recorded using table mounted *Shure* microphone connected to the HP desktop with *Praat* 6.0.28 version program in a quiet room. A switch craft was connected to the microphone to ensure nullifying pre-amplification. A constant 10cms distance was maintained from the mouth to the microphone. The recording was obtained at 16-bit resolution and 44.1 kHz sampling frequency to obtain the four individually weighted measures: maximum phonation time (MPT), jitter percent ($Jitt_{PPQ}$), softest intensity (IMin) and highest fundamental frequency (F_0Max). The participants were seated conducively and were instructed to phonate vowel /a/ as soft as possible to obtain IMin. Similarly, to obtain F_0Max, the participants were asked to phonate vowel /a/ at their highest pitch. For obtaining MPT the participant was instructed to phonate as long as possible in a single breath. For measuring the parameter $Jitt_{PPQ}$, the participants were asked to phonate vowel /a/ for 5-6 seconds. Following the instructions, the experimenter demonstrated each of the tasks. Three trials were obtained for $Jitt_{PPQ}$, IMin and F_0Max tasks, and the best of the three trials were considered and renamed to read as "Sound ppq", "Sound im" and "Sound fh", respectively for calculating the DSI using the algorithm developed by Maryn, Morsomme and Bodt (2017). To choose the best among the three trials, the recordings were separately analysed in the *Praat* program and IMin and F_0Max parameters were measured for each of the trials. The trials with lowest IMin, lowest $Jitt_{PPQ}$ and highest F_0Max were considered as best for deriving the DSI value.

After initiating the script, the sound level calibration formula and the MPT were filled in the fill-in form. A separate folder was made to save the recorded samples in '.wav' format. The samples were recorded again with a gap of 5minutes from 20% of the participants (16 participants) for the purpose of analysing the test-retest reliability of the DSI. The obtained data from all the measures were tabulated and subjected to further statistical analysis.

Analysis

The recorded and renamed .wav files (‘fh’, ‘im’ and ‘ppq’) were viewed in the *Praat* program (6.0.28 version) and DSI was obtained using the algorithm developed by Maryn et al. (2017). The algorithm to obtain the DSI includes the following formula: DSI = 0.149 + 0.140**MPT* + 0.00450* F_0Max − 0.0329* *I Min* − 4.530 *$Jitt_{PPQ}$. The ‘DSI script’ given by Maryn et al. (2017) was copied onto a text file, and was named as ‘DSI script’. Following the selection of ‘fh’, ‘im’ and ‘ppq’ files, the ‘DSI script’ was ‘run’ in the *Praat* program (6.0.28 version). The screenshots of the steps implicated in this procedure were given under Figure 1 and 2. Figure 3 depicts the final graphical DSI output on *Praat* program

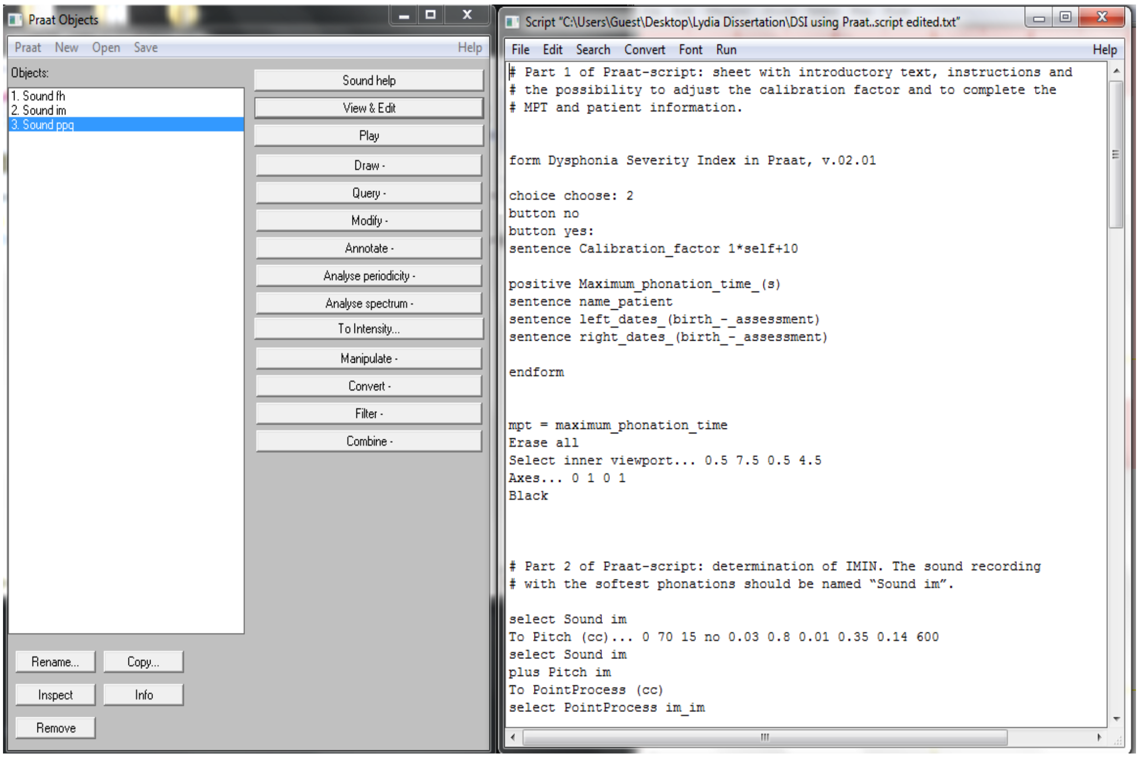

Figure 1. Screenshot revealing DSI script being run on *Praat* program (fh- Highest fundamental frequency, im- lowest intensity & ppq- pitch perturbation quotient).

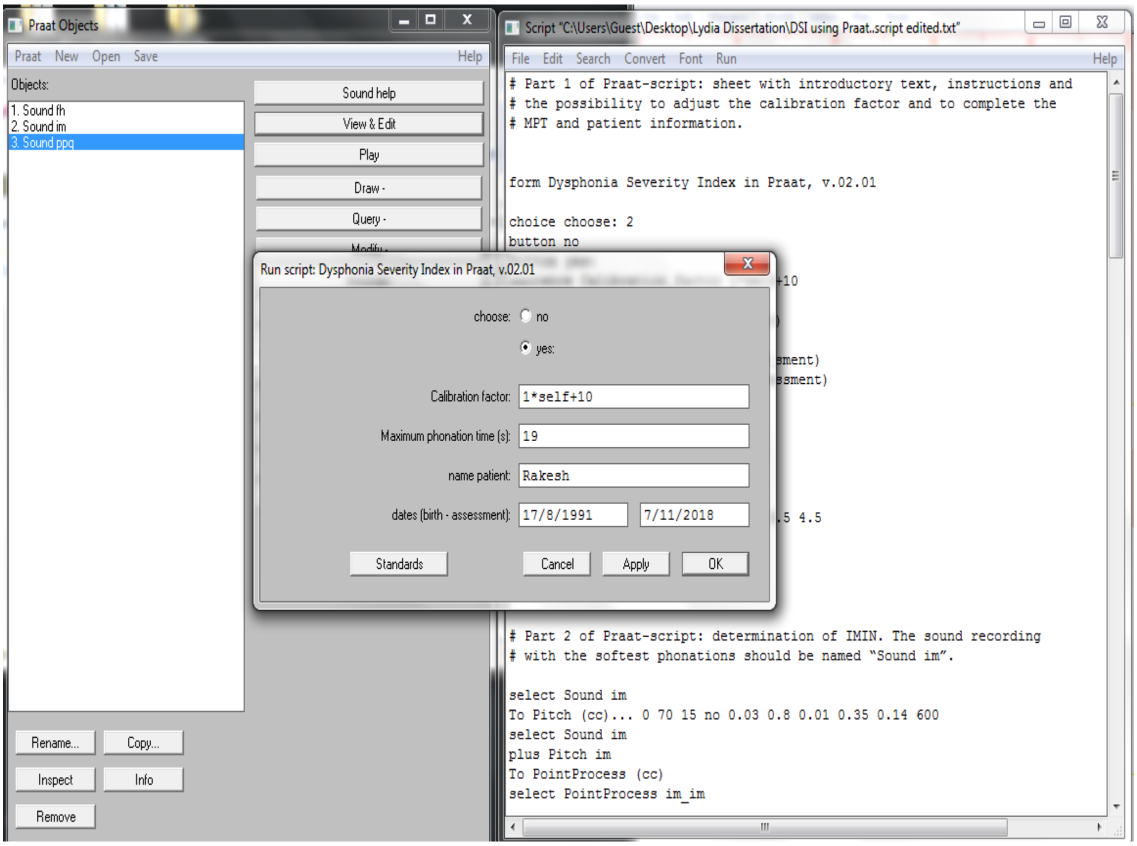

Figure 2. Screenshot revealing the entry of demographic data of the participant in *Praat* using DSI script.

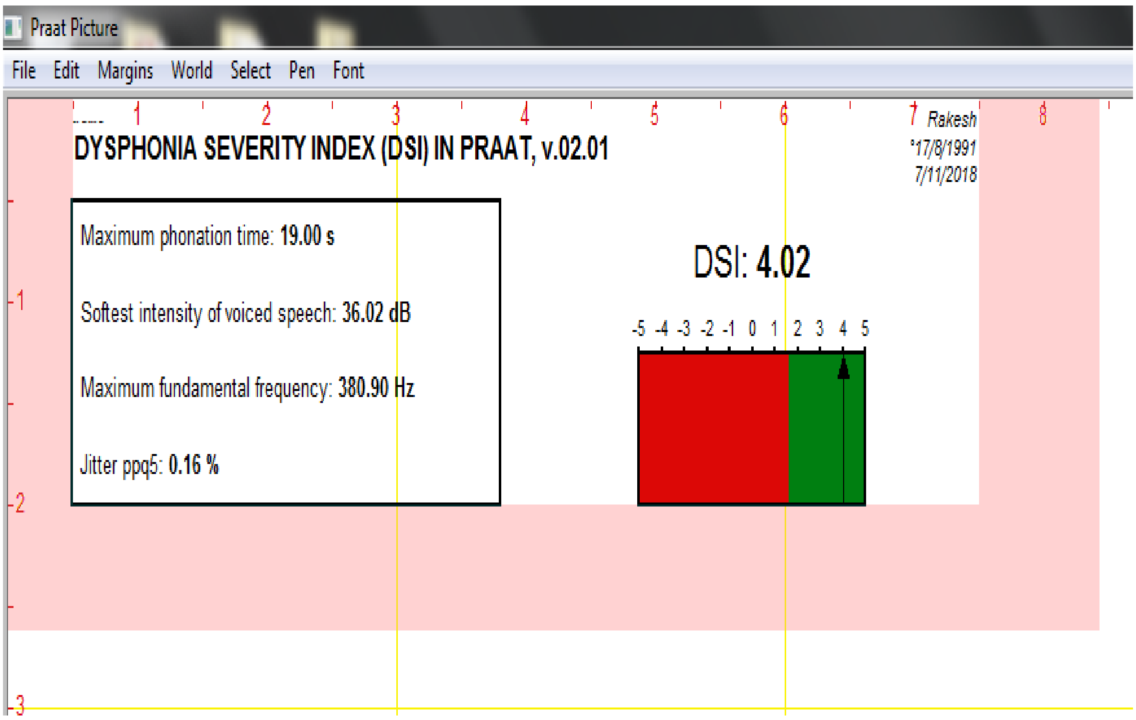

Figure 3. Graphical output of Dysphonia Severity Index results.

Statistical analysis

After objective evaluation of voice, the data obtained for the DSI and its constituent parameters were statistically analysed using the *SPSS* (version 20) to determine if the data is following normal distribution, to validate the effect of gender on DSI and its constituent parameters and to examine the test-retest reliability of the DSI and its constituent parameters. Shapiro Wilk's test was administered to determine the normality of the data. The mean, standard deviation, range and 95% confidence intervals were obtained for DSI and all its constituent parameters. To validate the statistical significance of the variation in DSI with respect to the gender, a non-parametric Mann-Whitney test was carried out. Cronbach's alpha coefficient was used to calculate the test-retest reliability on recordings obtained from 20% (16) of the randomly selected participants.

CHAPTER IV

RESULTS

The present study measured the DSI in phononormic young adults in the age range of 18-34 years. The procured data of the DSI and its constituent parameters were subjected to several statistical analyses to verify the normality of the data, the effect of gender on the DSI and test-retest reliability of the DSI. Thus the obtained results are presented in the following sections.

Normality of the data

Shapiro Wilk's test was done to determine the normality of the samples obtained from the participants of the present study with gender as the independent variable. Results revealed that the data is not normally distributed ($p<0.05$). Therefore, a non-parametric Mann-Whitney test was carried out to verify the statistical significance of the difference in DSI with respect to the gender.

Dysphonia Severity Index obtained using *Praat* program in phononormic young adults in the age range of 18-34 years

The mean and standard deviation of DSI values obtained using *Praat* program extracted from the samples obtained from 80 phononormic young adults are given under the table 1. The males and females obtained a mean DSI of 3.03 and 3.14 with a standard deviation of ±1.03 and ±0.99 respectively. As observed from the table 1, the standard deviation values in both males and females are markedly lower than their mean DSI values, indicating the DSI as a stable parameter with minimal variations within a homogenous group (table 1).

Table 1

Mean, standard deviation, range and 95% confidence inetrvals of dysphonia severity index obtained using Praat program in young adults in age range 18-34 years.

	DSI Mean (±SD)	Range	95% Confidence intervals
Male	3.03 (±1.03)	1.65 - 5.49	2.7038 to 3.3632
Female	3.14 (±0.99)	1.60 - 5.99	2.8298 to 3.4642

Table 2 shows the mean, standard deviation and 95% confidence intervals of DSI's constituent parameters for males and females. The males obtained higher MPT and $Jitt_{PPQ}$ values; and lower IMin and F_0Max values compared to their female counterparts (table 2).

Table 2

Mean, standard deviation and 95% confidence interval values of constituent parameters of DSI obtained using Praat program in males and females.

Parameters	Male Mean (±SD)	95% Confidence intervals	Female Mean (±SD)	95% Confidence intervals
MPT	17.77 (±5.48)	16.02 to 19.52	13.65 (±2.45)	12.86 to 14.43
IMin	35.18 (±6.3)	33.17 to 37.20	37.92 (±5.16)	36.13 to 39.72
F_0Max	276.55 (±104.52)	243.12 to 309.98	344.54 (±177.27)	287.84 to 401.23
$Jitt_{PPQ}$	0.21 (±0.195)	.18 to .23	0.12 (±0.050)	.10 to .13

(MPT- maximum phonation duration, IMin – intensity minimum, F_0Max –highest fundamental frequency, $Jitt_{PPQ}$ – pitch perturbation quotient).

Effect of gender on Dysphonia Severity Index obtained using *Praat* program

The results of the Mann-Whitney test indicated a significant effect of gender on MPT (Z = -4.099, $p < 0.05$), IMin (Z = -2.199, $p < 0.05$) and $Jitt_{PPQ}$ (Z = -6.086, $p < 0.05$). However, the F_0Max and the overall DSI values were found to be independent of the gender ($p > 0.05$) (table 3).

Table 3

Effect of gender on DSI and its constituent parameters as measured by Mann-Whitney test.

Parameters	Effect of gender	
	Z	*P*
MPT	-4.099	*.000
IMin	-2.199	*.028
F_0Max	-1.593	.111
$Jitt_{PPQ}$	-6.086	*.000
DSI	-.577	.564

** Indicative of statistically significant effect at p <0.05*

Test-retest reliability of Dysphonia Severity Index obtained using *Praat* program

In order to verify the test-retest reliability of the DSI, the recordings were obtained again from 20% (16) of the randomly selected participants. Cronbach's alpha test was carried out to compute the reliability coefficient 'α' for DSI scores obtained using *Praat* program. A Cronbach's Alpha coefficient 'α' of more than 0.7 and above is considered as statistically reliable. George and Mallery (2003) provided a rule of thumb that, above 0.9 the reliability is termed as 'excellent'. In the present study, the Cronbach's alpha for DSI was found to be above 0.7 (i.e. 0.994), indicating 'excellent' test-retest reliability for DSI. Also for the constituent parameters of the DSI, the Cronbach's 'α' ranged from 0.926 to 0.974 indicating 'excellent' test-retest reliability across the parameters.

CHAPTER V

DISCUSSION

The sensitivity, reliability, ease of measurement and the feasibility to obtain using the free software makes the DSI an optimal tool for a practicing Speech language pathologist. In this context, the present study establishes the reference values for the DSI measure for phononormic young Indian adults.

Dysphonia Severity Index in phononormic young adults

In the present study, the phononormic young adults obtained an average DSI value of 3.09 with a standard deviation of 1.00. Therefore, this study is one of the first attempts in Indian context to obtain the DSI value in phononormic individuals using the *Praat* program. Considering the variations in the instrument and procedures used for measurement and the difference in one of the constituent parameters in *Praat* based DSI (Jitt versus $Jitt_{PPQ}$), the results of this study cannot be directly compared to that of the literature in DSI.

Nevertheless, the DSI value obtained in this study is in similar levels to those reported in the literature. For instance, Jayakumar and Savitri (2012) reported a DSI value of 3.47 (±1.24) for Indian population in the age range of 18-25 years using the procedure described by Wuyts et al. (2000). Similarly, the DSI in the present study is also in coherence with values reported by Wuyts et al. (2000) with a DSI value of 5.0 (±0.23) and Hekkesteeget et al. (2006) with a DSI value of 4.1 (±2.0). Thus, indicating the value of DSI as a stable measure presenting minimal variations irrespective of the instrument and procedures used for measurement.

Effect of gender on the Dysphonia Severity Index

With respect to the gender, the males obtained DSI value of 3.03 (±1.03) and females obtained DSI value of 3.14 (±0.99). The mean difference between the males and females were not found to be statistically significant at $p<0.05$-value ($p=0.564$), indicating that the DSI is independent in terms of gender. When the constituent parameters of DSI were compared, the parameters MPT, IMin and $Jitt_{PPQ}$ were found to be significantly different between the males and the females. While the males obtained significantly better values in terms of higher MPT and lower IMin, the females obtained the better values for $Jitt_{PPQ}$. Although not statistically significant, the F_0Max was markedly higher in females (344.54 Hz) compared to that of their male counterparts (276.55 Hz). Therefore, it might be possible that the dominance of the males and females for different constituent parameters of the DSI would have resulted in counter balancing and lead to a similar value of overall DSI in these groups.

The DSI being independent of the variable gender is in accordance with the study done by Wuyts et al. (2000) and Hakkesteegt et al. (2006). Wuyts et al. claims that 'DSI does not show gender differences, because the differences in F_0-High (higher in females) and MPT (higher in males) are opposite and counteracting'. Similar trend was observed in the present study, where the lower $Jitt_{PPQ}$ in females was counter balanced for the higher MPT and IMin in males. Studies done by Jayakumar and Savitri (2009, 2012) had reported results with significant gender difference for MPT (males 17.6 and females 13.8). They attributed the difference to the anatomical and physiological variation between the males and females.

Significant difference in the IMin in the present study is in coherence with a study by Sulter, Schutte and Miller (1995), where it was reported that males were able to phonate softer than females. In contrast, studies done by Heyning, et al. (1998); Wuyts et al. (2000) and Hakkesteegt et al. (2006) found no such variation. Hollien, Dew and Philips (1971); Heyning et al. (1998) and Wuyts et al. (2000) reported higher F_0-High values in their female participants and attributed this to the vocal fold length and structural differences in the larynx. In the present study too, the females obtained higher F_0Max values compared to their male counterparts, however, this discrepancy was not found to be statistically significant at $p<0.05$ level of significance.

To summarize, the present study indicates that the DSI obtained using *Praat* is a reliable measure for evaluation of voice. As the present study indicates no effect of gender on DSI, the overall DSI value obtained in the present study 3.09 (±1.00) can be used as the reference value across the gender for young adults in the age range of 18-34 years.

Test-retest reliability of the Dysphonia Severity Index obtained using *Praat* program

In the present study, test-retest reliability of DSI was found to be excellent (Cronbach's alpha '∝' = 0.994). The high test–retest reliability value is a pre-requisite for any type of validity measurements as it indicates the robustness and reliability of the measure used. Thus, the findings of the present study indicate that the DSI is a robust measure. This finding is in coherence with the earlier studies which reported the DSI as a highly stable measure (Hakkesteegt et al., (2008); Neelanjana, 2011; Awan, Miesemer & Nicolia, 2012).

CHAPTER VI

SUMMARY AND CONCLUSIONS

Dysphonia Severity Index is a multiparametric measure derived from the weighted combination of four constituent parameters maximum phonation time (MPT), intensity minimum (ILow), highest fundamental frequency (F_0-High) and jitter (Jitt). A scale ranging from -5 to +5 is used to quantify the voice quality in which -5 denotes severe dysphonia and +5 denotes normal voice quality. The advantage of DSI is that it could differentiate among different dysphonic severity levels in an objective manner. Further, the recent studies indicate that the DSI can be obtained through the freely available *Praat* program. Therefore, the present study was taken up with the aim of documenting the DSI in phononormic young adults obtained using *Praat* program and also to investigate the effect of gender on the obtained DSI.

A total of eighty participants including 40 males and 40 females in the age range of 18-34 years were selected randomly from Mysuru city. The participants were asked to sit comfortably in a quiet room and to phonate the vowel /a/ at highest pitch, lowest intensity and the longest possible /a/ in a single breath. The samples were recorded using table mounted *Shure* microphone connected to the HP desktop with *Praat* 6.0.28 version program. These recordings were renamed as 'fh', 'im', and 'ppq' and were saved in .wav format. The saved samples were selected and the 'DSI script' was 'run' in the *Praat* program.

The procured data in terms of the DSI and its constituent parameters were statistically analysed. The results indicated that the mean and standard deviation of the DSI obtained using *Praat* program in males as 3.03 (±1.03) and in females as 3.14

(±0.99). These DSI values obtained for males and females are not statistically significant, indicating that the overall DSI value of 3.09 (±1.00) can be used as the reference value across the gender for young adults in the age range of 18-34 years. The present findings are in coherence with the DSI values of 3.47 with a standard deviation of ±1.24 reported by Jayakumar and Savitri (2009). A high test-retest reliability of DSI and its constituent parameters was obtained on Cronbach's alpha test.

The result of the present study facilitates the understanding of the effect of gender on DSI and its parameters obtained using the *Praat* program. As the scope of the present study is confined to document the scores of DSI measured using *Praat* program in young adults, future studies are warranted to document reference DSI values in individuals across the age groups. In addition to this, the cut off values for DSI needs to be established considering a larger normal and clinical population. Future studies are also recommended towards identifying the validity, sensitivity, specificity, accuracy and likelihood ratios for DSI obtained using the *Praat* program.

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