ACOUSTIC VOICE QUALITY INDEX IN KANNADA SPEAKING CHILDREN IN THE AGE RANGE OF 10 TO 12 YEARS

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APRIL 2018

CERTIFICATE

This is to certify that this dissertation entitled "***Acoustic Voice Quality Index in Kannada speaking children in the age range of 10 to 12 years***" is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 16SLP026. 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

April 2018

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CERTIFICATE

This is to certify that this dissertation entitled "***Acoustic Voice Quality Index in Kannada speaking children in the age range of 10 to 12 years***" is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 16SLP026). This has been carried out under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "***Acoustic Voice Quality Index in Kannada speaking children in the age range of 10 to 12 years***" is the result of my own study under the guidance of Dr. Pebbili Gopikishore, Lecturer 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.

Mysuru   Registration No. 16SLP026

April 2018

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CHAPTER I

INTRODUCTION

Comprehensive analysis of voice includes subjective evaluation by the voice pathologist which is substantiated by the instrumental analysis and the self-perceptual analysis by the client. The perceptual analysis is solely based on the voice pathologist perception of a particular voice sample with his or her mental reference to the normal voice characteristics. This is performed by listening to the speech and reading samples of the individuals and is rated on standardized perceptual rating scales. For instance, GRBAS (Hirano, 1981) and Consensus Auditory Perceptual Evaluation of Voice (Kempster, Gerratt, Verdolini, Barkmerer, Kraemer & Hillman, 2009) are frequently used perceptual rating scales for voice assessment. Voice is assessed objectively through acoustic, aerodynamic and imaging techniques. In addition to this, the consequence of voice problem on day-to-day activities and the quality of life of the individuals are assessed using self-rating measures such as voice handicap index (Jacobson, Johnson, Grywalski, Silbergleit, Jaconsen & Benninger, 1997).

Acoustic analysis of voice includes various spectral and cepstral parameters which can be used for both diagnoses as well as tracking intervention efficacy in voice disorders. These are frequently used by the Speech-language pathologist as it is non-invasive, time-saving, and easy to interpret. It has been used for diagnostic investigations as well as to track the treatment efficacy (Carding, Wilson, McKenzie, & Deary, 2009). It involves procedures such as inverse filtering, auto correlation, spectrum, cepstrum to extract the frequency related measures, amplitude related measures, perturbation related measures, noise/harmonic related measures, and measure of voice continuity (Hirano, Hibi, Yoshida, Hirade, Kasuya & Kikiuchi, 1988; Wolfe, Fitch & Cornell, 1995; Dejonckere & Lebacq, 1996 and Picirillo, Painter, Haiduk, Fuller & Fredrickson, 1998).

Despite being easy to analyze and interpret, most of the acoustic parameters found to have poor correlation with perceptual analysis and limited test-retest reliability (Bauser & Drinnan, 2011; Karnell, Hall, & Landanl, 1995; Bough, Heuer, Sataloff, Hills & Cater, 1996). These parameters were reported to be effective when they used in weighted combinations such as Dysphonia Severity Index (Wuyts, De 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).

The multiparametric measure Acoustic Voice Quality Index(AVQI) includes six constituent parameters such as cepstral peak prominence (CPPs), shimmer local (ShdB), the harmonics-to-noise ratio (HNR), the slope of the long-term average spectrum (slope) and tilt of the trend line through the long-term average spectrum (tilt). It incorporates both spectral and cepstral parameters and measured using sustained vowel and continuous speech task in praat software using AVQI script. It uses a scale ranging from 0 to 10 to quantify the voice quality in which 0 indicates normal voice quality and 10 indicates severe dysphonia. Primary advantages of AVQI over other multiparametric measures are inclusion of continuous speech task along with sustained vowel task which could strengthen the overall AVQI value, time-saving, easy to use as well as to interpret. Literature suggests that AVQI is independent of age, gender and language of the participants. Therefore, AVQI can be considered as a reliable diagnostic and outcome measure that can be used over awide range of the clinical population.

Despite the merits of AVQI, there has been the dearth of studies investigating the reliability, validity, and normative data for this measure. Further, there have been limited studies focused on investigating the efficacy of AVQI in differentiating normal and clinical population as well as to verify its utility as a measure for documenting the outcomes of surgical or therapeutic management of voice disorders. In addition to this, the voice characteristic has been reported to be influenced by the geographical and ethnic factors (Jayakumar & Savithri, 2009). Therefore, it is essential to establish normative data specific to individuals in a particular region, ethnicity, language, age and sex of the individuals.

Need for the study

AVQI is one of the multiparametric measures that are obtained using public domain software, and it is easy to administer, analyze and interpret. Studies indicated that this parameter is independent of the language, age, and gender of the individuals, at least within the adults. However, there is a dearth of research aimed at establishing normative data for this parameter for children in the developing age. Further, as the structural and physiological variations continuously in children in the developmental ages, it is essential to establish age and gender-specific normative values for this parameter. Therefore, considering the sensitivity and validity of the AVQI, and the dearth of studies documenting the normative data for this parameter in children, the current study was taken up with the aim of establishing the normative data for AVQI in Kannada speaking children.

Aim of the study: The current study was taken up with the aim of documenting the Acoustic Voice Quality Index in typically developing Kannada speaking children in the age range of 10-12 years.

Objectives of the study

1. To establish normative data for Acoustic Voice Quality Index for Kannada speaking typically developing children in the age range of 10-12 years.
2. To verify the effect of gender on Acoustic Voice Quality Index.
3. To verify the effect of age on Acoustic Voice Quality Index.
4. To investigate the test-retest reliability of Acoustic Voice Quality Index.

CHAPTER II

REVIEW OF LITERATURE

Voice is evaluated through the subjective and objective methods. Subjective evaluation of voice is also known as the psychoacoustic evaluation of voice as it is primarily based on listeners' hearing. It is considered as the ‘gold standard’ method for documenting the voice and speech assessment. The first step towards treatment for individuals with voice disorders is accurate diagnosis with quantification of severity. Psychoacoustic measures provide subjective and qualitative detail regarding the voice quality. The vocal features that can be described by perceptual evaluation include aphonic/intermittent aphonic, hyper-functional/tense, vocal fry, phonatory breaks, rough, diplophonia, instability of vocal pitch and pitch range. Major merits of perceptual evaluation are easy availability and lack of sophisticated instrumentation for using it in the clinical setup (Nerurkar, 2017).

Even though it has been used widely, because of its subjective nature, it has been heavily criticized. The major constraint of perceptual evaluation is that it is primarily based on listeners hearing and is susceptible to the variability due to factors such as hearing threshold and experience of the listener; task factors such as phonation, reading, spontaneous speech, and conversation; and further on the subject related factors (Nemr, Amar, Abrahao, Leite, Kohle, Santos & Correa, 2005).

In order to overcome these limitations and also to improve the agreement among the listeners regarding the judgment of voice quality, a plethora of perceptual rating scales have been formed. These perceptual scales make use of visual analog scale, equal appearing interval scale, Likert scale etc for making the judgement regarding voice quality. In literature, two most commonly used scales for perceptual analysis of voice are GRBAS (Hirano, 1981) and Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) (Kempster, Gerratt, Verdolini, Barkmerer, Kraemer & Hillman, 2009).

Auditory-perceptual ratings were also highly variable because of various factors such as listener experience; listener's shifting of internal standards, quality of voice sample and also the type of rating scale used for assessment. Fex (1992) had defined normal voice quality as a conception based on the subjective opinion that may vary with different cultures and represents a continuum in which a vast number of people may be judged as having normal but nevertheless individually differentiated voice. Another significant difficulty in auditory perceptual evaluation of voice was in achieving the description of different voice quality unambiguously so listeners were often forced to use standard terms that exit even though those words are not originally meant for describing the voice sample.

Objective evaluation of voice

Objective evaluation of voice is performed to substantiate the subjective measures of voice. It is performed to diagnose the etiology for the voice disorder, to determine the extent and degree of the voice pathology, to evaluate the nature and degree of dysphonia and to determine about prognosis as well as to monitor the therapeutic changes. The objective methods of voice analysis include imaging techniques (such as videostroboscopy), aerodynamic and acoustic measurement of voice.

Among these measures, acoustic analysis of voice is one of the objective measures that are frequently used by the Speech-language pathologist as it is non-invasive, time-saving, and easy to interpret. It has been used for diagnostic investigations as well as to track the treatment efficacy (Carding, Wilson, McKenzie, & Deary, 2009). It involves 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 (Hirano et al., 1988; Wolfe, Fitch & Cornell, 1995; Dejonckere & Lebacq, 1996 and Picirillo et al., 1998).

In literature, several studies have reported on the correlation of perceptual measure with objective measures of voice. In 2004, Bhuta, Patrick and Garnett compared the perceptual evaluation of voice using GRBAS scale and objective evaluation of voice using Multi-Dimensional Voice Program (MDVP) in 37 patients retrospectively. They reported that 'G' of GRBAS scale was correlated with Soft Phonation Index (SPI), Voice turbulence Index (VTI) and Noise Harmonic Ratio (NHR) whereas 'R' of GRBAS scale was correlated with only NHR, 'B' and 'A' of GRBAS scale were correlated with SPI only. Dejonckere and Lebacq in 1996 compared the perceptual measures of roughness, harshness and breathiness with an aerodynamic measure of glottal air leakage and an acoustic measure of jitter in 87 dysphonic individuals. They found that jitter can be more correlated with perceptual quality of roughness whereas turbulent noise associated with glottal air leakage can be more correlated with perceptual quality of breathiness.

Despite the applications of the acoustic analysis in the voice assessment and as an outcome measure, the validity and reliability of these measures were reported to be limited (Bauser & Drinnan, 2011). Karnell, Hall, and Landanl (1995) investigated the fundamental frequency, frequency and perturbation measurements using three different analysis system and found fundamental frequency measurements were more consistent compared to jitter and shimmer measurements across analysis systems. Bough, Heuer, Sataloff, Hills, and Cater (1996) reported poor to moderate correlation on investigating inter-device reliability in perturbation measures. De Felippe, Grillo, and Grechi (2006) reported that the parameter Harmonics-Noise ratio (HNR) is not sensitive in differentiating dysphonia from normal voice.

The spectral based parameters such as the perturbations and HNR are of time domain and their application is confined due to factors such as the cycle boundary identification, quality of voice etc. An alternate to this is application of the cepstral measures. The cepstrum is the inverse of spectrum, and is obtained by applying discrete Fourier transformation to the logarithmic power spectrum. Cepstral Peak Prominence (CPP) and Smothened Cepstral Peak Prominence (CPPs) are few of the cepstral parameters. Literature suggested that these measures have more accuracy on fundamental frequency extraction particularly in severe dysphonia voice. Also it has good correlation with perceptual measures of voice (Auditory-perceptual classification of dysphonia severity)and more consistent in discriminating mild dysphonia from normophonia compared to other dysphonia measures (Kumar, Bhat & Prasad, 2010 and Kumar, Bhat, Fahim & Raju, 2011 and Brinca, Batista, Tavares, Goncalves & Moreno, 2014). Estimation of cepstral parameters are more reliable to analyse the connected speech sample particularly Cepstral peak prominence (CPP) is the robust measure in estimating the dysphonia severity as well as tracking the intervention outcomes. It has demonstrated that decrease in the amplitude of the cepstral peak is often associated with increased dysphonia severity (Heman, Heuer, Michael, Ostrwoski & Horman, 2003).

Awan and Roy (2006) reported limited validity of most of the acoustic parameters when they were used individually (i.e., single parametric measure) for diagnostic or documentation purpose. Further, several researchers had opined that the use of multiparametric measurements which combine several objective parameters could be superior in assessing the voice quality than the single parameter measurements (Michaelis, Frohlich & Strube, 1998; Klein, Piccirillo & Painter, 2000; Yu, Ouaknine, Ravis & Giovanni, 2001; Yu, Revis, Wuyts, Zanaret & Giovanni, 2002 and Hartl, Hans, Vaissiere & Brasnu, 2003). Dysphonia severity index (Wuyts, De Bodt, Molenberghs, Remacle, Heylen, Millet & Heyning, 2000), Cepstral Spectral Index of Dysphonia, and Acoustic Voice Quality Index (Maryn et al., 2010) are some of the multiparametric measures of voice quality reported in the literature.

Dysphonia severity index (DSI) is a regression equation derived from the weighted combination of four single parameters namely highest frequency (Hz), lowest intensity (dB), maximum phonation time (seconds) and jitter (percent). Studies indicated that DSI was a good correlate of the perceptual dysphonia severity. For instance, Hakkesteegt, Brocaar, Wieringa, and Feenstra (2006) reported a good correlation of DSI with the grade of the GRBAS scale. They reported lower DSI scores in dysphonics compared to that of normals. Neelanjana and Jayakumar (2011) reported a significant correlation between CAPE-V and the DSI. Further, several studies had reported the successful use of DSI in documenting the outcomes of surgical as well as therapeutic management of voice disorders (Hakkesteegt et al., 2006 and Van Lierde, Claeys, De Bodt, & Van Cauwenberge, 2007).

Awan, Sara, and Nicolia (2012) reported the intra-subject variability on the DSI and found that two parameters of DSI (the lowest intensity and the jitter percentage) showed higher variability among its four constituent parameters. Similarly, Jayakumar and Savithri in 2012 reported the significant influence of geographical and ethnic variations on DSI, particularly on its constituent parameters highest F0 and maximum phonation time. Factors such as instrumentation, age, 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 lowest intensity. Further, the DSI estimates dysphonia severity using only the sustained vowel task which does not give information about 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).

Cepstral spectral index of dysphonia (CSID) is a multiparametric measure that utilizes both the sustained vowels as well as the continuous speech for the analysis of voice quality. CSID is available within Analysis of Dysphonia in Speech and Voice program (ADSV model 5109, Kay PENTAX. Montvale, NJ). CSID includes cepstral parameters and spectral such as cepstral peak prominence (CPP), the low-to-high spectral energy ratio (L/H spectral ratio and its standard deviation which were derived from both sustained vowel and connected speech task separately. It also automatically generates an estimation of dysphonia severity for each of the task. CSID values range 0 to 100 but sometimes it generates below and above that which indicates extremely periodic voice and profoundly aperiodic voice respectively.

Acoustic Voice Quality Index (AVQI) is the weighted combination of smoothened cepstral peak prominence (CPPs), shimmer local (ShdB), the harmonics-to-noise ratio (HNR), the slope of the long-term average spectrum (slope) and tilt of the trendline through the long-term average spectrum (tilt). It is measured using the equation AVQI = 2.571*(3.295 - 0.111*CPPs - 0.073*HNR - 0.213*SL + 2.789*Sh dB - 0.032*Slope + 0.077*Tilt). AVQI has an analysis script for automatic generation of dysphonia severity based on analysis of a concatenated sample of sustained vowel and connected speech which is compatible only with Praat software. AVQI score ranges between 0 to 10 which indicates normal voice and profoundly abnormal voice respectively in that continuum of severity. An earlier version of AVQI has undergone a major modification with respect to adjustments in the weighting of each parameter resulted in the production of version 3.01. Barsties & Maryn (2016) found that these modifications improved the overall performance of diagnostic precision as well as the external validity of it.

Barsties and Maryn (2013) reported that sustained vowel task has the greater contribution as well as greater influence on the final AVQI score compared to the connected speech task. Barsties and Maryn (2015) investigated the newer version of AVQI version 3.01 in terms of contribution of each task to final AVQI score. They varied the voice duration of the samples collected from different voice pathologies ranging from normal to severe. They used three different voice durations, in which the first one had 17 syllables text along with three seconds sustained vowel, the second one had connected speech of customized length along with three seconds sustained vowel and the last one had whole text along with three seconds sustained vowel. Results indicated a balanced contribution of both sustained vowel task and connected speech task for the final AVQI score with the second type of voice sample. Despite that, the first type of sample is commonly used for generating the final AVQI score.

A strong correlation between the AVQI and perceptual voice quality as measured on GRBAS and CAPE-V scales was reported by Maryn, Kim and Kim in 2016 (in the Korean language) and Uloza, Petrauskas, Padervinskis, Ulozaite, Barsties, and Maryn in 2017 (in the Lithuanian languages). Barsties and Maryn (2013) reported good test-retest reliability in AVQI. Benoy and Jayakumar (2017) also reported a good test-retest reliability of AVQI and also a good correlation with perceptual dysphonia severity. They also reported that AVQI differentiated the dysphonia of mild and moderate severities.

Applications of the Acoustic Voice Quality Index

Uloza, Latoszek, Staiene, Petrauskar and Maryn (2018) investigated and compared the diagnostic accuracy of AVQI and DSI in 105 paticipants with normal voice and 159 participants with various voice disorders. They also analysed and correlated the voice samples using visual analog scale (auditory perceptual rating scale). Results revealed that higher level diagnostic accuracy for AVQI with more correlation to the auditory perceptual measurement of voice in comparison to the DSI. Therefore, the AVQI has a more reliable voice screening potential compared to DSI.

Similarly, in pediatric subjects, Reynolds, Buckland, Bailey, Lipscombe, Nathan, Vijayasekaran, and Kelly (2012) reported a higher diagnostic accuracy of AVQI with good correlation to GRBAS scale. Therefore, AVQI is an appropriate tool for assessment, diagnosis as well as for documenting treatment related changes as a part of evidence-based practice in both paediatrics and adults with several voice disorders.

Acoustic Voice Quality Index can also be used to profile the voice of professional voice users. In literature, D'haeseleer, Meerschman, Claeys, Leyns, Daelman, and Lierde (2016) used AVQI to investigate the vocal behaviours of Dutch theatre artist. They analysed the voice of the participants following the performance. Analysis using AVQI showed a mean value of 3.48 which indicates mild dysphonia. This indicates the presence of poor vocal hygiene and vocally violent behaviours in theatre artist. Thus, these studies demonstrate the clinical applications of AVQI in a wide range of clinical populations from children to adults, in various other professional voice users and also in speakers of different languages and dialects.

Peterson, Roy, Awan, Merill, Banks and Tanner (2013) validated the CSID based on analysis of pre-post therapy samples of subjects across six diagnostic categories as well as with listener’s ratings of severity. They reported a strong correlation between CSID’s score and perceptual rating by listener’s. They further supported CSID as an objective tool for quantifying the treatment-related changes over time in voice quality. There are some of the significant differences between AVQI and CSID such as 1. AVQI estimates the dysphonia severity by concatenating the contexts whereas CSID estimates for each of the contexts separately 2. AVQI algorithm incorporates time-based measures as well as cepstral-spectral parameters while CSID algorithm contains only cepstral-spectral measures 3. AVQI functions only within Praat software similarly CSID functions only within ADSV program.

Despite the differences mentioned, both aid in quantifying the dysphonia severity. Lee, Roy, Peterson and Merrill (2017) compared the performance of CSID and AVQI of both 2.02 and 3.01 versions in pre – post-therapy comparison across six diagnostic categories such as adductor spasmodic dysphonia, unilateral vocal fold paralysis, primary muscle tension dysphonia, prebylaryngis, benign vocal fold lesions and mutational falsetto. And they reported that CSID outperformed as well as much stronger compared to either version of AVQI.

Factors affecting the Acoustic Voice Quality Index

As the AVQI involves the use of continuous speech task, it was assumed to be sensitive to the inter-linguistic differences such as stress-timed, syllable-timed, mora-timed and mixed rhythms. Therefore, several investigations were carried out to verify the effect of language on the AVQI. Some of the languages in which the AVQI values were validated include English (Reynolds et al., 2012 and Maryn et al., 2014), Dutch (Maryn et al., 2010 and Barsties & Maryn, 2015), French (Maryn, De Bodt, Barsties, & Roy, 2014), German (Barsties & Maryn, 2012), Japanese (Hosokawa, Barsties, Iwahashi, Iwahashi, Kato, Iwaki, & Maryn, 2017), Finnish (Kankare, Barsties, Maryn, Ilomaki, Laukkanen, Tyrmi, & Vilpas, 2015), and Lithuanian (Uloza et al., 2017). Maryn et al. (2014) stated that the AVQI is a robust measure that is free from the influence of language. In the Indian context, Benoy and Jayakumar (2017) reported AVQI value of 3.03 (± 0.32) in 120 phononormic individuals in the age range of 20-

50 years and reported no significant effect of the language of the participants on the obtained AVQI.

Latoszek, Staniene, Maryn, Petrauskar and Uloza (2017) investigated the influence of age and gender on AVQI and DSI in 68 female and 55 male vocally healthy participants. Voice samples for AVQI were collected using Praat software on sustained vowel and continuous speech task whereas for DSI was collected using lingWAVES software (WEVOSYS, Forchheim, Germany) on sustained vowel task only. Results revealed that the AVQI had no significant effect on age and gender which implies that AVQI does not depend on age and gender whereas DSI had the significant effect on age only and no gender effect. Similarly, Benoy and Jayakumar in 2017 also reported that AVQI is independent of age and gender in Indian context.

Acoustic Voice Quality Index in children

Three to nine percent of the children have voice disorders, and the prevalence is more in boys than the girls (Carding, Roulstone, Northstone & the ALSPAC study team, 2006). The growth of anatomical structures including laryngeal and respiratory structures are rapid in children which lead to changes in the voice parameters such as frequency, intensity range, and the vocal capacity (Hirano, Kurita, & Nakashima, 1983 and Lucero & Koenig, 2005). For instance, the layered structure of the vocal folds progresses to develop between 6 to 12 years and acquires a three-layered structure by 15 years of age (Gray, Hirano, & Sato, 1993). This continuous developmental change in structure and physiology of the laryngeal system in children makes it essential to develop standardized norms for them. However, very few attempts have been made in the literature to document the AVQI values in children.

Reynolds et al., (2012) is the only published study that utilized the AVQI for voice analysis in children. They compared the AVQI values in preterm participants who born less than 25 weeks of gestation in the age range of 6 to 15 years and full-term participants in the age range of 5 to 15 years. The results indicated the AVQI value of 2.98 in the full term, and 3.46 in preterm individuals and this difference was not reported to be statistically significant. The authors reported good sensitivity, specificity and diagnostic accuracy of AVQI in children with and without voice disorders.

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 AVQI is measured using the public domain software and also fulfils the requirement of usage of vowels as well as the speech stimuli for analyzing voice quality. Therefore, it is essential to establish normative data, and to investigate the efficacy of AVQI in various clinical conditions. However, there have been limited attempts made to establish reference data for this measure, especially in children.

CHAPTER III

METHOD

Participants: A total of 80 typically developing children in the age range of 10-12 years had participated in the study. These participants were divided into two groups with one year age interval (10-11 and 11-12 years) with upper limit excluded from the class interval. Each of the group had an equal number of males and females. All the participants were selected randomly from three of the schools in the Mysore city. Table 1 depicts the details of the participants.

Inclusionary criteria: The participants who fulfilled the following criteria were considered for the study

- Individuals with Kannada as their native language.
- The individual with no neurological, cognitive, oro-motor, sensory-motor, communicative or academic impairment as screened by “WHO Ten-question disability screening checklist” (WHO, 2011).
- Individuals with adequate language abilities as measured by “Assessment checklist for speech-language domain” (Swapna, Jayaram & Prema, 2010).
- Individuals with perceptually normal voice as examined by Speech Language Pathologist.

Exclusionary criteria

- The participants with active vocal tract related infections, or history of the chronic obstructive pulmonary disorder, asthma or any other lung infections were excluded from the study.

- Participants with complaints of hearing loss, any associated communication disorders, or neurological impairment were excluded from the study.

Table 1

Details of the participants.

10-11 years		11-12 years	
Males	Females	Males	Females
20	20	20	20

Stimuli: The current study included recording of the phonation of vowel /a/ as well as reading task. The standardized Kannada passage (Savithri & Jayaram, 2005) was used for the reading task.

Procedure: The recording was obtained in a quiet room within the premises of the particular school. The participants were asked to sit comfortably in the chair and to phonate vowel /a/ and read the passage at comfortable pitch and loudness. The recording was obtained using Olympus WS-550M digital voice recorder with mouth to microphone distance constantly maintained at 10 cm (Figure 2). The recording was performed at the sampling frequency of 44.1 KHz and 16 bit resolution. The recorded samples were converted from windows media audio file (.WMA) to .wav format and saved in a separate folder. The steady middle portion of the vowel /a/ for about three seconds and the first and second sentences of continuous speech task were named as 'sv'(sustained vowel) and 'cs' (continuous speech) respectively. The sustained phonation of vowel /a/ was taken for three trails, and the continuous speech task (reading of the standardized passage of Kannada) was taken for two trails. Among the given trials, those with perceptually stable vowel phonation and fluent reading by the participant's were considered for further analysis. The samples were obtained again from 10% of the participants (eight participants) with a gap of one week for the purpose of analysing the test-retest reliability of the AVQI. The obtained data from all the measures were tabulated and subjected to further statistical analysis.

Figure 1. Digital microphone placement during sample collection for AVQI

Analysis: The recorded and renamed .wav files ('sv' and 'cs') were opened in the Praat software (6.0.28 version), and AVQI was measured using the algorithm developed by Maryn et al. (2010). The script for AVQI algorithm for obtaining AVQI contains the following regression equation $AVQI = 2.571*(3.295 - 0.111*CPPs - 0.073*HNR - 0.213*SL + 2.789*ShdB - 0.032*Slope + 0.077*Tilt)$. The 'AVQI script' given by Maryn et al., (2010) was copied onto a text file, and was named as 'AVQI script'. Following the selection of 'cs' and 'sv' files, the 'AVQI script' was 'run' in the Praat software (6.0.28 version). The screenshots of the steps involved in this procedure were given under Figure 2 and 3. Figure 4 depicts the final graphical AVQI output on Praat.

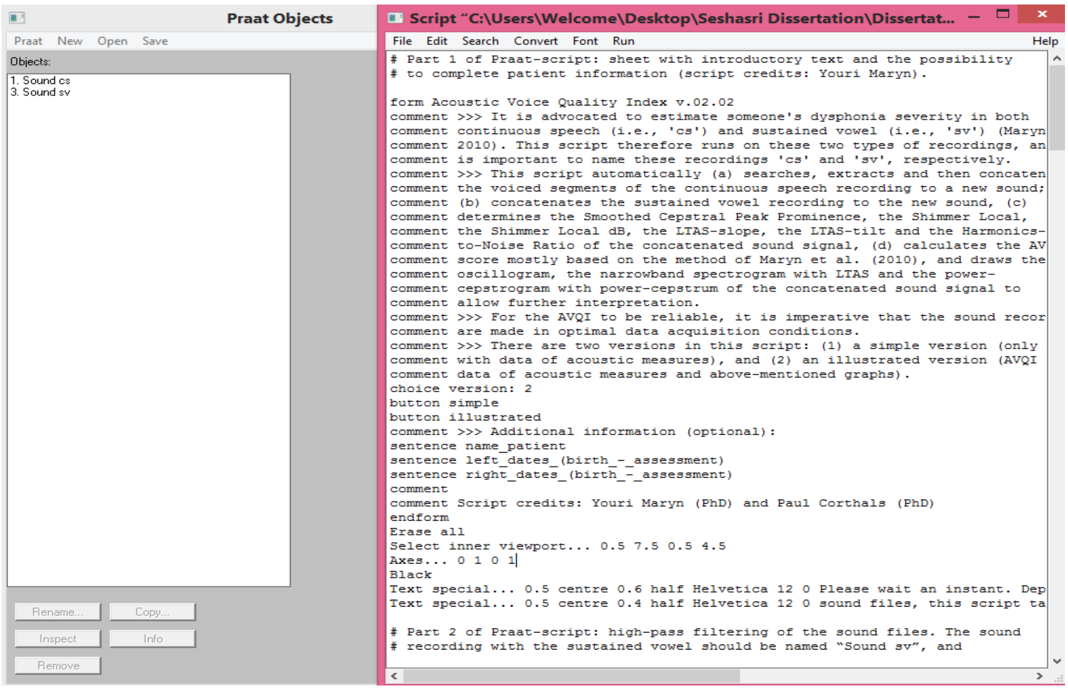

Figure 2. Screenshot revealing AVQI script being run on Praat software (cs-continuous speech & sv-sustained vowel).

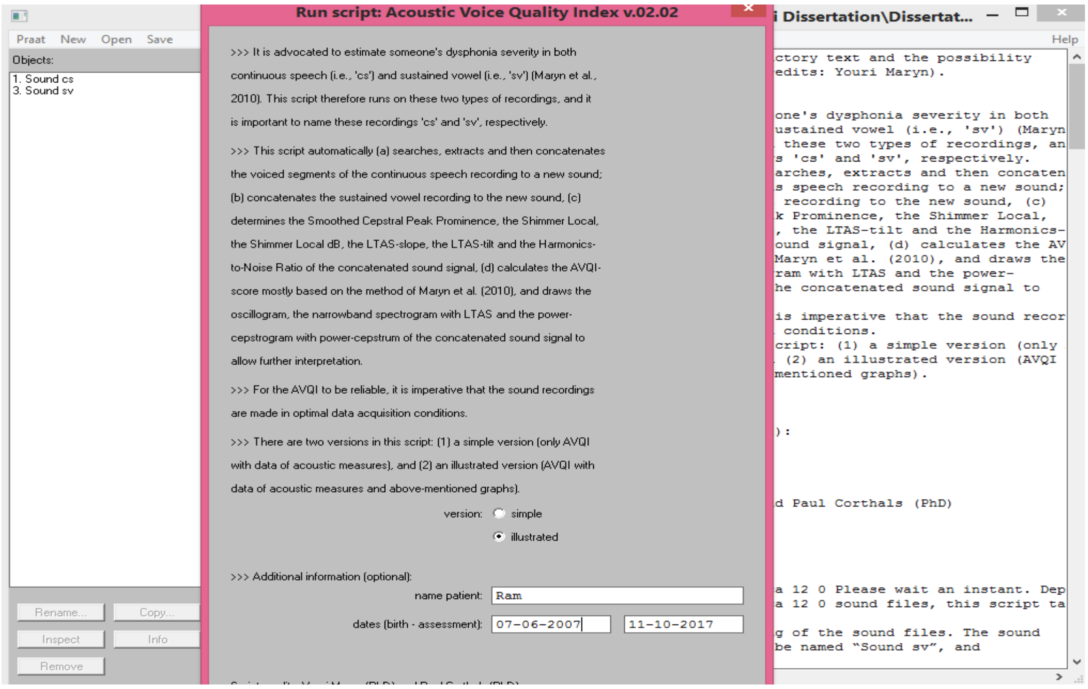

Figure 3. Screenshot revealing the entry of demographic data of the participant in Praat using AVQI script.

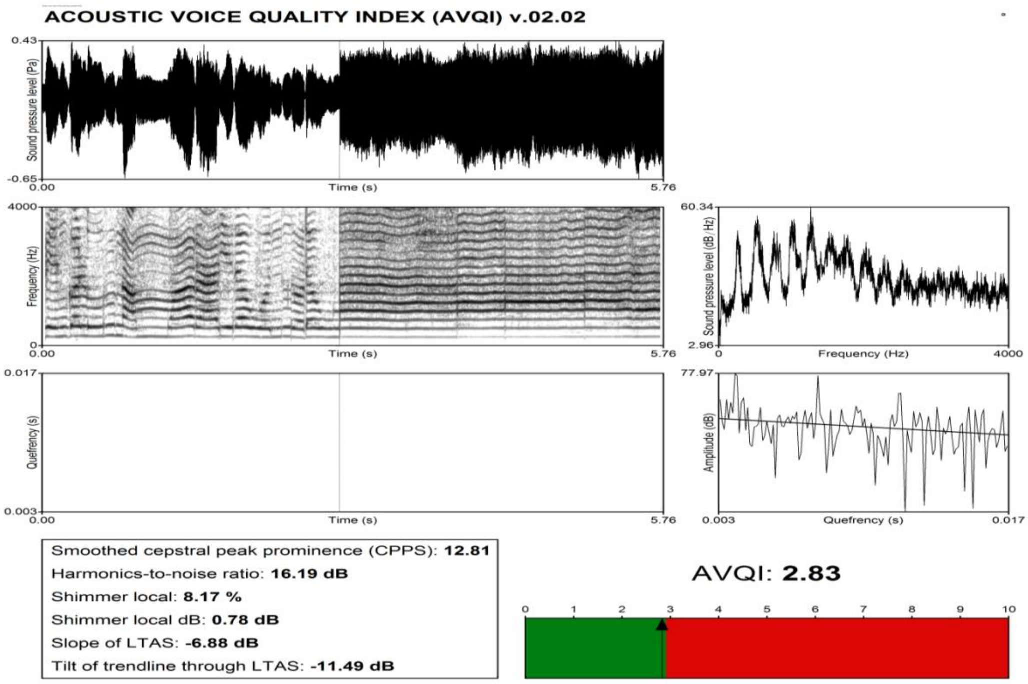

Figure 4. Graphical output of Acoustic Voice Quality Index results.

Statistical analyses

The obtained AVQI values across the participants were subjected to appropriate statistical analysis using SPSS (Version 20). In order to verify the normality of the samples, Shapiro Wilks test of normality was used. Descriptive statistics was used to deduce the average AVQI and its deviation from the average. To verify the effect of age and gender on AVQI and its six constituent parameters Multivariate Analysis of Variance (MANOVA) was performed. As MANOVA did not reveal any significant effect of age and gender observed on these parameters, the two way ANOVA was performed subsequently to verify the effect of age and gender exclusively on each of these measures. Further, Cronbach's Alpha measures was used to investigate the test-retest reliability of the AVQI.

CHAPTER IV

RESULTS

The current study involved measuring the AVQI in typically developing children in the age range of 10-12 years. The obtained data in terms of the AVQI and its constituent parameters were subjected to various statistical analyses to verify the normality of the data, test-retest reliability of the AVQI, and the effect of age, gender and age-gender interaction on the AVQI. The results thus obtained 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 respect to the independent variables such as age and gender. Results revealed that all the four subgroups with all the parameters followed the normal distribution with $p > 0.05$.

Acoustic Voice Quality Index in children in the age range of 10-12 years

The mean and standard deviation of AVQI values extracted from the samples of 80 typically developing Kannada speaking children are given under table 2. The males in the age range of 10-11 years obtained marginally higher AVQI values compared to the females in that group. Similarly, the males in the age range of 11 – 12 years also obtained slightly higher values compared to the females in that group. With reference to age, participants in older group obtained higher values of AVQI compared to those in the younger group. This trend is observed across the genders (Table 2 & figure 5).

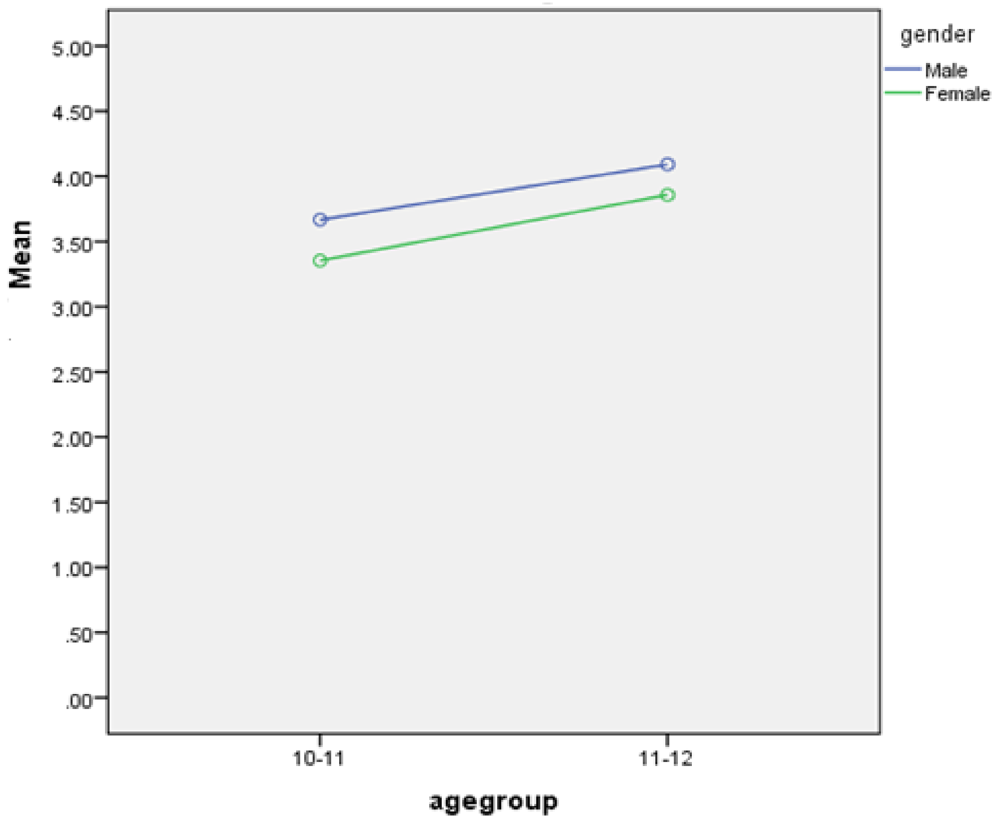

Figure 5. Effect of age and gender on of Acoustic Voice Quality Index

Table 2

Mean and standard deviation of acoustic voice quality index in children in the age range of 10-12 years.

Acoustic Voice Quality Index (AVQI)			
10-11 Years		11-12 Years	
Male	Female	Male	Female
3.66(±0.58)	3.35(0.60)	4.09(±1.03)	3.85(±0.65)

Table 3 and 4 shows the mean and standard deviation of AVQI's constituent parameters in 10-11 years and 11-12 years for males. The CPPs and HNR values in the younger males are higher than those in the elder group (11-12years), whereas, the perturbation measures (shimmer local and shimmer dB) had revealed a reverse trend with decrease in their values with increase in the age. Further, while the slope of the LTAS has increased with age, the spectral tilt increased with age (Table 3 & 4).

Table 3

Mean and standard deviation values of the constituent parameters of AVQI in males in the age range of 10-11 years.

CPPs	HNR	Shimmer local(%)	Shimmer(dB)	Slope(dB)	Tilt(dB)
11.51 (±1.09)	15.17 (±1.56)	8.75 (±1.123)	0.83 (±0.1)	-11.59 (±3.26)	-11.83 (±0.69)

Table 4

Mean and standard deviation values of the constituent parameters of AVQI in males in the age range of 11-12 years.

CPPs	HNR	Shimmer local(%)	Shimmer (dB)	Slope(dB)	Tilt(dB)
10.94 (±1.57)	14.37 (±2.39)	9.07 (±2.07)	0.87 (±0.18)	-12.57 (±2.93)	-11.79 (±0.66)

Table 5 and 6 shows the mean and standard deviation of the constituent parameters AVQI in 10-11 years and 11-12 years for females. As observed from the table, a trend was observed in which the females in the elder group obtained higher CPPs, HNR and lower shimmer local and shimmer dB compared to the younger group. Further, while the slope of the LTAS has increased with age, the spectral tilt increased with age (Table 5 & 6).

Table 5

Mean and standard deviation values of the constituent parameters of AVQI in females in the age range of 10-11 years.

CPPs	HNR	Shimmer local(%)	Shimmer(dB)	Slope(dB)	Tilt(dB)
11.98 (±1.26)	16.17 (±1.29)	7.92 (±1.13)	0.76 (±0.08)	-11.66 (±2.96)	-11.77 (±0.53)

Table 6

Mean and standard deviation values of the constituent parameters of AVQI in females in the age range of 11-12 years.

CPPs	HNR	Shimmer local(%)	Shimmer(dB)	Slope(dB)	Tilt(dB)
11.37 (±1.05)	14.56 (±2.26)	8.57 (±1.59)	0.82 (±0.12)	-11.99 (±2.92)	-11.70 (±0.50)

Effect of age and gender on AVQI

The results of MANOVA did not reveal a significant effect of either age or gender on the AVQI and its constituent parameters (table 7).The subsequent two way ANOVA on the individual parameters indicated a significant effect of age only on the AVQI [F (1, 76) = 7.855, $p < 0.05$], CPPs [F (1, 76) = 4.371, $p < 0.05$], and HNR [F (1, 76) = 7.693, $p < 0.05$] (table 8). The results however, did not reveal any significant main effect of gender on any of the obtained AVQI and its constituent parameters (table 8). Further, no age and gender interaction effect was revealed for AVQI or its constituent parameters ($p > 0.05$).

Table 7

Multivariate analysis of the effect of age, gender and their interaction on AVQI and its constituent parameters.

Effect	Wilk's Lambda	F (7, 70)	*P*
Age	.852	1.744	.113
Gender	.925	.812	.580
Age * Gender	.976	.250	.970

Table 8

Effect of age and gender on AVQI and its constituent parameters as measured by subsequent two way ANOVA.

Parameter	Effect of age		Effect of gender		Interaction of age and gender	
	F	*P*	F	*P*	F	*P*
AVQI	7.855	*.006	2.723	.103	.057	.812
CPPs	4.371	*.040	2.584	.112	.007	.935
HNR	7.693	*.007	1.872	.175	.883	.350
Shimmer Local	1.985	.163	3.822	.054	.232	.632
Shimmer dB	2.481	.119	4.052	.048	.119	.731
Slope	.928	.338	.138	.712	.231	.632
Tilt	.167	.684	.339	.562	.016	.899

**p <0.05 indicative of statistically significant effect*

Test-Retest reliability of acoustic voice quality index

In order to verify the test-retest reliability of the AVQI, recordings were repeated on 10% (08) of the randomly selected participants. Cronbach's alpha test was carried out to compute the reliability coefficient 'α' for AVQI. A Cronbach's Alpha coefficient 'α' of more than 0.7 and above is considered as statistically reliable. In the present study, the Cronbach's alpha for AVQI was found to be above 0.7 (0.891), indicating 'good' test retest reliability for AVQI.

CHAPTER V

DISCUSSION

Literature indicates that the multiparametric measures such as dysphonia severity index, cepstral spectral index for dysphonia and acoustic voice quality index are reliable and valid for assessing the voice quality and quantifying dysphonia severity compared to that of those parameters in unison. Further, the multiparametric measures are preferred over the single parametric measures as the latter considers the multi-dimensional nature of the voice quality and describe the voice quality in defined single values. The AVQI is considered to be more ecologically valid as it involves the use of continuous speech sample along with the sustained vowel for voice analysis. Therefore, the present study aimed at investigating the AVQI values in typically developing Kannada speaking children in the age range of 10-12 years. The following section describes the obtained results with reference to their physiological relations and with reference to the existing literature in the acoustic analysis of voice quality.

Acoustic Voice Quality Index in children in the age range of 10-12 years

The average AVQI value obtained in the current study in Kannada speaking children in the age range of 10-12 years was 3.74. This AVQI value obtained in the current study is in concordance with that reported by the Reynolds et al. (2012) for English speaking pediatric population in the age range of 6-15 years who reported a median AVQI value of 3.0 with Q_1-Q_3 at 2.5-3.4. Further, they reported AVQI value of 3.46 as the best cut-off with good sensitivity, specificity, accuracy and likelihood ratios. This similarity in the findings irrespective of the participant's language indicates that the AVQI value is independent of the language. Similar findings were reported in the literature by Maryn et al. (2010, 2014); Reynolds et al., (2012); Barsties and Maryn, (2012), Hosokawa et al., (2017) and Benoy and Jayakumar (2017) reported that AVQI is independent of language. With respect to the gender, the males obtained AVQI value of 3.66 (± 0.58) and 4.09(±1.03) in 10-11 years and 11-12 years respectively. Similarly, the females obtained AVQI value of 3.35(±0.60) and 3.85(±0.65) in 10-11 years and 11-12 years respectively. This indicates that the elder participants obtained higher AVQI values than that of the younger counterparts which is true with respect to both males and females. The higher value of AVQI in the elder participants indicates that they have a relatively poor quality of voice than those children in the younger age group.

Effect of age on Acoustic Voice Quality Index

Results of the current study indicated a significant effect of age of the participants on AVQI. This relatively poorer voice quality in elder children can be attributed to the onset of mutational changes in these children. Studies performed on children in the mutational transition phase revealed marked unstable and poor voice quality with pitch breaks in them both in terms of perceptual as well as on objective findings (Curry, 1949; Senturia & Wilson, 1968; Kambic, Radsel, Gale, 1989 and Silverman & Zimmer, 1995). For instance, Boltezar, Burger and Zargi (1997) reported elevated instability in voice especially with reference to the fundamental frequency and intensity and attributed it to the rapidly growing structures of the voice production. They hypothesized that speech apparatus and nervous control develops at different phases during the adolescence. They opined that "instability in the voice in adolescence due to the rapid growth of the speech apparatus, which is gradually followed by the adaptation of the nervous control of the apparatus".

Further, in the current study, the constituent parameters of the AVQI such as the CPPs, HNR, shimmer local, shimmer dB, slope and tilt of long-term average spectrum also revealed better values in the younger participants. Thus, indicating a strong consistency irrespective of the measured parameter. The changes in the values of the AVQI's constituent parameters can be attributed to significant anatomical dimorphism of the vocal tract during the pre-pubertal stage (Vorperian, Wang, Schimek, Durtschi, Kent, Gentry & Chung, 2011). Therefore, it would be interesting to investigate the AVQI and its constituent parameters further in the elder children of 12-18 years.

The finding of the compromised voice quality in the elder age group in the current study is in consensus with the earlier studies reported in the literature (Weiss, 1950; Schilling & Karthaus, 1961; and Pederson, Agersted & Jonsson, 2015). However, this result is not in coherence with the study by Reynolds et al., (2012). The age range of the participants in their study is wide (6-15 years) with the median age around 11 years. So the incoherence in the results of our study with the earlier study can be attributed to this wide age range.

Effect of gender on Acoustic Voice Quality Index

There was a trend observed in which the females obtained slightly lower AVQI values compared to that of their male counterparts in both the age groups. Thus indicating that the voice quality in females was slightly better compared to the males. However, this difference is not found to be statistically significant. This can be attributed to the similarity in terms of height and weight between the male and female children in the age range of 8–12 years (Stathopoulos & Sapienza, 1997). This finding in the current study is in coherence with the earlier studies by Reynold et al., (2012), Barties and Maryn, (2012); Maryn et al., (2014); Benoy & Jayakumar, (2017) and Latoszek et al. (2017). For instance, Latoszek et al. (2017) reported that the investigation of AVQI in 68 female and 55 male participants in the age range of 20 to 79 years revealed no significant gender effect on AVQI. However, this finding is in contradiction to some of the physiological findings reported by Huber, Stathopoulos and Curoine (1999) who revealed that mutational changes starts much earlier for females around 10-12 years and later around 12-14 years in males. Similarly, in terms of aerodynamic aspects of voice production, females tend to have small lung dimensions compared to the males at the age of 10 years (Stathopoulos & Sapienza, 1993).

Test-Retest Reliability of Acoustic Voice Quality Index

In the present study, test-retest reliability of AVQI was found to be very good (Cronbach's alpha "∝" = 0.891). The literature reported that a high test–retest reliability value as a pre-requisite for any type of validity measurements as it indicates the robustness and reliability of the measure used. This finding is in coherence with the earlier studies which reported low test–retest variability with the confirmed excellent re-measurement reliability of AVQI (Barties & Maryn, 2012; Lee et al., 2017; and Benoy & Jayakumar, 2017).

CHAPTER VI

SUMMARY AND CONCLUSIONS

Acoustic voice quality index is a multiparametric measure derived by the weighted combination of six constituent parameters such as CPPs, HNR, Shimmer local, Shimmer dB, Slope and Tilt of LTAS. It uses a scale ranging from 0 to 10 to quantify the voice quality in which 0 indicates normal voice quality and 10 indicates severe dysphonia. Primary advantage of AVQI over other multiparametric measures is the inclusion of continuous speech along with phonation to arrive at single defined value. Literature suggested that even though AVQI includes continuous speech task, it is independent of language. However, there is dearth of studies on AVQI in pediatric population. Therefore, the current study was taken up with the aim of establishing normative data for Kannada speaking children in the age range of 10-12 years and also to examine the effect of age and gender on AVQI.

Results indicated that the mean and standard deviation of AVQI in males were 3.66(±0.58) and 4.09(±1.03) in 10-11 years and 11-12 years respectively. Similarly, in females mean and standard deviation were 3.35(0.60) and 3.85(±0.65) in 10-11 years and 11-12 years respectively. The males in the age range of 10-11 years obtained marginally higher AVQI values compared to the females in that group. Similarly, the males in the age range of 11-12 years also obtained slightly higher values compared to the females in that group. With respect to age, participants in older group obtained higher values of AVQI compared to those in the younger group. This trend was observed across the genders. This relatively poorer voice quality in elder children can be attributed to the onset of mutational changes in these children. This finding is in support with the studies which reported marked unstable and poor voice quality with pitch breaks in terms of both perceptual as well as on objective measures during this mutational transition phase.

Implications of the study: The current study established the normative data for AVQI in Kannada speaking children in the age range 10-12 years. The result of the present study facilitates the understanding of the effect of age and gender on AVQI.

Limitations and future directions: The scope of the current study is confined to children in the age range of 10-12 years; however, considering the age related variations in the AVQI, it is warranted to be measured in other age ranges from 12-19 years to understand the AVQI as function of age. Further, the normative and cut off values for AVQI needs to be established across the other age groups including geriatric population. Considering the dearth of studies verifying the clinical robustness and application of AVQI, future studies are recommended towards identifying the validity, sensitivity, specificity, accuracy and likelihood ratio's and cut off scores have to be established for this parameter Indian population across the age range.

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