ACOUSTIC VOICE QUALITY INDEX (AVQI) FOR KANNADA AND MALAYALAM SPEAKING NORMOPHONIC CHILDREN

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Register no: P01II22S123033

A dissertation submitted in part Fulfillment of Degree of

Master of Science (Speech Language Pathology)

University of Mysore, Mysuru

All India Institute of Speech and Hearing

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July, 2024

CERTIFICATE

This is to certify that this dissertation entitled **"Acoustic Voice Quality Index (AVQI) for Kannada and Malayalam speaking Normophonic Children"** is a bonafide work submitted in part Fulfillment of Degree of Master of Science (Speech Language Pathology) of the student Registration number: P01II22S123033. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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July, 2024

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DECLARATION

This is to certify that this dissertation entitled **"Acoustic Voice Quality Index (AVQI) for Kannada and Malayalam speaking Normophonic Children"** is the result of my own study under the guidance of Dr. T. Jayakumar, Professor in Speech Sciences, Department of Speech- Language Sciences, 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

July, 2024

Registration number: **P01II22S123033**

ACKNOWLEDGEMENT

I thank ***God almighty*** for giving strength and helping me throughout this rollercoaster of a journey.

I thank my parents, ***Kuttan*** & ***Miniyamma,*** and ***Kichu*** for their unwavering faith and support they gave me for all these years and for making me the person who I am today. ***Zimba,*** my personal stress buster and constant companion.

I would like to thank my guide, ***Dr. T. Jayakumar***, for letting me choose him. You are really the humblest person I have ever known. You were always calm and composed even while correcting the simplest of my mistakes. I am deeply thankful to your guidance for the smooth completion of my dissertation and I consider the time under your mentorship as an invaluable experience sir.

Sincere thanks to ***Dr. M. Pushpavathi***, for permitting me to conduct my research.

I also wish to extend my heartfelt gratitude to ***Dr. Vasanthlakshmi ma'am,*** statistician, for helping me with the results of my study.

I thank ***Jesnu sir,*** for giving me his best valuable inputs and helping me out several times from the beginning of my research journey. I consider you as my second guide sir.

I extend my heartfelt gratitude to all the school principals of both Kerala and Karnataka, for granting me permission to collect data from their respective schools. In particular, I would like to thank ***Ms. Geetha Devi Varma***, Principal of Chinmaya Vidyalaya, my own former school, for her invaluable assistance in facilitating a smooth data collection process.

I also thank all the participant ***kids***, without whom I could never have completed my dissertation.

I thank my dearest of friends ***Sniktha, Sruthi*** and ***Shalabha,*** for always having my back. I also thank my dissertation partners ***Muskan*** and especially ***Moksh,*** for his constant support from the inception of my dissertation.

I thank all my ***'B section' girlies*** for their brimming positivity and companionship.

This dissertation would not have been possible without the collective efforts and support of everyone mentioned.

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ABSTRACT

This study aimed to establish normative data for the Acoustic Voice Quality Index (AVQI) version 03.01 in typically developing Kannada and Malayalam-speaking children, analyzing the effects of gender, language, and age groups. The study included 180 children aged 5-8 years, equally divided by gender and language into three subgroups of age with one year age interval. Acoustic samples of sustained vowels and continuous speech were analyzed using Praat software. The mean AVQI value was 3.97 (± 0.87) for the age range considered. While gender, language, and age did not significantly affect overall AVQI values, specific parameters like Shimmer dB, Shimmer local, and LTAS measures showed significant differences. The lack of significant language differences might be due to both languages belonging to the Dravidian family. This study provides important pediatric normative data for AVQI (v03.01), aiding in pediatric voice assessments in these languages.

CHAPTER I

INTRODUCTION

Human voice is defined as the audible sound produced by the vibration of the vocal folds resulting in the physical act of sound production (Aronson, 2011). Voice serves as the means through which verbal expression is manifested. The speaking voice inherently communicates details about the individual, with voice quality being a key method through which speakers express their physical, psychological, and social traits to others (Laver, 1980). A significant difference in one's voice with respect to the quality, pitch or loudness in comparison to normative data implies that he/ she may have dysphonia (Coyle, Weinrich & Stemple, 2001).

Speech Language Pathologist (SLP) who deals with dysphonic patients, needs to conduct a comprehensive assessment so as to arrive at the correct diagnosis which will later provide basis for that patient's management. Comprehensive analysis should include both perceptual evaluation by an SLP and objective analysis by means of instruments which can be substantiated by the patient's self-perceptual analysis (Lechien et al., 2023).

The subjective or perceptual analysis is carried out by an SLP on the basis of the comparison of the voice sample of the patient to that of normal voice characteristics in his/ her mental reference. Some of the widely used perceptual rating scales are GRBAS scale (Hirano, 1981), Consensus Auditory Perceptual Voice Evaluation scale (Kempster et al., 2009), Vocal Profile Analysis (VPA) (Laver, 1991) and Buffalo Voice Screening Profile (Wilson, 1987).

While perceptual evaluation of voice is considered as the gold standard (Oates, 2009) in the evaluation of individuals with dysphonia, it is also susceptible to variety of variations stemming from factors such as differences in the listeners, subjects, or tasks. In contrast, acoustic measurements of voice offer additional benefits such as non-invasiveness and ease of use, making them a valuable tool in the assessment of voice.

Acoustic analysis of voice includes several spectral and cepstral parameters which can be used to scale the severity of dysphonia and this data can be utilized in monitoring improvements in voice quality of the patient. Therefore, according to Carding et al. (2009), acoustic measures serve as one of the most reliable ways through which quality of voice can be objectively measured.

Regardless of most of the acoustic parameters being easy for analysis and interpretation, it is found to have poor correlation with perceptual analysis. Also, it lacks test- retest reliability (Karnell, Hall, & Landanl, 1995; Bauser & Drinnan, 2011; Bough et al., 1996). However, these parameters were reported to be more effective when used in weighted combinations of multiparametric measures for voice quality.

Wutys et al. (2000) developed one such multiparametric measure known as the Dysphonia Severity Index (DSI) which is a diagnostic tool that measures the severity of dysphonia in an individual. Several studies have reported DSI to give a robust diagnostic measure (Timmermans et al., 2004). Hakkesteegt et al. (2008) has reported the mean DSI scores are also well correlated with the perceptual measures available. Sobol and Sielska-Badurek (2022) has reported a mean normative value of DSI to be 3.05 in their meta-analytical study. DSI value reflects the voice quality of a particular individual based on the Maximum Phonation Time (MPT), highest frequency, lowest intensity and jitter. A normative reference data for DSI in Indian population has been developed by Jayakumar and Savithri (2012).

Maryn et al. (2010) sought to study the viability and diagnostic accuracy by combining continuous phonation with speech in the assessment of quality of voice through a recently introduced technique, the Acoustic Voice Quality Index (AVQI). The six parameters assessed in AVQI are Smoothed Cepstral Peak Prominence (CPPS), Harmonics-to-Noise Ratio (HNR), Shimmer Local (SL), Shimmer local dB (ShdB), slope of long-term average spectrum (slope) and tilt of the trendline through the long-term average spectrum (tilt). AVQI possesses a script designed for the automated assessment of dysphonia severity, utilizing an analysis of a combined sample involving sustained vowel and connected speech. Hence, AVQI is constructed with the following formula: “AVQI = 2.571*(3.295-0.111*CPPS - 0.073*HNR - 0.213*SL + 2.789*ShdB - 0.032*Slope + 0.077*Tilt)” (Maryn et al., 2010). This script is exclusively compatible with Praat software. A score of 2.95 or below obtained on AVQI identifies the sample to be normophonic adults as proposed by the authors. The AVQI score, ranges from 0 to 10, serves as an indicator of voice severity, with 0 representing normal voice and 10 signifying profoundly abnormal voice on the severity continuum.

A positive correlation of approximately 0.78 was identified between AVQI and the G parameter of GRBAS. This indicates that as the AVQI score increases, reflecting a higher degree of disturbance, there is a corresponding deterioration in overall voice quality, and conversely, a lower AVQI score is associated with better voice quality (Maryn et al., 2010).

Version 03.01 of AVQI has undergone significant modifications, particularly in the adjustment of parameter weights, leading to its current form. AVQI holds good diagnostic accuracy and cross- linguistic validity (Maryn et al., 2014). The script for obtaining AVQI (v03.01) published by Barsties and Maryn (2015b), contains the formula, "AVQI = (4.152- (0.1777* CPPs) – (0.006* HNR) – (0.037* Shim) + (0.941* ShdB) + (0.01* Slope) + (0.093* Tilt) * 2.8902".

Jayakumar & Benoy, (2022) has reviewed eight studies investigating AVQI (v03.01) and found the overall sensitivity and specificity of 0.85 and 0.92 for AVQI (v02.02) and 0.82 and 0.92 for AVQI (v03.01). Also found the area under the curve was found slightly better for AVQI (v03.01) (0.94) than AVQI (v02.02) (0.92). The diagnostic threshold of AVQI (v02.02) is within the range of 2.72 to 3.33 while, in case of AVQI (v03.01), it is found to be in the range of 1.33 to 3.15 (Jayakumar & Benoy, 2022).

AVQI v02 does not have an effect on gender as reported by Latoszek et al. (2019). The result was in consensus with the study done by Shabnam and Pushpavathi (2021) in AVQI and DSI in the Indian context even though there was significant effect seen in their individual parameters. Jayakumar et al. (2022) also reported that there is no effect of gender on AVQI (v02.02), however, his study across the lifespan revealed that age can have an impact on AVQI (v02.02).

There are numerous studies that reports AVQI values in adult population. In Indian context, Benoy (2017) has developed and validated an AVQI (v02.02) reference data with perceptual measurements between normal voice quality and dysphonia. Vishali, (2019) has established standard reference data for AVQI (v02.02) in native Tamil speakers between the age range of 20 to 50 years.

On the other hand, there is dearth in studies among pediatric population focusing on their voice quality even when there are notable differences between adults and children, primarily due to anatomical variations also the usage of voice. Significant anatomical alterations along with the changes in the laryngeal size, occurs simultaneously during the pre-pubertal period that will have an aftermath in the acoustic measurement (Glaze et al., 1988). The intermediate and deep layers of lamina propria is not fully differentiated until the age of 10 years (Hirano et al., 1985). Also, the depth of the individual layers change with maturation. Boseley and Hartnick (2006) found that at the age of seven years, the superficial layer's depth makes up about 22% of the total depth of the lamina propria, which is similar to the proportion found in adult vocal folds.

Both boys and girls will go through a period of mutation and the difference noted between the two genders can be seen as early as pre-school age. Studies have found a drop in the fundamental frequencies of boys by approximately 12 semitones and by about 3-4 semitones in girls (Sjölander & McAllister, 2013).

The stages of childhood and adolescence are crucial periods for the development of both vocal quality and speech. An abnormal voice quality suggests that the child may have either a functional or organic voice disorder (Sjölander & McAllister, 2013). It is important to better understand the normal process of vocal development as any case of dysphonia in children could interfere with their communication skills which are fundamental for their social and intellectual development.

According to Reynolds et al. (2012) in a pediatric population, AVQI (v02.02) is found to have diagnostic accuracy, which makes the tool appropriate for determining the presence and severity of voice disorders in pediatric population.

Seshasri, (2018) has established normative data for AVQI (v02.02) for Kannada speaking typically developing children in the age range of 10 -12 years. However, there is paucity in AVQI (v03.01) data in pediatric population which could prove to be resourceful in pediatric voice assessment.

Furthermore, Jayakumar & Savithri (2012) has studied the impact of geographical and ethnic variations considering the potential for differences in the fundamental parameters of DSI and results of the study urge the clinicians to establish normative data tailored to individuals within specific regions, ethnicities, language, ages and genders.

Need for the study

To date, studies carried out in adult population have found that AVQI (v02.02) is independent of gender (Jayakumar & Benoy, 2022) and considering the fact that there is the paucity in pediatric normative reference data, the current study is taken up with the aim of establishing the normative data for AVQI (v03.01) in Malayalam and Kannada speaking typically developing children of Indian population.

Aim of the study

The aim of this study is to establish a normative reference data for AVQI (v03.01) in normophonic Kannada and Malayalam speaking children among Indian population.

Objectives of the study

i. To determine AVQI scores of normophonic children of three age groups (5-6 years, 6-7 years & 7-8 years).

ii. To compare the AVQI scores obtained for the three age groups of children.

iii. To compare the AVQI scores obtained for boys and girls.

iv. To compare the AVQI scores obtained for the Malayalam speaking children and the Kannada speaking children.

CHAPTER II

REVIEW OF LITERATURE

Human voice is assessed on the basis of factors such as quality, pitch, loudness and other attributes. A significant change in one's voice with respect to any of these attributes in comparison to normative data implies that he/ she may have dysphonia (Coyle, Weinrich & Stemple, 2001). The voice quality is a multidimensional perceived construct through which speakers express their physical, psychological, and social traits to others (Laver, 1980). Quality of voice can be measured either through a subjective assessment or by an objective measurement, which involves using specific algorithms to quantify certain aspects related to vocal production (Barsties & De Bodt, 2015). A Speech Language Pathologist often tend to devise a comprehensive evaluation of voice, including perceptual, as well as, acoustic analysis, along with the visual examination of larynx by an otolaryngologist.

Perceptual evaluation of Voice

The voice characteristics are subjectively judged to be normal by a trained SLP in a perceptual evaluation. Unlike many instrumental measures, the perceptual properties of voice have much more intuitive meaning and shared reality among listeners (Oates, 2009). Despite its widespread use, perceptual evaluation of voice has faced significant criticisms also, because it is subjective. There are several factors which could affect the listener reliability such as the rating scale being used, the voice sample being assessed, the evolving internal standards of the listener and so on.

The four most used scales documented in the literature are Grade, Roughness, Breathiness, Asthenia, Strain (GRBAS) scale (Isshiki, Okamura, Tanabe, Morimoto, 1969; Hirano, 1981), Vocal Profile Analysis (VPA) (Laver, 1991); Buffalo Voice Screening Profile (Wilson, 1987); and Consensus Auditory Perceptual Voice Evaluation (CAPE- V) scale (Kempster et al., 2009).

Grade, Roughness, Breathiness, Asthenia, Strain (GRBAS) scale

The Committee for Phonatory Function Tests of the Japanese Society of Logopedics and Phoniatrics proposed the GRBAS scale (Hirano, 1981). It uses a four-point rating scale for all five characteristics, ranging from 0 (normal) to 3 (extreme), and is intended as a minimum examination of voice quality. Every measure pf the scale denotes a different aspect of phonation: R stands for roughness, B for breathiness, A for asthenic (weakness), S for strain, and G (Grade) for the overall severity of the voice (Hirano, 1981).

Vocal Profile Analysis (VPA) Scheme

A trained listener may both describe and analyse conversational or reading voice quality using the descriptive technique known as Vocal Profile Analysis (VPA) Scheme (Laver, 1991). It gives a detailed analysis of vocal tract configurations including at the laryngeal and supra-laryngeal levels as well as in the prosodic parts of vocal function are thought to contribute to the overall impression of voice quality. Each element of voice is evaluated against a predetermined "neutral" baseline, with a numerical value assigned to each characteristic.

The Buffalo Voice Screening Profile (BVSP)

The Buffalo Voice Screening Profile (BVSP) (Wilson, 1987) was developed to systematically analyze twelve key elements of voice production such as Laryngeal tone, Pitch, Loudness, Nasal resonance, Oral resonance, Breath supply, Muscles, Voice abuse, Rate, Speech Intelligibility, Speech anxiety and overall Voice rating, on an equal-appearing interval scale of five points, ranging from 1 (normal) to 5 (very severe). The inclusion of parameters unrelated to the voice quality of an individual is the major limitation of using this scale for evaluation (Carding et al., 2000).

Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) scales

Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) scales (Kempster et al., 2009) developed by the American Speech-Language-Hearing Association, to encourage a consistent method for the assessment and recording of auditory-perceptual evaluations of voice quality. The ratings are carried out on a visual analog scale of 1- 100mm on aspects of voice quality such as overall severity, roughness, breathiness, strain, pitch and loudness.

Kelchner et al. (2010) conducted a prospective study to check the inter- and intra-rater reliability of CAPE-V in pediatric patients with severe voice disorders post-laryngotracheal reconstruction. They found that the tool showed robust inter-rater reliability across four out of six vocal parameters assessed. They also noted that, the parameter of strain was comparatively more difficult to be rated on the basis of auditory sample alone.

GRBAS may be the preferable option for clinical or research purposes where time efficiency is crucial, because, the GRBAS is found to be faster in assessing the voice problems compared to the CAPE-V. The fact that CAPE-V uses a visual analog scale of 1-100mm, posits a potential for reduced test-retest reliability. At the same time, GRBAS has a 4-point rating scale, which is of advantage in this aspect (Nemr et al., 2012).

The study done by Webb et al. (2003b) examined, in a controlled experiment setting, the optimal reliability of skilled judges using the three common auditory rating scales such as The Buffalo Voice Profile, The Vocal Profile Analysis Scheme (VPA) and GRBAS. Results of the study supported the use of GRBAS as a simple and reliable clinical tool, for the reason that it was reliable in all its parameters except for Strain ($\kappa = 0.48$).

According to Carding et al. (2000), the drawbacks of GRBAS scale is that it includes rating of the parameters only at the laryngeal level; supra-glottic factors are not scored. Additionally, it leaves out the rating for parameters of pitch and loudness.

While perceptual evaluation of voice is considered as the gold standard (Oates, 2009) in the evaluation of individuals with dysphonia, it is also susceptible to variety of variations stemming from factors such as differences in the listeners, subjects, or tasks. However, the findings from perceptual evaluation is indispensable in complimenting the findings from an objective evaluation in patients with voice disorders.

Objective evaluation of Voice

Objective evaluation involves the use of instruments and techniques to quantitatively measure the vocal parameters such as frequency related measures (fundamental frequency, habitual frequency, frequency range etc), amplitude related measures (habitual intensity, intensity range etc), perturbation measures (jitter, shimmer etc) and harmonics related measures (Harmonic-to-Noise ratio etc). The findings of objective evaluations are crucial to substantiate the subjective measures of voice quality as part of a comprehensive assessment. It proves to be essential for diagnosing a voice disorder, keeping track of the treatment progress and in conducting clinical research, as they provide reproducible results independent of subjective interpretations.

It can be either invasive or non-invasive technique. Invasive methods include Laryngoscopy, Videostroboscopy and some aerodynamic measurements such as Sub-glottal Pressure measurement. Non-invasive measures mainly include acoustic evaluation of voice, Electroglottography etc.

The acoustic voice analysis offers an objective and quantitative assessment of voice, making it valuable for both clinical applications and research purposes (Yu, Ouaknine, Revis & Giovanni, 2001). It has an advantage over perceptual measures with the fact that they are least subjective and thus offer better reliability and uniformity in diagnostic examinations across different settings and practicing clinicians.

The correlation between the perceptual and objective measures have been studied several times in the literature. The study by Bhuta, Patrick and Garnett (2004) focused on the perceptual evaluation of voice quality using GRBAS and its correlation acoustic measurements using Multi-Dimensional Voice Program (MDVP) retrospectively including 37 participants. A correlation was found between the 'G' of GRBAS scale and voice turbulence index (VTI), noise harmonic ratio (NHR), and soft phonation index (SPI) while 'R' was correlated with NHR and 'B' and 'A' with SPI only.

Nonetheless, study by Bauser & Drinnan (2011) reported limited validity and reliability for acoustical measures for voice quality. The significant variations in correlations between the perception of overall voice quality and acoustic measurements questions the validity and usefulness of these acoustic indicators (Kreiman & Gerratt, 2000a).

In their meta-analysis Maryn et al. (2009) assessed the relationship between perceptual and acoustic measurements of overall voice quality and determine whether a combination of acoustic measures, especially cepstral and spectral measures, could provide more accurate and reliable diagnostics for voice disorders compared to using individual acoustic measures alone. A total of 25 study reports were included for the analysis. They considered four measures which followed the homogeneity, such as the Pearson autocorrelation peak, pitch amplitude, spectral flatness of residue signal, and smoothed cepstral peak prominence for analysis of sustained vowel studies. The measures that satisfied homogeneity for continuous speech are signal-to-noise ratio from Qi, cepstral peak prominence, and smoothed cepstral peak prominence. Findings of this study concluded that a multiparametric approach enhances the diagnostic accuracy and better reflects the perceptual evaluations, promising a better clinical outcome for the patients with voice disorders.

Awan et al. (2010) aimed in quantifying varying degrees of dysphonia in 24 voice disordered participants, using a spectral/cepstral acoustic index and in determining how well this index correlated with perceptual evaluations made using CAPE-V by expert listeners. The spectral and cepstral measures demonstrated a high diagnostic accuracy for identifying the dysphonia severity, and especially the CPP, was a strong predictor of voice quality. Thus, the indices were proved to be a clinically relevant and valid indicator for severity of dysphonia.

Furthermore, multiple researchers have suggested that utilizing multiparametric measurements, which integrate several objective parameters, might be more effective in evaluating voice quality than using single-parameter measurements (Michaelis, Frohlich & Strube, 1998; Klein, Piccirillo & Painter, 2000; Yu, Ouaknine, Ravis & Giovanni, 2001; Yu, Ravis, Wuyts, Zanaret & Giovanni, 2002). Literature reports few such multiparametric measures of voice quality including Dysphonia Severity Index (DSI) (Wuyts et al., 2000), Cepstral Spectral Index of Dysphonia (CSID) (Peterson et al., 2013) and Acoustic Voice Quality Index (AVQI) (Maryn et al., 2010).

Cepstral Spectral Index of Dysphonia (CSID)

Cepstral Spectral Index of Dysphonia (CSID) (Peterson, Roy, Awan, Merrill, Banks & Tanner, 2013) is a multivariate estimate of the dysphonia severity, which utilizes both sustained vowels as well as connected speech. CSID involves various components such as cepstral and spectral parameters like Cepstral Peak Prominence (CPP), the low-to-high spectral energy ratio (L/ H spectral ratio) and its standard deviation, derived separately from sustained vowel and connected speech samples. It automatically estimates the dysphonia severity for each of the tasks. The CSID value ranges from 0 to 100, and at times, values lesser than and greater than it is generated, indicating an extremely periodic and profoundly aperiodic voice respectively.

Dysphonia Severity Index (DSI)

Wuyts et al. (2000) developed a multiparametric measure known as the Dysphonia Severity Index (DSI), which reflects the voice quality and measures the severity of dysphonia based on its components such as Maximum Phonation Time (MPT in s), highest frequency (F0-High in Hz), lowest intensity (I-Low in dB) and jitter (%). The authors constructed this measure based on a multivariate analysis of 387 participants. The weighted multiparametric regression equation for DSI = 0.13 x MPT + 0.0053 x F0-High – 0.26 x I-Low – 1.18 x Jitter (%) + 12.4 (Wuyts et al., 2000). The DSI scores ranges from +5 (perceptually normal voice) to -5 (severely dysphonic voice). As the scores obtained reflect an individual's voice quality, the poorer the scores obtained, the more severe his or her voice is considered dysphonic.

Hakkesteegt et al. (2008) studied the utility of DSI in assessing the severity of dysphonia, in 294 participants with different voice pathologies, by comparing the scores obtained with ‘G’ of the GRBAS scale. The experiment group was found to have lower DSI values and higher grades on the GRBAS scale when compared to the control group. They calculated a maximum sensitivity of 0.72 and a specificity of 0.75 with a cut-off point of 3.0.

The correlation between DSI with gender and perceptual evaluation data using CAPE-V was studied by Nemr et al. (2016). They recruited 66 Brazilian adults (with and without voice disorders) of both genders for their study. Results of this study showed that DSI was well able to discriminate between individuals with and without voice disorders. Even though the mean MPT was higher in men than expected, this was compensated by the higher F0-high in women. Hence, no correlation was found between DSI and gender. They also report a moderate negative correlation of DSI with overall severity and breathiness and a weak negative correlation for DSI with roughness in the participants with voice disorders.

The impact of age and gender on DSI was studied by Hakkesteegt et al. (2006), and they also confirmed that gender has no significant effect on DSI. However, few parameters, such as highest frequency and maximum phonation time, showed a significant effect. However, age significantly impacts the DSI and its parameters, especially the highest frequency and lowest intensity, with this effect being observed only in females.

Jayakumar and Savithri (2012) recruited 120 participants (60 males, 60 females) who had G0 rating on the GRBAS scale to evaluate DSI in Indian population. They observed a significant difference for gender on MPT and F0-high, with females showing higher DSI compared to males. When comparing the Indian population with the European norms, there was a noticeable difference, were the MPT was found to be significantly lower in Indian population. Thus, the study urges the clinicians to establish normative data tailored to individuals within specific regions, ethnicity, language, ages and genders.

DSI incorporates a voice quality-related measure (i.e., jitter percent) and three more related to vocal performance and functioning (i.e., MPT, F0-high and I-Low).

These vocal range parameters can be difficult to be obtained in reality, as it can vary in different trials and the estimation requires more time and effort. Titze et al., (1995) found that it takes an average of 20 to 30 minutes in order to a satisfactory Voice Range Profile. In addition, the lowest intensity considered for DSI requires high-standard instrumentation that gives precise intensity measurements. A high-quality sound level meter can be utilized to obtain this parameter, but this might not be a feasible option considering most commercially available diagnostic instruments.

Compared to a sustained vowel phonation sample with lesser variations, connected speech is a more natural speaking behavior. It is the environment in which perceptual judgments regarding voice quality are made (Carding, Carlson, Epstein, Mathieson & Shewell, 2000). However, considering that the acoustic characteristics of sustained phonation and connected speech differ, incorporating connected speech can enhance the ecological validity of the analysis (Wolfe, Cornell, & Fitch, 1995; Zraick, Wendel, & Smith-Olinde, 2005). Several studies confirmed the assumption that AVQI, which incorporates six acoustic parameters and concatenates continuous speech and the sustained phonation for the analysis, is a more valid measurement and shows better clinical utility than DSI (Barsties & Maryn, 2016; Uloza et al., 2018). Further, Maryn and Roy (2012) found no significant difference was found in inter-rater reliability between dysphonia severity ratings of sustained vowels versus continuous speech, hence, both types of speech/voice tasks should be elicited and judged by clinicians in the auditory-perceptual rating of dysphonia severity.

Acoustic Voice Quality Index (AVQI)

Maryn et al. (2010) sought to study the viability and diagnostic accuracy by combining continuous phonation with speech in the assessment of quality of voice through a recently introduced technique, the Acoustic Voice Quality Index (AVQI). It is a multivariate model integrated into the free software program Praat. It constitutes six acoustic parameters such as the Smoothed Cepstral Peak Prominence (CPPS), Harmonics-to-Noise Ratio (HNR), Shimmer Local (SL), Shimmer local dB (ShdB), slope of long-term average spectrum (slope) and tilt of the trendline through the long-term average spectrum (tilt). Hence, AVQI is constructed with the following formula: "AVQI = 2.571*(3.295-0.111*CPPS - 0.073*HNR - 0.213*SL + 2.789*ShdB - 0.032*Slope + 0.077*Tilt)" (Maryn et al., 2010).

The AVQI model is thought to evaluate voice quality alone because it includes parameters like smoothed cepstral peak prominence and shimmer as its constituents. Hence, it is primarily a model related to periodicity prominence (Maryn et al., 2009b). The scores obtained for AVQI can range 0 to 10, serving as an indicator of voice severity, with 0 representing normal voice and 10 signifying profoundly abnormal voice on the severity continuum. AVQI was originally developed for Dutch population and a score of 2.95 or below was considered to be a normophonic voice quality.

Considering the higher probability of the primary version of AVQI to be more time consuming, poor user friendliness and chances for error, there was a need to simplify the processing of the two acoustic signals for the analysis. As a result, AVQI (v02.01) was developed by Bartsies & Maryn, (2015), which had a simplified signal processing and calculation process (Batthyany et al., 2022). They validated this in Dutch speaking adult population and found the mean AVQI to be 2.80.

Maryn, Kim & Kim (2016) in the Korean language and Uloza et al. (2017) in the Lithuanian language revealed a significant correlation between the AVQI (v02.02) and perceived voice quality as measured on the GRBAS scale and CAPE-V scales.

Barsties and Maryn (2013) reported good test-retest reliability in AVQI. In Indian context, Benoy & Jayakumar (2017) also reported a good test-retest reliability. Additionally, they noted a strong association between the intensity of perceptual dysphonia and the ability of AVQI to distinguish between mild and moderate severity of dysphonia.

Factors affecting AVQI

Investigations on AVQI reveals consistent and acceptable diagnostic precision and high concurrent validity (Maryn et al., 2010; Barsties & Maryn, 2012; Reynods et al., 2012; Maryn et., 2014; Hosakawa et al., 2017; Uloza et al., 2017; Hernández et al., 2018).

Barsties et al. (2017) investigated the influence of age and gender on AVQI (v02.02) and DSI. A total of 123 normophonic adults of both genders, in the age range of 20 - 79 years were included in the study. This was the first study to evaluate the impact of age and gender on AVQI, even though there were earlier studies present for DSI in his aspect. The results of this study revealed that there are no significant differences between genders for both the multiparametric indices. AVQI also revealed no significant impact across age groups. However, age correlated significantly lower with DSI scores, indicating that DSI is slightly dependent on age.

In Indian population, Shabnam and Pushpavathi (2021) studied the effect of gender on AVQI and DSI in 138 normophonic individuals (74 females and 64 males). The results revealed that gender has significant effect on the constituent parameters of AVQI such as CPPS, HNR and Tilt of LTAS. However, the effect on AVQI and Slope of LTAS was not significant.

Jayakumar et al. (2022) analyzed the significant difference across age group and gender on AVQI (v02.02) and its constituent parameters in Kannada and Malayalam languages. This study included 200 participants of three different age groups with pediatric, adult and older adult population. Findings of the study revealed that there is no gender effects observed in AVQI in both the languages. Thus, they concluded that AVQI (v02.02) is independent of gender. But the values obtained were more stable in adults than in pediatric and older adult groups, they summarized that age can have an impact on AVQI (v02.02) values.

Vishali, (2019) has established standard reference data for AVQI (v02.02) in native Tamil speakers between the age range of 20 to 50 years. She found that males had a significantly higher mean AVQI, Shim dB and Slope of LTAS values comparing with the female counterparts. At the same time, females presented with a higher mean for HNR values. Males also revealed a higher but statistically insignificant values for CPPS and Tilt of LTAS.

AVQI v02.02 vs v03.01

Version 2 of AVQI had a disproportionate contribution the two acoustic signals for the analysis with the sustained phonation contributing more compared with the combined length of concatenated voice fragments in continuous speech sample and this demanded for another significant upgradation (Batthyany et al., 2022). Version 03.01 of AVQI has undergone significant modifications, particularly in the adjustment of parameter weights, leading to its current form. The script for obtaining AVQI (v03.01) contains the formula, “AVQI = (4.152- (0.1777* CPPs) – (0.006* HNR) – (0.037* Shim) + (0.941* ShdB) + (0.01* Slope) + (0.093* Tilt) * 2.8902” (Barsties and Maryn, 2015b).

The primary distinction between the second and third version of the AVQI and different languages is in the thresholds obtained, which differentiates whether the hoarseness is present or not (Latoszek et al., 2018). Several researchers have studied this difference across languages such as English, German, Lithuanian, French, Japanese, Korean etc. and the thresholds obtained in these studies are summarized in the table 2.1 as follows:

Table 2.1 Summary of AVQI scores across languages for v02.02 and v03.01 reported in the literature

AVQI version	**Language**	**Author**	**Threshold of AVQI value**
v02.02	Dutch	Maryn et al. (2010)	2.95
		Barsties & Maryn (2015)	2.80
	German	Barsties & Maryn (2012)	2.70
		Maryn et al. (2014)	3.05
	French	Maryn et al. (2014)	3.07
	Australian English	Reynolds et al. (2012)	3.46
	English	Maryn et al. (2014)	3.25
	Japanese	Hosokawa et al. (2017)	3.15
	Lithuanian	Uloza et al. (2017)	2.97
	Finnish	Kankare et al. (2020)	3.09
	Kannada	Jayakumar et al. (2020)	4.02*
		Pebbili et al. (2021)	2.72
		Seshasri, (2012)	3.74*

	Kannada & Malayalam	Jesnu, (2017)	3.03
	Tamil	Vishali, (2019)	2.76
v03.01	Dutch	Barsties & Maryn (2015)	2.43
		Barsties & Maryn (2016)	2.43
	Japanese	Hosokawa et al. (2017)	1.41
	Spanish	Delgado Hernández et al. (2018)	2.28
	Brazilian	Rabelo et al. (2024)	2.01*
	Italian	Fantini et al. (2023)	2.35
	French	Pommée et al. (2020)	2.33
	Korean	Kim et al. (2021)	3.15
	Brazilian Portugese	Englert et al. (2021)	1.33
	German	Latoszek et al. (2020)	1.85
	Kannada & Malayalam	Jayakumar, Rajasudhakar, et al. (2022)	2.45

**studies in pediatric population*

Given that AVQI (v03.01) has an equal contribution of both sustained vowel and connected speech samples, variations across languages can have an impact on the outcomes of AVQI measurements (Jayakumar & Benoy, 2022). Table above depicts the language specificity of AVQI (v03.03) across different world languages with the threshold showing a wide range of values. In their meta-analysis study, Jayakumar & Benoy, (2022) reviewed seven studies on (v02.02) and eight studies investigating AVQI (v03.01) and they revealed a diagnostic threshold ranging from 2.72 to 3.33 and 1.33 to 3.15 respectively. Also, for AVQI (v02.02), the combined results showed a pooled sensitivity and specificity of 0.85 and 0.92, and for AVQI (v03.01), 0.82 and 0.92. The results revealed that AVQI (v03.01) had a relatively better Area under the Curve (0.94) than AVQIv02 (0.92).

Englert et al. (2022) reported that the length of standardized syllables utilized for the continuous speech recording will affect the AVQI (v03.01) values such that the values tend to be higher for increased sample length.

Acoustic Voice Quality Index in children

According to Reynolds et al. (2012), AVQI may be a more appropriate acoustic measure, even when other measures like DSI have also demonstrated reliability and validity. This is because AVQI has been found to correlate well with subjective assessments of dysphonia severity, while other measures have shown a mixed correlation with perceptual attributes. In addition, AVQI incorporating connected speech samples improves its ecological validity by reflecting more natural speaking behaviour. There are numerous studies in the literature on AVQI in adult population, but there is dearth in studies among pediatric population focusing on their voice quality.

A study by Reynolds et al. (2012) aimed to evaluate the AVQI in the pediatric population. The study included an experimental group of 67 preterm children in the age range of 6-15 years and 40 normophonic term-born children aged 5-15 years in the control group. They collected both a sustained vowel and connected speech sample from the participants. The study results shows that the AVQI had good diagnostic accuracy and specificity in both groups. The threshold value for term-born children was an average of 2.98 and for the preterm children was 3.46. The results obtained moderately correlated with the severity rated using the GRBAS scale.

In an observational, cross-sectional study, Rabelo et al. (2024) compared the acoustic measurements of CPPS and AVQI (v03.01) in pre-pubertal children aged 3-12 years. From a pre-existing database, they collected 185 samples of children (93 boys and 92 girls) with normal and altered voices. The samples collected included a sustained vowel and counting numbers task. Auditory Perceptual Judgement was also done individually for each task. The results of this study revealed that children with altered voices have higher AVQI scores and lower CPPS values. The cut-off scores to differentiate between the presences of vocal deviation in children are 14.07 for CPPS vowel, 7.62 for CPPS numbers, and 2.01 for the AVQI.

In the Indian context, Seshasri, (2018) has established normative data for AVQI (v02.02) for Kannada speaking typically developing children in the age range of 10 -12 years. The average threshold scores of AVQI for this age range was 3.74. The results obtained was in consensus with the findings reported by Reynolds et al. (2012) for English speaking population. Hence, she proposed that AVQI may be independent of the language. Literature on AVQI (v02.02) shows this independency of language (Maryn et al., 2014; Bartsies & Maryn, 2012; Hosokawa et al., 2017; Benoy & Jayakumar, 2017).

Based on the evidence available, version 3 of AVQI is yet to be explored in children in the Indian population. From the literature review, it is apparent that AVQI is a promising tool for assessing voice quality. Compared with the studies to date on AVQI in European and Eastern Asian languages, Indian languages such as Kannada and Malayalam are unalike. These Dravidian languages are disparate in their inherent attributes, such as their syllabic structures. Consequently, there is a need to probe into them and develop reference data for these languages, as the results can likely be disparity. Therefore, the current study is taken up with the aim of establishing the normative data for AVQI (v03.01) in Malayalam and Kannada speaking typically developing children of Indian population.

CHAPTER III

METHOD

Research Design

The current study used a normative research design.

Participants

A total of 180 children participated in the present study. There were two groups of participants on the basis of their native language. Group 1 consisted of 90 Malayalam speaking children selected randomly from 3 different schools in Kerala. Similarly, Group 2 consisted of 90 Kannada speaking children randomly selected from 3 different schools in Karnataka. Each group had 3 different age groups: 5-6 years, 6-7 years and 7-8 years. Each age group had 30 children with equal number of boys (15 children) and girls (15 children). Informed consent were taken from all participant/ parents/ guardians. Table 3.1 show the details of participants for each group across age group and gender.

Table 3.1: Details of participants

Group 1 (Kannada) (n = 90)						Group 2 (Malayalam) (n = 90)					
5-6 years		6-7 years		7-8 years		5-6 years		6-7 years		7-8 years	
Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
15	15	15	15	15	15	15	15	15	15	15	15

Inclusionary criteria

i. Children who speak native Kannada and Malayalam languages.

ii. Participants of both Group 1 and Group 2 having perceptually normal voice quality rated with on G of the GRBAS (Hirano et al., 1981) scale by researcher herself.

Exclusionary criteria

i. Participants having any active Upper Respiratory Tract Infections, vocal tract related infections or allergies at the time of recording were excluded from the study.

ii. Participants with any history of voice disorders were excluded from the study.

iii. Participants with complaints of hearing loss, any associated communication disorders, or neurological impairment were excluded.

Stimuli

Voice samples of sustained phonation task of vowel /a/ for minimum of 5-7 seconds duration and continuous speech recording using standard passages of Kannada (Savithri & Jayaram, 2005) for Group 1 and Malayalam (Dokhe et al., 2020) for Group 2 was collected from all children by repetition task from both the groups.

Procedure

The participants, their parents/ guardians and/or teachers were explained about the procedures and tasks prior to the audio recording. Their consent was collected before the recording session. The participants were seated comfortably in an upright position in a quiet room for the recording. Voice samples were recorded using Olympus LS-100 with sampling rate of 44.1 kHz and 32 bits of resolution. The microphone was kept 10 cm from the mouth and a mouth angle of 40-90 degrees. The recording of the voice samples from each participant took around 5-10 minutes, with two to three trials of sustained vowel and continuous speech sample.

Analysis

The stable middle portion of the vowel phonation was extracted and renamed as ‘sv’ (sustained vowel). For the continuous speech (renamed as ‘cs’), 3 sec of standard reading passages of Malayalam (first 29 syllable length) and 3 sec of Kannada (first 26 syllables) was used (Benoy & Jayakumar, 2017). These extracted samples saved in .wav format was fed into the Praat script (Barsties and Maryn, 2015b) for obtaining the AVQI v03.01. The AVQI output obtained on Praat for a normophonic participant is depicted in figure 3.1

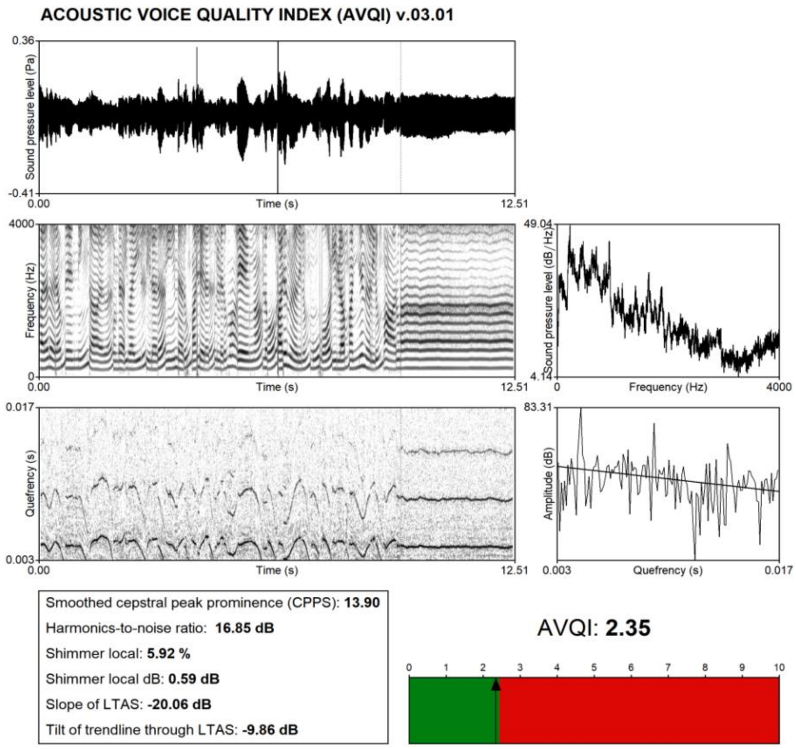

Figure 3.1: Example of graphical output AVQI results

Statistical analysis

All the statistical analysis were carried out using SPSS (version 26) statistical analysis software. Shapiro Wilk’s test was done to check for the normality of the obtained data. Descriptive statistics were done to obtain the mean and standard deviation of AVQI and its constituent parameters. Furthermore, the effect of age, gender and language on AVQI was checked using three-way Analysis of Variance (ANOVA). Three-way Multivariate Analysis of Variance (MANOVA) was done to check for the effect of age, gender and language on the constituent parameters of AVQI and also to check for the interaction effects.

CHAPTER IV
RESULTS

The main objective of the study was to develop normative reference data for AVQI (v03.01) scores of normophonic children of three age groups (5-6 years, 6-7 years & 7-8 years). The AVQI and its six constituent parameters such as CPPs, HNR, Shimmer local, Shimmer dB, Slope and Tilt of LTAS were analysed. Age, gender and language were the independent variables while AVQI and constituent six parameters were the dependent variables for the study.

The data obtained for AVQI and the six parameters were subjected to statistical analysis to verify the normality of the data and the effect of age, gender and the two languages on them.

The results of this study will be discussed under the following headings:

i. Normality of the data.

ii. Descriptive statistics of AVQI and its constituent parameters.

iii. Effect of age, gender and language on AVQI scores.

iv. Effect of gender on the constituent parameters of AVQI.

v. Effect of age on the constituent parameters of AVQI.

vi. Effect of language on the constituent parameters of AVQI.

vii. Reference measures for AVQI and its constituent parameters

Normality of the data

Shapiro Wilk's test was done to check for the normality of the obtained data with respect to the independent variables gender, language and age groups. Results revealed that data is following normal distribution. Hence, further analyses were carried out using parametric tests.

ii. Descriptive statistics of AVQI and its constituent parameters

AVQI and its constituent parameters were obtained from a total of 180 normophonic Kannada and Malayalam speaking children. Table 4.1 shows the mean, standard deviation and range of AVQI and its constituent parameters for typically developing normophonic children of three age groups 5- 6 years, 6- 7 years and 7- 8 years. The three age groups consisted of 60 participants each.

Table 4.1: Mean, standard deviation and range of AVQI in children of three age group

	5 - 6 years Mean (± SD) (Range)	**6 - 7 years** Mean (± SD) (Range)	**7-8 years** Mean (± SD) (Range)
AVQI	3.98 (± 0.85)	4.07 (± 0.90)	3.86 (± 0.85)
	2.55- 6.62	1.74- 5.88	2.19- 5.41
CPPS	11.19 (± 1.32)	11.26 (±1.24)	11.53 (± 1.18)
	7.28- 13.34	8.68- 14.66	9.07- 14.03
HNR	15.68 (± 1.36)	15.23 (± 1.58)	15.24 (± 1.47)
	11.87- 18.01	12.42- 18.42	12.50- 18.42
Shimmer local	7.99 (± 1.51)	8.75 (± 1.74)	8.20 (± 1.45)
	5.31- 11.25	5.71- 13.37	5.57- 11.47
Shimmer dB	0.80 (± 0.13)	0.86 (± 0.15)	0.80 (± 0.13)
	0.56- 1.09	0.57- 1.27	0.59- 1.08

Slope	-17.18 (± 3.69)	-18.37 (± 3.68)	-17.96 (± 3.76)
	-24.70- -9.62	-25.75- -8.17	-26.16- -9.04
Tilt	-10.60 (± 0.81)	-10.32 (± 0.95)	-10.31 (± 1.10)
	-12.64- -9.28	-11.86- -7.90	-12.06- -6.03

The participants of the study were divided into two groups on the basis of the language. Group 1 (Kannada) and Group 2 (Malayalam) with 90 participants each. There was a total of 90 each normophonic girls and boys of the age range 5- 8 years. Table 4.2 summarizes the mean, standard deviation and range of AVQI across the two languages and genders.

Table 4.2: Mean, standard deviation of AVQI across gender and languages

Parameter	**Gender**		**Languages**	
	Boys (n = 90)	Girls (n = 90)	Kannada (n = 90)	Malayalam (n = 90)
AVQI Mean (± SD)	4. 00 (± 0.85)	3.94 (± 0.89)	3.96 (± 0.80)	3.98 (± 0.93)

Effect of age, gender and language on AVQI scores

Three-way Analysis of Variance (ANOVA) was carried out to check for the between-subject main effects and interaction effects of age group, gender and language on AVQI for all the 180 participants of the current study. Tests of between-subject effects revealed that there is no significant difference for main effects across the subject groups for gender F (1, 168) = 0.184, P > 0.05, age F (1, 168) = 0.918, P > 0.05 and language F (1, 168) = 0.019, P > 0.05.

Similarly, no significant difference was observed for interaction effects between- subject groups for age*gender F (2, 168) = 1.641, P > 0.05, gender*language F (1, 168) = 0.695, P >0.05, age*language F (2, 168) = 0.236, P > 0.05 and age*gender*language F (2, 168) = 0.875, P > 0.05. Figure 4.1 and 4.2 shows the gender comparison across language

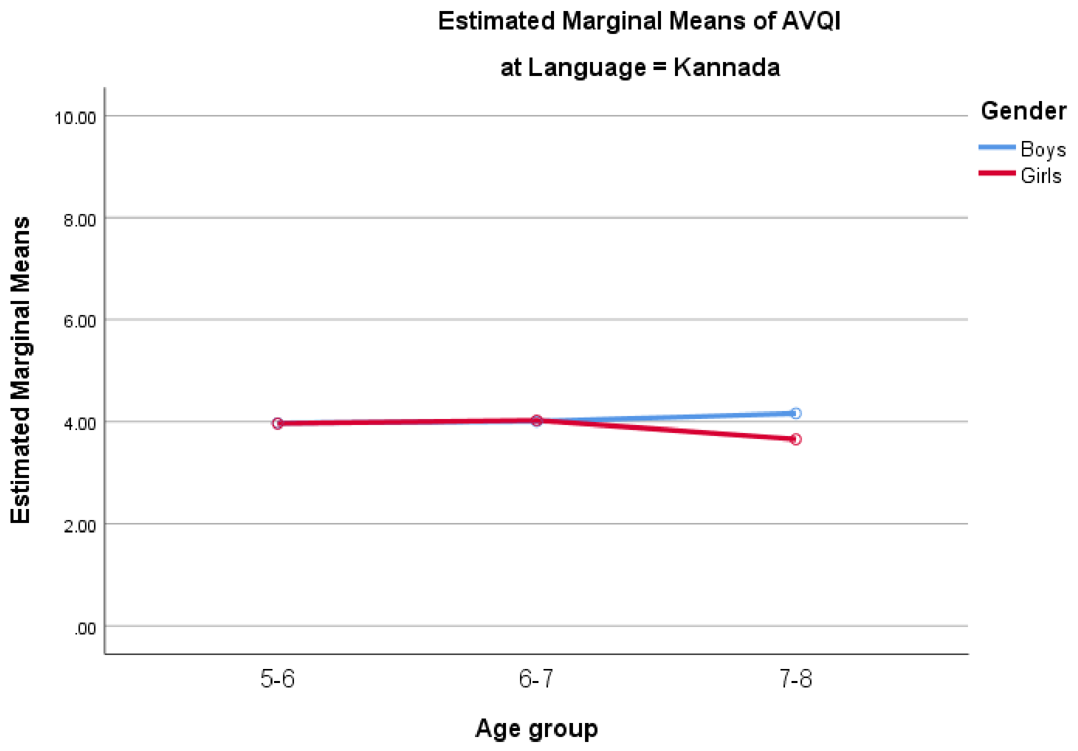

Figure 4.1: Effect of age and gender on AVQI for Group 1 (Kannada)

In Group 1, the boys in the age group 7- 8 years shows comparatively slightly higher scores of AVQI than their corresponding group of girls. At the same time, this trend is not observed between the boys and girls of the lower two age groups (5- 6 years and 6- 7 years).

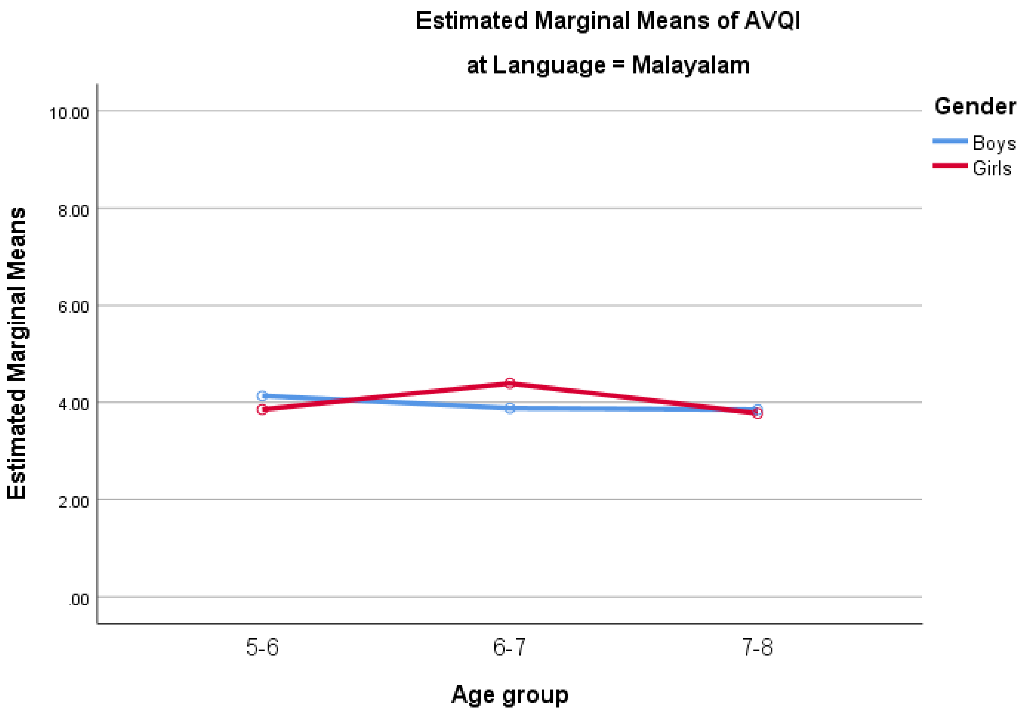

Figure 4.2: Effect of age and gender on AVQI for Group 2 (Malayalam)

In Group 2, girls in the age group of 6- 7 years showed comparatively slightly higher AVQI scores than their corresponding group of boys, while it was the opposite way in the age group of 5- 6 years with the boys having slightly higher AVQI scores. Meanwhile, the boys and girls in age range of 7- 8 years did not show any significant difference between their AVQI scores obtained.

Effect of gender on the constituent parameters of AVQI.

Three- way Multivariate Analysis of Variance (MANOVA) was done to check for the effect of age, gender and language on the constituent parameters of AVQI and also to check for the interaction effects. The tests of between-subject effects results revealed the majority of parameters showed no significant effect except few parameters having marginal difference.

Gender F (6, 163) = 3.183, (P = 0.006, h_p^2 = 0.105). Even though there was not any significant effect found for AVQI scores across gender, a significant difference was observed across gender on constituent parameters such as Slope (P = 0.021) and Tilt (P = 0.021) was found. The results are tabulated in Table 4.3

Table 4.3: *F*-value and *p*-value of the constituent parameters of AVQI across gender

Parameter	***F*-value**	***p*-value**	**Partial Eta Squared**
CPPS	0.261	0.610	0.002
HNR	1.132	0.289	0.007
Shimmer local	1.446	0.231	0.009
Shimmer dB	0.652	0.421	0.004
Slope	5.469	0.021*	0.032
Tilt	5.472	0.021*	0.032

*p< 0.05

Effect of age on the constituent parameters of AVQI

Similarly, age F (12, 328) = 3.504, (P = 0.000, h_p^2 = 0.114). There was a significant difference observed across age groups on the parameters such as Shimmer local (P = 0.028) and Shimmer dB (P = 0.032) was found. Table 4.4 summarizes these results.

Table 4.4: *F*-value and *p*-value of the constituent parameters of AVQI across age

Parameter	*F*-value	*p*-value	Partial Eta Squared
CPPS	1.162	0.315	0.014
HNR	1.179	0.169	0.021
Shimmer local	3.659	0.028*	0.042
Shimmer dB	3.518	0.032*	0.040
Slope	1.621	0.201	0.019
Tilt	1.845	0.161	0.021

*p< 0.05

Additionally, a post-hoc analysis was done using the Tukey HSD test for pairwise comparisons. All the groups fall into a homogeneous subset, indicating no significant difference among the constituent parameters of AVQI except for Shimmer local and Shimmer dB. Table 4.5 summarizes the results of the post-hoc analysis for those two parameters.

Table 4.5: Post-hoc analysis using Tukey HSD test

Age group Comparison	Shimmer local	Shimmer dB
	p-value	*p*-value
5 - 6 y vs 7 – 8 y	$p > 0.05$	$p > 0.05$
5 – 6 y vs 6 - 7 y	***p < 0.05***	***p < 0.05***
7 - 8 y vs 6 – 7 y	$p > 0.05$	$p > 0.05$

Considering the parameter of Shimmer local, the age groups 5- 6 y and 7- 8 y are in the first subset, and the age groups 7- 8 y and 6- 7 y are in the second subset. Each age group consisted of 60 participants each. This indicates that the age groups 5- 6 y and 7- 8 y do not differ significantly from each other, nor do the age groups 7- 8 y and 6- 7 y. But there is a trend towards significance when comparing the age groups 5- 6 y and 6- 7 y. The error term for the analysis was Mean Square Error = 2.519.

Shimmer dB also displayed a similar trend towards significance when comparing age groups 5- 6 y and 6- 7 y, with a Mean Square Error = 0.021 for the tested age range.

Effect of language on the constituent parameters of AVQI.

The test of between-subject results did not show any significant difference for the constituent parameters across language F (6, 163) = 1.686, (P = 0.128, h_p^2 = 0.058), except for the parameter of Tilt (P = 0.011) as shown in the Table 4.6. Also figure 4.3 to 4.14 shows age group, gender and language variations across AVQI constituent parameters

Table 4.6: *F*-value and *p*-value of the constituent parameters of AVQI across language

Parameter	***F*-value**	***p*-value**	**Partial Eta Squared**
CPPS	0.036	0.581	0.002
HNR	0.031	0.860	0.000
Shimmer local	2.380	0.125	0.014
Shimmer dB	1.716	0.192	0.010
Slope	1.035	0.310	0.006
Tilt	6.613	0.011*	0.038

*p< 0.05

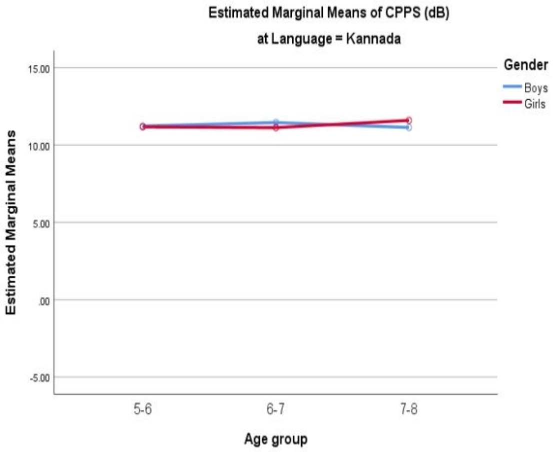

Figure 4.3: Effect of age and gender on CPPS for Group 1 (Kannada)

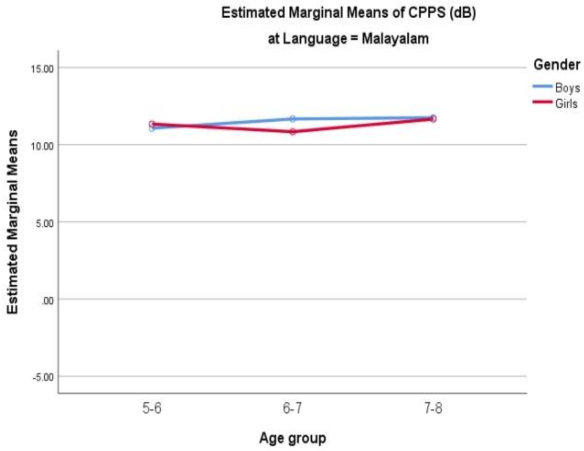

Figure 4.4: Effect of age and gender on CPPS for Group 2 (Malayalam)

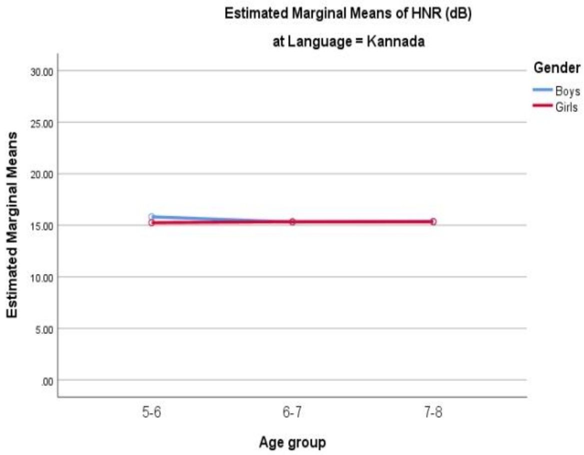

Figure 4.5: Effect of age and gender on HNR for Group 1 (Kannada)

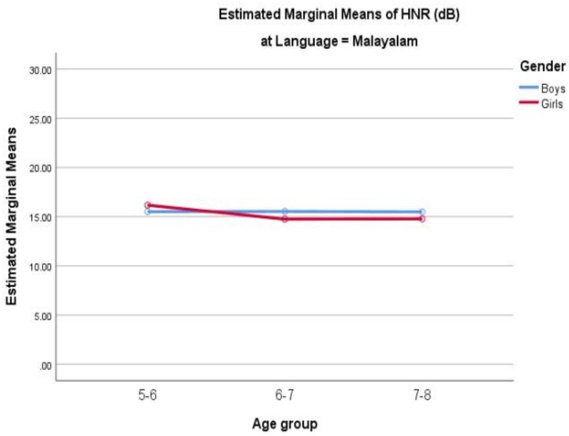

Figure 4.6: Effect of age and gender on HNR for Group 2 (Malayalam)

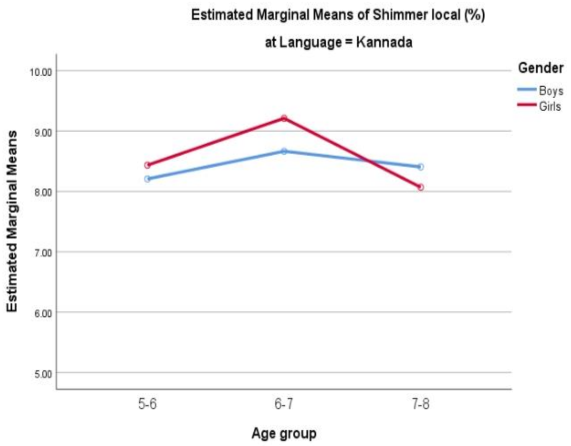

Figure 4.7: Effect of age and gender on Shimmer local for Group 1 (Kannada)

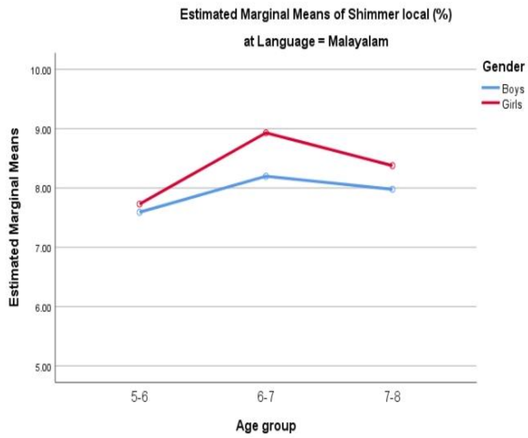

Figure 4.8: Effect of age and gender on Shimmer local for Group 2 (Malayalam)

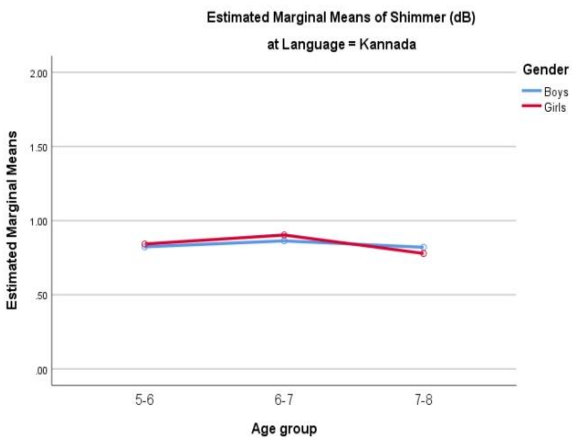

Figure 4.9: Effect of age and gender on Shimmer dB for Group 1 (Kannada)

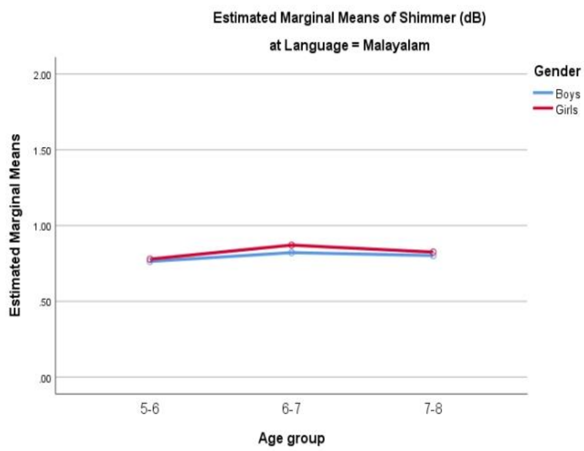

Figure 4.10: Effect of age and gender on Shimmer dB for Group 2 (Malayalam)

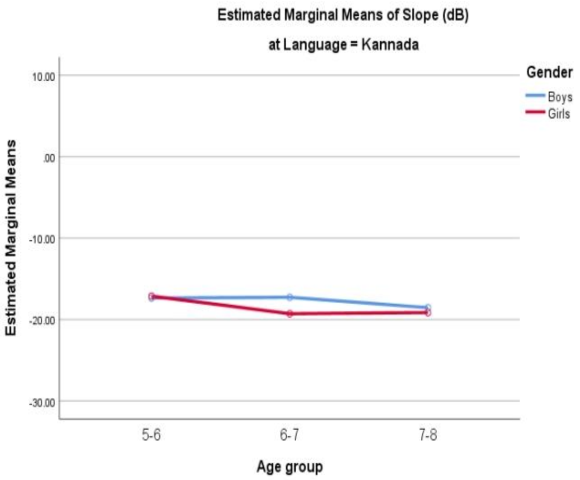

Figure 4.11: Effect of age and gender on Slope for Group 1 (Kannada)

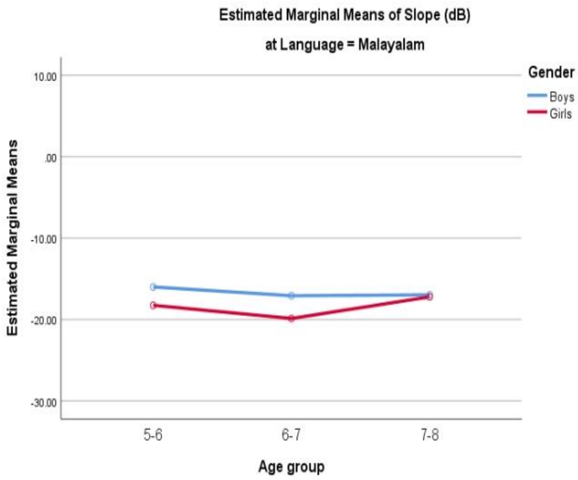

Figure 4.12: Effect of age and gender on Slope for Group 2 (Malayalam)

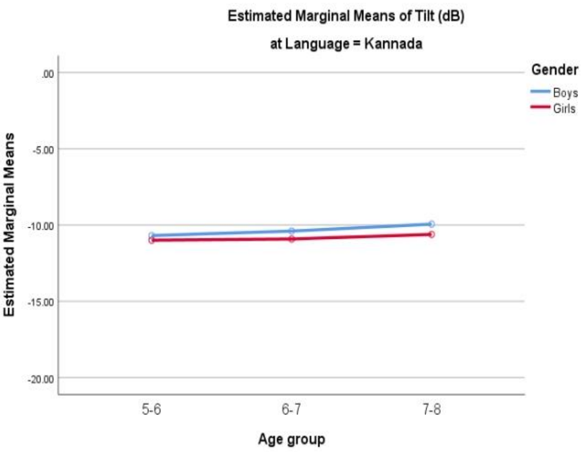

Figure 4.13: Effect of age and gender on Tilt for Group 1 (Kannada)

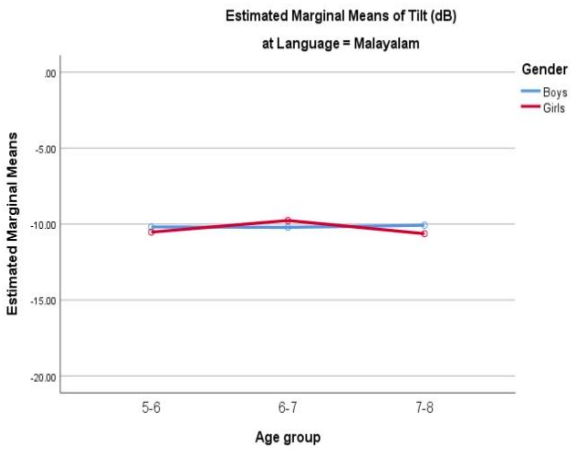

Figure4.14: Effect of age and gender on Tilt for Group 2 (Malayalam)

Reference measures for AVQI and its constituent parameters

The AVQI values across the two languages, genders, or age groups did not show any significant difference. Table 4.7 summarizes the reference measure for AVQI (v03.01) for Kannada and Malayalam speaking normophonic children in the age range of 5 - 8 years.

Table 4.7: Reference score of AVQI (v03.01) for Kannada and Malayalam speaking normophonic children aged 5 - 8 years.

Parameter	Value
Mean AVQI (± SD)	3.97 (± 0.87)
Range	1.74 - 6.62

However, Shimmer values were found to be slightly significant across the three age groups. Similarly, Slope and Tilt of LTAS were found to have slight significance across the two genders. Considering these results, the reference measures for the constituent parameters of AVQI for Kannada and Malayalam speaking normophonic children in the age range of 5 - 8 years is summarized in the table 4.8 below:

Table 4.8: Reference score for the constituent parameters of AVQI

Parameter	**Gender**		**Age groups**		
	Boys	Girls	5 - 6 years	6 - 7 years	7 - 8 years
CPPS			11.33 (± 1.25)		
HNR			15.38 (± 1.48)		
Shimmer local			7.99 (± 1.51)	8.75 (± 1.74)	8.20 (± 1.45)
Shimmer dB			0.80 (± 0.13)	0.86 (± 0.15)	0.80 (± 0.13)
Slope	-17.20 (± 4.01)	-18.48 (± 3.31)			
Tilt	-10.25 (± 1.02)	-10.57 (± 0.89)			

CHAPTER V

DISCUSSION

The primary objective of the study was to develop normative reference data for AVQI (v03.01) scores of normophonic children of three age groups (5- 8 years). A total of 180 normophonic children were divided into two groups based on their native language. Each group consisted of 90 children each with equal number of boys and girls in the three age groups.

Normative data on AVQI (v03.01) for children in the age range 5- 8 years

The mean AVQI value obtained for the Kannada and Malayalam speaking children in the age range of 5 - 8 years is 3.97 (± 0.87). The value obtained in the current study is in consensus with that reported by Reynolds et al. (2012) for English speaking children, 3.46. Seshasri, (2018) reports the mean AVQI to be 3.74 in Kannada speaking children in the age range of 10 - 12 years, which is also in consensus with the current study. These two studies were done using version 2 of AVQI. However, a recent cross-sectional study by Rabelo et al. (2024) using the version 3 of AVQI reported the mean AVQI for children in the age range of 3 - 12 years to be 2.01, which is less than the mean obtained in the current study. The possible reason for this disparity could be related to difference in the age ranges (Jayakumar et al., 2022), language considered (Jayakumar & Benoy, 2022; Englert et al., 2022) for the current study and general variations in voice quality, but one cannot presume this as a fact as there is no other studies currently to contribute to the literature for further comparison.

Effect of gender, language and age groups on AVQI

The current study did not show any significant effect of gender, language or age on AVQI. These results were in agreement with earlier studies using AVQI (v02.02) by Maryn et al. (2010, 2014); Bartsies & Maryn (2012); Reynolds et al. (2012); Hosakowa et al. (2017); Bartsies et al. (2017).

The current study had three age groups of children and the results revealed a mean AVQI of 3.98 (± 0.85) for 5 - 6 years, 4.07 (± 0.90) for 6 - 7 years and 3.86 (± 0.85) for 7 - 8 years of age. With respect to gender, the current study revealed that boys had a mean AVQI of 4. 00 (± 0.85) and girls had mean AVQI of 3.94 (± 0.89). However, study by Seshasri, (2018) using AVQI (v02.02) had two age groups of 10 - 11 years and 11 - 12 years. Her study revealed that elder participants obtained a higher AVQI, relating with poorer voice quality than their younger counterparts. This may be due to abuse of voice is high in the older children than younger one.

This study utilized 3 seconds of standard Kannada and Malayalam languages passage with different number of syllables, for the connected speech sample. And no significance was noted for AVQI across these languages. Similar studies using AVQI (v02.02) also revealed a similar result in different languages (Bartsies & Maryn, 2012; Reynolds et al., 2012; Kankare et al., 2015; Hosokowa et al., 2017). Also, according to Hosokowa et al, (2017), the number of syllables does not have an impact on AVQI (v02.02) values. In addition, Rabelo et al. (2024) also confirmed that children with voice disorder had a higher AVQI value, irrespective of the speech task utilized for the continuous speech task.

Language differences are anticipated because AVQI (v03.01) utilizes language-specific stimuli for its measurements. To substantiate this, literature has shown that normative scores vary across different languages (Barsties and Maryn, 2016; Delgado Hernández et al., 2018; Hosokawa et al., 2019; Kim et al., 2021; Barsties v. Latoszek et al., 2020; Pommée et al., 2020; Englert et al., 2021). However, the current study found no significant differences, as Kannada and Malayalam both belong to the Dravidian language family.

Effect of gender, language and age group on the constituent parameters of AVQI

A gender effect was found for the Slope (P = 0.021) and Tilt of LTA (P = 0.021) in the current study, but these findings were only marginal significant. This could be due to the difference in the boy and girls with respect to energy values of their formants (White, 1999). Boys generally have a steeper slope in their LTAS, indicating more energy in their lower frequencies and less energy on their higher frequencies. Similarly, Girls generally have a higher tilt in their LTAS, indicating more energy in the higher frequencies (Coleman, 1976). Anatomical variations such as the length of vocal tract between the two genders may be the cause for this difference.

Similarly, effect of age was observed for the constituent Shimmer parameters such as Shimmer local (P = 0.028) and Shimmer dB (P = 0.032). In both these parameters, there was a trend towards significance when comparing the age groups 5- 6 years and 6- 7 years. Nonetheless, this effect was also found to be only marginal significant. Literature has reported higher perturbation in the voices of younger children and older adults (Stathopoulos et al., 2011).

CHAPTER VI

SUMMARY AND CONCLUSION

Acoustic Voice Quality Index (AVQI) is a multiparametric tool developed by Maryn et al, (2010) for acoustic analysis of voice quality. The tool has been refined several times and the latest version, AVQI (v03.01) is found to have a higher ecological validity compared to the previous. Researchers across the world has confirmed that this newer version holds a good diagnostic accuracy and concurrent validity. There are numerous studies that reports AVQI values in adult population. There are numerous studies that reports AVQI values in adult population. However, there is a paucity in the literature for pediatric normative even when there are notable differences between adults and children, in terms of their anatomical variations, which could also impact their voice quality thresholds. Hence, the reference data using the latest version of AVQI could prove to be resourceful in pediatric voice assessment. and the current study was taken up with the aim of establishing the normative data for AVQI (v03.01) in Malayalam and Kannada speaking typically developing children of Indian population. The effect of gender, language and age groups were also investigated in this study.

The current study included a total of 180 participants in two different languages (Kannada and Malayalam), three different age groups (5-6 y, 6-7 y and 7-8 y) with equal number of boys and girls. Acoustic samples of sustained vowel (/a/ phonation) and continuous speech (by repetition of standard passages in Kannada and Malayalam language). Corresponding values of AVQI and its constituent parameters were obtained by the running the script for AVQI (v03.01) in the Praat software.

The obtained results were subjected to appropriate statistical analysis using SPSS (version 26).

The mean normative AVQI (v03.01) value obtained for Kannada and Malayalam speaking normophonic children is 3.97 (± 0.87). The current obtained value is higher than what is reported in the literature for adults and pediatric populations. Effect of gender, language and age groups were not significantly affecting the AVQI values in the current study. However, this was not case for the constituent parameters of AVQI. Time-related measures such as Shimmer dB and Shimmer local were found to have a significant difference across age groups. Frequency-related measures such as Slope and Tilt of LTAS were found to significant difference across the genders. Also, language was found to have a significant effect on the Tilt of LTAS. Other parameters did not show any evident differences across age, gender and language.

Even though literature has found the AVQI (v03.01) to be language specific, the current study did not show such a significant difference across the languages, Kannada and Malayalam. This may be due to the fact that the two Indian languages belong to the same language family of Dravidian. Thus, the current study adds on to the literature for reference measures of AVQI (v03.01) for pediatric population.

Implications of the study

i. The current study will establish the normative data for AVQI v03.01 in Malayalam and Kannada speaking children in the age range of 5- 8 years, which will help in pediatric voice assessment.

ii. The present study will provide an understanding about the effect of age and gender on AVQI v03.01 in children.

Limitations and future directions of the study

i. The study considered only the children in the limited age range of 5-8 years, limiting the applicability of the findings. Hence, future studies should aim to include a wider age range.

ii. The study had participants of native Kannada and Malayalam languages and these languages belong to the same language family. As literature has found the current version of AVQI to be language specific, the current study could limit the impact of the language on the mean scores obtained. Future studies should aim to explore the language differences on AVQI scores for other Indian languages belonging to different language families.

REFERENCES

Aronson, A. E., Bless, D. (2011). Clinical Voice Disorders. United States: Thieme Publishers New York.

Awan, S. N., Roy, N., Jetté, M. E., Meltzner, G. S., & Hillman, R. E. (2010). Quantifying dysphonia severity using a spectral/cepstral-based acoustic index: Comparisons with auditory-perceptual judgements from the CAPE-V. *Clinical Linguistics & Phonetics*, *24*(9), 742–758. https://doi.org/10.3109/02699206.2010.492446

Barsties, B., & De Bodt, M. (2015). Assessment of voice quality: Current state-of-the-art. *Auris, Nasus, Larynx*, *42*(3), 183–188. https://doi.org/10.1016/j.anl.2014.11.001

Barsties, B., & Maryn, Y. (2015). The improvement of internal consistency of the Acoustic Voice Quality Index. American Journal of Otolaryngology, 36(5), 647-656.

Barsties, B., & Maryn, Y. (2016). External validation of the Acoustic Voice Quality Index Version 03.01 with extended representativity. *the Annals of Otology, Rhinology & Laryngology*, *125*(7), 571–583. https://doi.org/10.1177/0003489416636131

Batthyany, C., Latoszek, B. B. V., & Maryn, Y. (2022). Meta-Analysis on the validity of the Acoustic Voice Quality Index. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2022.04.022

Benoy, J. J. (2017). Acoustic voice quality index (AVQI) and perceptual measures in the Indian population. Master's Dissertation submitted to the University of Mysore, Mysore.

Bhuta, T., Patrick, L., & Garnett, J. D. (2004). Perceptual evaluation of voice quality and its correlation with acoustic measurements. *Journal of Voice*, *18*(3), 299–304. https://doi.org/10.1016/j.jvoice.2003.12.004

Boseley, M. E., & Hartnick, C. J. (2006). Development of the Human True Vocal Fold: Depth of Cell Layers and Quantifying Cell Types within the Lamina Propria. *the Annals of Otology, Rhinology & Laryngology*, *115*(10), 784–788. https://doi.org/10.1177/000348940611501012

Carding, P., Carlson, E., Epstein, R., Mathieson, L., & Shewell, C. (2000). Formal perceptual evaluation of voice quality in the United Kingdom. *Logopedics Phoniatrics Vocology*, *25*(3), 133-138.

Carding, P., Carlson, E., Epstein, R., Mathieson, L., & Shewell, C. (2000). Formal perceptual evaluation of voice quality in the United Kingdom. *Logopedics, Phoniatrics, Vocology*, *25*(3), 133–138. https://doi.org/10.1080/140154300050175860

Coyle, S. M., Weinrich, B. D., & Stemple, J. C. (2001). Shifts in relative prevalence of laryngeal pathology in a treatment-seeking population. *Journal of Voice*, *15*(3), 424-440.

Darley, F. L., Aronson, A. E., & Brown, J. R. (1969). Differential diagnostic patterns of dysarthria. Journal of speech and hearing research, 12(2), 246-269.

Englert, M., Lima, L., Latoszek, B. B. V., & Behlau, M. (2022). Influence of the voice sample length in perceptual and acoustic voice quality analysis. *Journal of Voice*, *36*(4), 582.e23-582.e32. https://doi.org/10.1016/j.jvoice.2020.07.010

Fantini, M., Maccarini, A. R., Firino, A., Gallia, M., Carlino, V., Gorris, C., Bisetti, M. S., Crosetti, E., & Succo, G. (2023). Validation of the Acoustic Voice Quality Index (AVQI) version 03.01 in Italian. *Journal of Voice*, *37*(4), 631.e1-631.e6. https://doi.org/10.1016/j.jvoice.2021.02.029

Gerratt, B. R., & Kreiman, J. (2001). Measuring vocal quality with speech synthesis. *the Journal of the Acoustical Society of American the Journal of the Acoustical Society of America*, *110*(5), 2560–2566. https://doi.org/10.1121/1.1409969

Glaze, L. E., Bless, D. M., Milenkovic, P., & Susser, R. D. (1988). Acoustic characteristics of children's voice. Journal of Voice, 2(4), 312-319.

Hakkesteegt, M. M., Brocaar, M. P., Wieringa, M. H., & Feenstra, L. (2008). The relationship between perceptual evaluation and objective multiparametric evaluation of dysphonia severity. Journal of Voice, 22(2), 138-145.

Hakkesteegt, M. M., Brocaar, M. P., Wieringa, M. H., & Feenstra, L. (2008). The relationship between perceptual evaluation and objective multiparametric evaluation of dysphonia severity. *Journal of Voice*, *22*(2), 138–145. https://doi.org/10.1016/j.jvoice.2006.09.010

Hakkesteegt, M. M., Brocaar, M. P., Wieringa, M. H., & Feenstra, L. (2006). Influence of age and gender on the Dysphonia Severity Index. *Folia Phoniatrica Et Logopaedica*, *58*(4), 264–273. https://doi.org/10.1159/000093183

Hernández, J. D., Gómez, N. M. L., Jiménez, A., Izquierdo, L. M., & Latoszek, B. B. V. (2018). Validation of the Acoustic Voice Quality Index Version 03.01 and the Acoustic Breathiness Index in the Spanish language. *the Annals of Otology, Rhinology & Laryngology*, *127*(5), 317–326. https://doi.org/10.1177/0003489418761096

Hirano, M. (1981). *Clinical examination of voice* (Vol. 5). Springer.

Hirano, M. (1983). Growth, development, and aging of human vocal folds. Vocal fold physiology, 22-43.

Hosokawa, K., Barsties, B., Iwahashi, T., Iwahashi, M., Kato, C., Iwaki, S., Sasai, H., Miyauchi, A., Matsushiro, N., Inohara, H., Ogawa, M., & Maryn, Y. (2017). Validation of the Acoustic Voice Quality Index in the Japanese language. *Journal of Voice, 31*(2), 260.e1-260.e9. https://doi.org/10.1016/j.jvoice.2016.05.010

Jayakumar, T., & Benoy, J. J. (2022). Acoustic Voice Quality Index (AVQI) in the measurement of voice quality: a systematic review and meta-analysis. *Journal of Voice.*

Jayakumar, T., Rajasudhakar, R., & Benoy, J. J. (2022). Comparison and Validation of Acoustic Voice Quality Index Version 2 and Version 3 among South Indian Population. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2022.02.019

Jayakumar, T., &Savithri, S. R. (2012). Effect of geographical and ethnic variation on Dysphonia Severity Index: a study of Indian population. *Journal of Voice, 26(1),* 11-16.

Jayakumar, T., Benoy, J. J., & Yasin, H. M. (2022). Effect of age and gender on acoustic voice Quality Index across lifespan: a cross-sectional study in Indian population. *Journal of Voice*, *36*(3), 436.e1-436.e8. https://doi.org/10.1016/j.jvoice.2020.05.025

Karnell, M. P., Hall, K. D., & Landahl, K. L. (1995). Comparison of fundamental frequency and perturbation measurements among three analysis systems. *Journal of Voice, 9(4)*, 383–393.

Kelchner, L. N., Brehm, S. B., Weinrich, B., Middendorf, J., deAlarcon, A., Levin, L., & Elluru, R. (2010). Perceptual Evaluation of Severe pediatric voice disorders: rater reliability using the consensus auditory Perceptual evaluation of voice. *Journal of Voice*, *24*(4), 441–449. https://doi.org/10.1016/j.jvoice.2008.09.004

Kempster, G. B., Gerratt, B. R., Abbott, K. V., Barkmeier-Kraemer, J., & Hillman, R. E. (2009). Consensus auditory-perceptual evaluation of voice: development of a standardized clinical protocol. *American Journal of Speech-Language Pathology*, *18*(2), 124-132.

Latoszek, B. B. V., Ulozaitė-Stanienė, N., Maryn, Y., Petrauskas, T., & Uloza, V. (2019). The influence of gender and age on the acoustic voice quality index and dysphonia severity index: a normative study. Journal of Voice, 33(3), 340-345.

Latoszek, B. B. V., Ulozaitė-Stanienė, N., Petrauskas, T., Uloza, V., & Maryn, Y. (2018). Diagnostic Accuracy of Dysphonia Classification of DSI and AVQI. *the Laryngoscope*, *129*(3), 692–698. https://doi.org/10.1002/lary.27350

Laver, J. (1980). The phonetic description of voice quality. Cambridge Studies in Linguistics London, 31, 1-186.

Laver, J. D., Wirz, S. L., Mackenzie, J., & Miller, S. (1981). A perceptual protocol for the analysis of vocal profiles. University of Edinburgh Work in Progress. Linguistics Department, 14.

Lechien, J. R., Geneid, A., Bohlender, J. E., Cantarella, G., Avellaneda, J. C., Desuter, G., ... & Crevier-Buchman, L. (2023). Consensus for voice quality assessment in clinical practice: guidelines of the European Laryngological Society and Union of the European Phoniatricians. *European Archives of Oto-Rhino-Laryngology*, 1-15.

Maryn, Y., & Roy, N. (2012). Sustained vowels and continuous speech in the auditory-perceptual evaluation of dysphonia severity. *Jornal Da Sociedade Brasileira De Fonoaudiologia*, *24*(2), 107–112. https://doi.org/10.1590/s2179-64912012000200003

Maryn, Y., Corthals, P., Van Cauwenberge, P., Roy, N., & De Bodt, M. (2010). Toward improved ecological validity in the acoustic measurement of overall voice quality: Combining continuous speech and sustained vowels. *Journal of Voice, 24(5)*, 540–555.

Maryn, Y., De Bodt, M., Barsties, B., & Roy, N. (2014). The value of the Acoustic Voice Quality Index as a measure of dysphonia severity in subjects speaking different languages. *European Archives of Oto-Rhino-Laryngology, 271(6),* 1609–1619.

Maryn, Y., Roy, N., De Bodt, M., Van Cauwenberge, P., & Corthals, P. (2009). Acoustic measurement of overall voice quality: A meta-analysis. *the Journal of the Acoustical Society of American the Journal of the Acoustical Society of America*, *126*(5), 2619–2634. https://doi.org/10.1121/1.3224706

Nemr, K., Simões-Zenari, M., Cordeiro, G. F., Tsuji, D., Ogawa, A. I., Ubrig, M. T., & Menezes, M. H. M. (2012). GRBAS and Cape-V scales: high reliability and consensus when applied at different times. *Journal of Voice*, *26*(6), 812.e17-812.e22. https://doi.org/10.1016/j.jvoice.2012.03.005

Nemr, K., Simões-Zenari, M., De Souza, G. S., Hachiya, A., & Tsuji, D. H. (2016). Correlation of the Dysphonia Severity Index (DSI), Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V), and gender in Brazilians with and without voice disorders. *Journal of Voice*, *30*(6), 765.e7-765.e11. https://doi.org/10.1016/j.jvoice.2015.10.013

Oates, J. (2009). Auditory-Perceptual evaluation of disordered voice quality. *Folia Phoniatrica Et Logopaedica*, *61*(1), 49–56. https://doi.org/10.1159/000200768

Patel, R. R., Awan, S. N., Barkmeier-Kraemer, J., Courey, M., Deliyski, D., Eadie, T., ... & Hillman, R. (2018). Recommended protocols for instrumental assessment of voice: American Speech-Language-Hearing Association expert panel to develop a protocol for instrumental assessment of vocal function. *American journal of speech-language pathology*, *27*(3), 887-905.

Peterson, E. A., Roy, N., Awan, S. N., Merrill, R. M., Banks, R., & Tanner, K. (2013). Toward validation of the Cepstral Spectral Index of Dysphonia (CSID) as an objective treatment outcomes measure. *Journal of Voice*, *27*(4), 401–410. https://doi.org/10.1016/j.jvoice.2013.04.002

Pommée, T., Maryn, Y., Finck, C., & Morsomme, D. (2020). Validation of the Acoustic Voice Quality Index, version 03.01, in French. *Journal of Voice*, *34*(4), 646.e11-646.e26. https://doi.org/10.1016/j.jvoice.2018.12.008

Rabelo, E. C. D. S., Dassie-Leite, A. P., Ribeiro, V. V., Madazio, G., & Behlau, M. S. (2024). Cepstral Peak Prominence Smoothed - CPPS and Acoustic Voice Quality Index - AVQI in healthy and altered children's voices: comparation, relationship with auditory-perceptual judgment and cut-off points. *CoDAS*, *36*(4). https://doi.org/10.1590/2317-1782/20242023047en

Reynolds, V., Buckland, A., Bailey, J., Lipscombe, J., Nathan, E., Vijayasekaran, S., Kelly, R., Maryn, Y., & French, N. (2012). Objective assessment of pediatric voice disorders with the acoustic voice quality index. Journal of Voice, 26(5), 672-e1-672.e7.

Seshasri, D. (2018). Acoustic Voice Quality Index in Kannada Speaking Children in the Age Range of 10 To 12 Years. Master's Dissertation submitted to the University of Mysore, Mysore.

Shabnam, S., & Pushpavathi, M. (2022). Effect of gender on acoustic voice quality index 02.03 and dysphonia severity index in Indian normophonic adults. Indian Journal of Otolaryngology and Head & Neck Surgery, 74(Suppl 3), 5052-5059.

Sjölander, P., & McAllister, A. (2013). Children's voice and voice disorders. *Seminars in Speech and Language*, *34*(02), 071–079. https://doi.org/10.1055/s-0033-1342978

Sobol, M., & Sielska-Badurek, E. M. (2022). The dysphonia severity index (DSI) - normative values. Systematic review and meta-analysis. Journal of Voice, 36(1), 143-e9.

Timmermans, B., De Bodt, M. S., Wuyts, F. L., & Van De Heyning, P. H. (2004). Training Outcome in Future Professional Voice Users after 18 Months of Voice Training. *Folia Phoniatrica Et Logopaedica*, *56*(2), 120–129. https://doi.org/10.1159/000076063

Uloza, V., Latoszek, B. B. V., Ulozaite-Staniene, N., Petrauskas, T., & Maryn, Y. (2018). A comparison of Dysphonia Severity Index and Acoustic Voice Quality Index measures in differentiating normal and dysphonic voices. *European Archives of Oto-rhino-laryngology/European Archives of Oto-rhino-laryngology and Head & Neck*, *275*(4), 949–958. https://doi.org/10.1007/s00405-018-4903-x

Vishali, P. (2019). Acoustic Voice Quality Index (AVQI) in Tamil Language. Master's Dissertation submitted to the University of Mysore, Mysore.

Webb, A., Carding, P., Deary, I., MacKenzie, K., Steen, N., & Wilson, J. (2003). The reliability of three perceptual evaluation scales for dysphonia. *European Archives of Oto-rhino-laryngology/European Archives of Oto-rhino-laryngology and Head & Neck*, *261*(8). https://doi.org/10.1007/s00405-003-0707-7

Wilson, D. K., (1987). Voice problems of children. Baltimore: Williams & Wilkins.

Wuyts, F. L., De Bodt, M. S., Molenberghs, G., Remacle, M., Heylen, L., Millet, B., ...& Van de Heyning, P. H. (2000). The Dysphonia Severity Index, An Objective Measure of Vocal Quality Based on a Multiparameter Approach. *Journal of Speech, Language, and Hearing Research, 43(3)*, 796-809.

Yu, P., Ouaknine, M., Revis, J., & Giovanni, A. (2001). Objective voice analysis for dysphonic patients: a multiparametric protocol including acoustic and aerodynamic measurements. Journal of voice, 15(4), 529-542.