PERTURBATION AND NOISE MEASURES IN TYPICALLY DEVELOPING CHILDREN IN THE AGE RANGE OF 6-12 YEARS

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Abstract

Perturbation and noise measures of voice have been reported to be the ones that tap subtle and early changes in voice. Although attempts have been made to document these measures in Western context, considering the geographical and ethnic variations, the same values might not be applicable in Indian context. In this context, the present study was taken up to document noise and perturbation measures in voice of typically developing children in the age range of 6-12 years and comparing them across the western norms in children and the Indian norms in adults. Participants included in the study were typically developing children with normal voice in the age range of 6-12 years. The Multi-dimensional voice profile (MDVP), advanced version (Model 5150) module with Computerized Speech Lab hardware system was used for the analysis of voice sample to obtain the perturbation measures jitter %, RAP, PPQ, sPPQ, shimmer %, APQ, sAPQ and noise measures NHR, VTI and SPI. The participants were instructed to phonate vowel /a/ at their comfortable pitch and loudness. A three second steady segment of the voice sample was used to obtain perturbation and noise measures. The obtained measures were tabulated and subjected to statistical analysis to compute mean, standard deviation and range. One way MANOVA indicated no significant effect of gender on any of the measured parameters (p>0.05). One sample t-test revealed that most of the measured parameters are significantly different from western norms in children and also from adult Indian norms. Considering these variations, it may be concluded that the database established in any population cannot be used universally and indigenous norms are essential. The results of the present study may be used as preliminary norms for children in the age range of 6-12 years.

Introduction

Comprehensive evaluation of voice involves measurements under perceptual, acoustic, aerodynamic, physiological, and self-perceptual domains. Although perceptual analysis is considered as the gold standard, it is known to be influenced by the factors such as experience of the clinician. Among the objective measures of voice, acoustic analysis is considered as a non-invasive, easily applicable and low cost measurement of voice that complements other laryngeal diagnostic methods. Measurement of frequency and amplitude perturbations and noise related measures are commonly used as a part of the comprehensive objective voice evaluation. They provide information regarding periodic and aperiodic components of the voice production.

Perfect periodicity is absent even in normal voices. From one voice pulse to the other there are minimal changes in the fundamental frequency. This is an indication of a neuromuscular physiological process where twitches of the slow rate single motor unit occur in the vocal folds (Baer, 1980). Studies related to speech synthesis have shown that human voice is inherent with such arbitrary variation. The minor disturbances in the frequency and the amplitude of the voice signal, called perturbations are unavoidably present even during the production of a steady sound (Titze, 1994). The normal voice production and normal physiology of the human body is inherent of such minor irregularities in the sound wave output (Oriloff & Baken, 1989). It was found that when vocal folds vibrate asymmetrically it yields sub-harmonic structures in the spectrum and thus produces a rough or creaky voice (Isshiki & Ishizaka, 1976). Stiffness, nodules or other histological pathology causes these perturbations to become worse and result in more severe deviation from the normal pattern of voice. This is perceptually defined as dysphonia and the quality is described as breathy, hoarse and rough (McAllister, Sederholm, Ternstorm, & Sundberg, 1996).

Voice perturbations such as jitter and shimmer correlate with the perceived "roughness" and "breathiness" (Dejonckere, Remacle, Fresnel-Elbaz,Woisard, Crevier –Buchmann, and Milet,1996). Voice perturbations increases with increase in the laryngeal pathology (Schoentgen, 1982; Murry and Doherty, 1980) and is also helpful in partially discriminating different functional voice disorder types (Gelzinis, Verikas, & Bacauskiene, 2008; Ortega, Cassinello, & Dorcatto, 2009). Studies have also reported that perturbation measures can identify the subtle changes in voice which are not evident by other methods like auditory or visual (Hanson, 1997 and Stojadinovic, Shaha, Orlikoff, et al., 2002). Despite the significance of perturbations measures in voice evaluation, they were found to be influenced by several factors.

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Stimulus related variable such as pitch, loudness, and vowel (Orlikoff & Kahane, 1991; Dejonckere, 1998; and Brockmann, Storck, Carding, & Drinnan, 2008), instrumental variables such as sampling rate, smoothing factor (Jafari, Till, & Law-Till, 1992), microphone characteristics, algorithm used for analysis, and participant related variables such as ethnicity, age, and gender of the participant (Steinsapir, Forner, & Stemple, 1986 and Jafari et al., 1992) have been reported to influence perturbation measures.

Jitter and shimmer value change across the voice range and thus they vary across the pitch and loudness. In the study by Orlikoff and Baken (1990) it was seen that the jitter and shimmer were similar in women and men at comfortable pitch. It was also observed that the change in jitter with change in F_0 was more evident in men. Orlikoff and Kahane (1991) described a reciprocal linear relation of the perturbation measures to SPL. Also Pabon (1991) reported that the jitter and shimmer values were higher at low frequencies and SPLs. Dejonckere (1998) reported that there was a significant reduction in the perturbation measures when the loudness was increased. In one of the recent studies by Brockmann et al., (2008) the authors concluded that both jitter and shimmer values increased drastically as SPL decreased. This increase was most evident when the loudness dropped from “medium” to “soft” loudness. It was also reported that there were large changes in jitter and shimmer even when there were small changes in SPL below 80 dB. The authors also explain this finding as at lower intensities and frequencies, the muscle tension of the inherent vocal fold muscle is low, resulting in better mucosal cover variability and thus higher perturbation of voice at lower SPLs (Hodge, Colton & Kelley, 2001).

Perturbations are also affected by the stimuli used i.e. vowel and running speech. Sederholm (1996) reported that listeners found instability in voice was almost absent in running speech but seen in sustained vowels. This could be because sustaining a vowel may be a rather unfamiliar vocal task. Influence of type of vowel phonated during the measurement of jitter and shimmer has been explored by a number of authors (Kane & Wellen, 1985; Steinsapir et al., 1986; and Glaze, Bless, Milenkovic & Susser, 1988). Highest jitter values have been reported in vowels /u/, /i/ or /a/ and lowest shimmer in /i/ or /u/. In a recent study by Brockmann, Drinnan, Storck, and Carding (2011) it was seen that there was a significant influence of vowel on shimmer whereas the jitter was not influenced by the vowel type.

Studies also reported higher jitter values for children compared to adult (Steinsapir et al., 1986). In a study by Cappellari and Cielo (2008) the authors found higher jitter values in children who are 4 years old compared to 7 years suggesting that the control of airflow was steadier with increase in age i.e. the aperiodicity in the vibrations of the vocal folds decreased with neurological maturation. Authors also suggested that frequency perturbations have a reciprocal relationship to the development of motor control.

Noise related measures

Voice signal consists of periodic and aperiodic energy. Periodic component of the signal results from vibration of the vocal folds. The additive noise/aperiodic component in the voice signal results from perturbations in the voice and turbulence at the level of glottis during voice production. Perturbations in frequency and sound pressure level results in the noise of low frequency and turbulence due to poor glottic closure leads to additive noise in the high frequency region. The noise thus produced increases the inter-harmonic energy and reduces the energy at harmonics. Therefore, parameters which measure the overall noise energy level and relative energy levels of noise and harmonics in the given signal can reflect the information of voice quality.

Harmonic to noise ratio (HNR) is an acoustic measure that is sensitive indicator of the laryngeal function. HNR quantifies the comparative amount of noise that gets added in the voice signal (Awan & Frenkel, 1994). The ratio is an indication of how abundant the harmonics in the voice are over the noise. The harmonics represent the periodicity and the noise represents aperiodicity in the voice and this ratio of HNR is quantified in terms of dB. Perceptually HNR reflects the quality of voice, because the quality of voice is influenced by the amount of noise in the spectrum (De Krom, 1993). Martin, Fitch, & Wolfe (1995) reported that HNR is a significant predictor of perceptually rough voice.

Carole (1996) compared the efficacy of HNR and jitter in identifying additive noise in the voice signal. Results indicated that, when the voice signal had additive noise, jitter showed very minimal or no change while HNR showed significant variation. From this the authors concluded that amount of noise added in the signal is better reflected by HNR than jitter. The authors also suggested that acoustic measures of jitter were poorly correlated with the stroboscopic patterns.

Soft phonation Index (SPI) is another acoustic measure that reflects the poverty in the harmonic components at the high frequencies which may be suggestive of poor adduction of the vocal folds during phonation. It reflects the average ratio of low to high harmonic energies. The low frequency energy ranges from 70-1600Hz while the high frequency harmonic energy ranges from 1600-4500Hz.

Cappellari and Cielo (2008) reported that the SPI values decreased as the mean APQ values increased. The study also reports that APQ, PPQ, and HNR highly correlated with each other. This may be because all of them are affected by common factors of poor control of the neuro-musculature and by transglottic airflow. In order to resist the pressure of the airflow good neural control of the musculature of the vocal folds is essential. Adequate neuromuscular control is essential for maintaining firmness and stability of the vocal folds in order to withstand the resistance of the airflow. SPI and the VTI correlated negatively with each other.

Thus the perturbation and noise measures yield valuable information that can aid in understanding the functioning of phonatory system. However these objectives measures may be influenced by age, gender, ethnicity etc. In a study Hema, Sangeetha and Pushpavathi (2009) attempted to develop a normative data for adults in the Indian context and compare it with the western norms. The authors reported difference in perturbation measures when compared with the western norms. Further, there has been dearth of such attempts in this regard for children especially in the Indian scenario. This is essential as the production of voice in children is different from that of adults primarily because of variations in the anatomy and the physiology of the paediatric larynx. The paediatric larynx differs from the adult larynx in terms of its size, orientation, consistency and shape. The laryngeal cartilaginous structures are not ossified in the paediatric larynx with the exception of the hyoid bone. Also the paediatric larynx is positioned at a higher level at C2-C3 level (Hudgins, Siegel, Jacobs & Abramowsky, 1997). Stathopoulos and Sapienza (1997) reports of differences in anatomy of the upper and lower respiratory tracts with increasing age, which inturn affect the acoustic output. Muller and Brown (1980) also report of differences in the layers of vocal folds and stability of the thyroarytenoid muscle to improve as the children get older.

Need for the study

In voice clinics and voice research, acoustic analysis of voice is considered as a non-invasive, easily applicable and low cost measurement of voice that complements other laryngeal diagnostic methods. Measurement of frequency and amplitude perturbations and noise related measures are commonly used as part of the comprehensive objective voice evaluation. They supplement the information obtained through visual laryngeal examination as well as perceptual evaluation. These measures are useful in describing pathological as well as normal voices. However, the lack of normative data in Indian context requires them to be interpreted in comparison with the western norms, thus reducing the sensitivity and specificity of them. This assumption was further strengthened by the reported significant differences in acoustic measures among adult Indians to that of Western. Further these measures are also known to be influenced by the age and sex of the participants. Therefore, it is essential to have a database for Indian children for appropriate interpretation of the data and to verify thus obtained data with western norms and adult Indian norms. In this context, the present study was an attempt to document noise and perturbation measures in voice of typically developing children in the age range of 6-12 years and to compare them across the western norms in children and the adult Indian norms.

Objectives of the Study

1. To document perturbation and noise measures of voice in typically developing children in the age range of 6-12 years.
2. To compare the data thus obtained with the Western norms.
3. To compare the data obtained with the adult Indian norms.
4. To verify the effect of gender on these parameters.

Method

Participants: The sample population included a total of 60 children (28 male and 32 female) aged between 6-12 years. The children had no history of any voice problem and had perceptually normal voice at the time of recording. Children with no complaints/reports of upper respiratory tract infection, reduced hearing acuity, and previous history of neurological problems were considered for the study. The subjects had not been part of any singing activity either as solo or choir. During the data collection, some of the participants achieved extreme scores, influencing the mean value. In order to eliminate this, box plots were drawn using the statistical software SPSS 18.0 for the nine acoustic parameters. The box plots indicated the extreme scorers and thus they were removed manually from the main data. Statistical analysis was performed further on a total of the remaining 50 participants (24 males and 26 females).

Instrumentation: The Multi-dimensional voice profile (MDVP), advanced version (Model 5150) module with Computerized Speech Lab hardware system (Kay PENTAX Corp, Lincoln Park, NJ) was operated on a compatible desktop computer. The window length of 6 seconds was used for recording and the signal was sampled at the rate of 50 KHz.

Procedure: The children were instructed to phonate the vowel /a/ at their comfortable pitch and loudness. The mouth to microphone distance was maintained at 15 cm. Three trials were given and the best trial was selected for further analysis. A three second steady portion of the phonated vowel was taken and was subjected to analysis. The MDVP analysis was performed to obtain the acoustic parameters of voice. MDVP provides a total of 33 parameters which can be classified under frequency measures, perturbation measures, noise measures, tremor measures, voice irregularity (voice break and sub-harmonic) measures. From the obtained parameters, the perturbation measures jitter%, RAP, PPQ, sPPQ, shimmer %, APQ, sAPQ and noise measures NHR, VTI and SPI (Table 1) were noted down for further analysis. The absolute jitter (µsec) and absolute shimmer (dB) values were not included in the present study as these were reported to be influenced by major variations in average pitch period and amplitude during phonation (Titze, 1994).

Table 1: Perturbation and noise measures analysed in the study

Acoustic Parameter	Abbreviation
Jitter %	Jitt
Pitch period perturbation quotient	PPQ
Relative average perturbation	RAP
Smoothened pitch period perturbation quotient	sPPQ
Amplitude perturbation quotient	APQ
Smoothened amplitude perturbation quotient	sAPQ
Noise to harmonic ratio	NHR
Voice turbulence index	VTI
Soft phonation index	SPI

Statistical analysis: The data was analysed using the software Statistical Package for Social sciences (SPSS) version 18. Measurement of mean, standard deviation and range for all the parameters across the gender included the descriptive statistics. Two way multivariate analysis of variance (MANOVA) was performed to determine the effect of independent variables on the dependent variables. The independent variable was gender, and the 9 acoustic parameters measured (Jitter%, RAP, PPQ, sPPQ, APQ, sAPQ, NHR, VTI and SPI) were the dependent variables. One sample t – test was performed to check if there was a significant difference in the acoustic parameters between the results obtained in the present study with that of the adults and the Western norms.

Results and Discussion

Acoustic analysis of voice is an easy, non-invasive, and economical way of objectively measuring an individual's voice. Thus obtained measures can be used in differentiating normal from abnormal voices, screening individuals who are at-risk for developing voice disorders, and for documenting therapeutic and surgical treatment outcomes. In this context, the present study was an attempt to document perturbation and noise measures of voice in typically developing children in the age range of 6-12 years, and to compare them with western children and adult Indian norms. It further attempted to verify the influence of gender on the perturbation and noise measures of voice. The results of the study are presented and discussed under the following subheadings.

- Perturbation and noise measures in typically developing children in the age range of 6-12 years.
- Comparison of perturbation and noise measures with Western norms.
- Comparison of perturbation and noise measures with the adult Indian norms.
- Effect of gender on perturbation and noise measures.

Perturbation and noise measures in typically developing children in the age range of 6-12 years: Mean, standard deviation and range across perturbation and noise measures were computed. Table 2 shows the mean and standard deviation values for perturbation and noise measures in these children. Overall the frequency perturbation measures were found to have less deviated from their average values compared to the amplitude perturbation measures (figure 1). sPPQ under the frequency perturbation measures and VTI under the noise measures revealed larger variations with standard deviation higher than their mean values.

Table 2: Mean, standard deviation, and range of the perturbation and noise measures in children.

Parameter	Mean	Standard Deviation	Range Minimum	Range Minimum
Jitter%	1.13	0.68	0.19	3.01
RAP	0.68	0.41	0.117	1.81
PPQ	0.67	0.42	0.11	1.81
sPPQ	0.93	0.96	0.08	5.62
Shimmer%	5.12	1.96	1.37	9.55
APQ	3.76	1.62	1.00	8.17
sAPQ	5.23	1.79	2.38	11.33
NHR	0.14	0.04	0.10	0.33
VTI	0.05	0.17	0.17	0.05
SPI	5.94	4.55	1.06	18.52

The wider range of perturbation can be attributed to the type of task used to elicit the voice sample. Sustaining a vowel is a rather unfamiliar task and causes instability of voice causing a wider range in the perturbation measures (Sederholm, 1996). Further, the study included children of 6 years as well as 12 years of age. The anatomical and physiological changes may improve the vocal functioning in children as they grow older. Therefore, the group might have been heterogeneous with children at different levels of anatomical and physiological maturation.

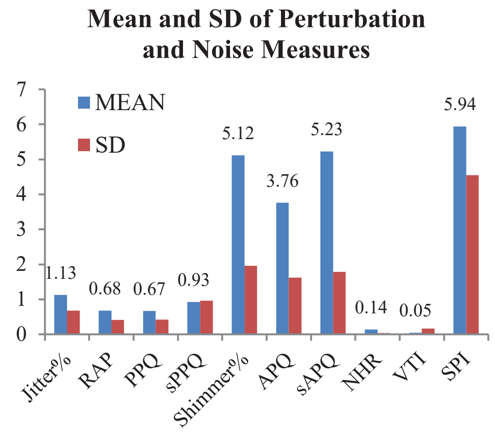

Figure 1: Mean and SD of perturbations and noise measures

The findings of laryngeal and respiratory anatomical and physiological variations in developing children have been reported by earlier studies (Muller and Brown, 1980; Stathopoulos and Sapienza, 1997; and Karike and Kishore, 2012). Muller and Brown (1980) reported of differences in the layers of vocal folds and stability of the thyroartenoid muscle to improve as the children get older. Stathopoulos and Sapienza (1997) also reported of differences in anatomy of the upper and lower respiratory tracts with increasing age, which in turn affect the acoustic output.

Karike and Kishore (2012) reported increase in estimated subglottic pressure (ESGP) value in males increased till 10-11 years of age then declined in the age group of 11-12 years. Even in females the ESGP value increased till 8-10 years and declined afterwards. Thus, indicating that the development variations in the laryngeal system will have a significant effect on the acoustic measures of voice. The results of the present study indicate that the children in the developmental age will be heterogeneous with respect to their voice characteristics. Therefore, considering the preliminary status of the present study, the findings have to be verified on larger population with more number of children under each age group.

Comparison of perturbation and noise measures in present study with Western norms: The results of the present study were compared with the Western norms that are provided in the MDVP database. The results of one sample t-test indicated that compared to Western norms the values in Indian children differ significantly for all frequency perturbation measures, APQ and NHR (table 3). The frequency perturbations are higher in general in the Western children compared to the Indian children. The APQ and NHR values are higher in Indian children compared to Western children (figure 2). This may be due to the factors that generally influence perturbation and noise measures such as differences in the vocal tract length, intensity, type of phonatory initiation and termination, F0 level (Koike 1973, Hollien, Michel & Doherty, 1973).

Table 3: Mean and p values of the perturbation and noise measures across Indian and Western population

	Indian	Western	*p* value
Jitter%	1.13	1.69	0.00*
RAP	0.68	1.03	0.00*
PPQ	0.67	0.98	0.00*
sPPQ	0.93	3.8	0.00*
Shimmer%	5.12	4.25	1.94
APQ	3.76	2.81	0.00*
sAPQ	5.23	3.8	5.85
NHR	0.14	0.12	0.00*
VTI	0.05	0.03	1.00
SPI	5.94	10.2	0.20

*parameters found to be significant at $p<0.05$

The present study used the mouth-to-microphone distance of 15cm, and the recordings are made in a quiet room rather sound treated room, possibly contributing to increase in amplitude perturbations. However, it is not clear to what extent this difference is due to the methodological differences as these details are not provided in the MDVP manual or in the official website. Nevertheless, according to the manual, the database was based on a small group of participants, and suggests having indigenous normative database.

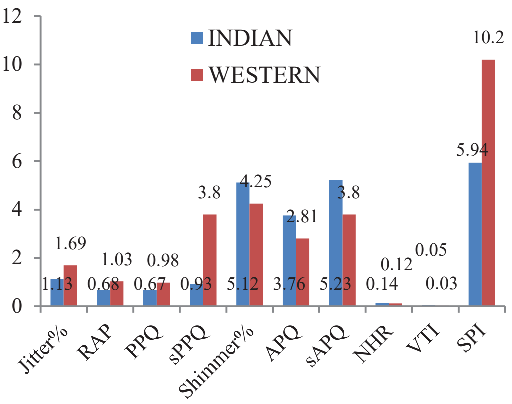

Figure 2: Perturbation and noise measures in Indian children (present study) and Western children (KayPentax database)

Comparison of perturbation and noise measures with the adult Indian norms: The results of the present study are compared with the study in Indian adults by Hema, Sangeetha, and Pushpavathi (2009). The results of one sample t-test indicated that compared to adults the values in Indian children differ significantly for all perturbation measures. Noise measures are comparable to adults and showed no statistically significant difference (table 4). However, the SPI value was found to be lower in children compared to the adults. The lower SPI value may be due to use of loud voice by children both habitually and due to performance related enthusiasm. As louder voice demands a firm glottic closure, which allows lower air turbulence and subsequently lower high-frequency noise than usual phonation, hence decreasing the SPI value.

The perturbation measures especially the amplitude perturbation measures are higher in children when compared to that of adults (figure 3). This finding is consistent with the study by Cappellari and Cielo (2008) who reported jitter values to be higher in younger children when compared to older ones. The authors reason the finding that as the maturation increases the perturbations decrease as there was a gradual higher control of emission as the age increased. The higher values of jitter % in children was also in agreement with the study by Steinsapir et al., (1986) who also reported higher jitter values for children compared to adults.

Table 4: Mean and p values of the perturbation and noise measures across Indian children and adults.

	Children (Mean)	Adults (Mean)	*p* value
Jitter%	1.13	0.99	0.00*
RAP	0.68	0.58	0.00*
PPQ	0.67	0.56	0.00*
sPPQ	0.93	0.6	0.00*
Shimmer%	5.12	3.14	0.00*
APQ	3.76	2.19	0.00*
sAPQ	5.23	2.91	0.00*
NHR	0.14	0.12	0.00*
VTI	0.05	0.04	0.3
SPI	5.94	14.47	0.5

*parameters found to be significant at $p<0.05$

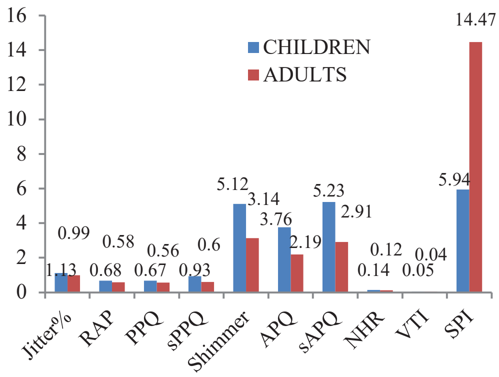

Figure 3: *Perturbation and noise measures in Indian Children (present study) and Adults (Hema et al., 2009).*

Effect of gender on perturbation and noise measures: The mean values of the parameters obtained were compared across the gender using one way MANOVA to verify the effect of gender on the perturbation and noise measures (Table 5). The results indicated that there was no effect of gender for any of the measured parameters indicating that they are independent of the participant's gender. These findings are in consensus with the study by (Nicollas, Garrel, Ouaknine, Giovanni, Nazarian, & Triglia 2008; Lundeborg, Hultcrantz, Ericsson, & McAllister, 2012). These authors attributed this finding to the developmental and maturational similarities in children during pre-pubertal age. They opined that as the development and physiological functioning of the phonatory system remains similar pre pubertally in children and the gender differences are more evident during and post-pubertally.

Further, the relative measures of perturbation such as Jitter %, RAP, APQ etc. are less influenced by the level of average fundamental frequency or average amplitude (Horri, 1979). Therefore, the absence of gender effect in the present study may be due to the fact that only relative measures of frequency and amplitude perturbations were considered. Hema et al., (2009) also reported no significant influence of gender on the noise measures NHR, VTI and SPI; and on majority of the perturbation measures. It may be possible that both males and females are using similar physiological patterns in terms of glottic closure and cycle-to-cycle variations, despite the presence of structural differences in vocal tract and vocal folds. This indicates that both males and females compensate for variations in their vocal tracts in order to reach the goal of voice production without majorly perturbing the system.

Table 5: Effect of gender on the perturbation and noise measures.

Parameter	*p* value (Between Gender)
Jitter%	0.31
RAP	0.33
PPQ	0.22
sPPQ	0.06
Shimmer%	0.67
APQ	0.87
sAPQ	0.90
NHR	0.07
VTI	0.12
SPI	0.14

Conclusion

Perceptual assessment remains the gold standard for voice evaluation. However evaluation of voice perceptually is affected by factors such as experience of the examiner and expertise in the field. Thus the perceptual evaluation requires to be validated by an objective method for better reliability. MDVP is one such objective method of evaluation which gives an insight into a wide arena of parameters that tap different parameters of vocal physiology non- invasively. However the lack of normative data of children in the Indian scenario might limit the effective use of this module. This study is a preliminary effort at documenting the perturbation and noise measures in children between 6-12 years. The results of the study indicated no effect of gender on the perturbation and noise measures. The study also revealed a significant difference of the mean values of the perturbation measures when compared with those of the adults. The study may be replicated in a larger population with larger sample size under each age group and by better controlling the factors that affect perturbation and noise measures for better validation of the results.

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