Severity of Voice Disorders in Children: Correlations Between Perceptual and Acoustic Data

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Summary: Objectives. The aims of this study were to verify whether there is correlation between perceptual and acoustic data and to verify which measures are useful to identify the severity of voice deviation in children.

Methods. The participants were 71 children aged 3–9 years. The severity of voice deviation, roughness, breathiness, strain, and instability was evaluated by three speech therapists, experts on perceptual voice evaluation. A visual analog scale was used; speech material consisted of a sustained vowel sound /ɛ/ and the counting of numbers from one to 10. The means and standard deviations of fundamental frequency (F_0), jitter, shimmer, and glottal-to-noise excitation (GNE) ratio were extracted from the sustained vowel, and the mean and variability of F_0 were extracted from automatic speech (counting). Perceptual and acoustic data were correlated.

Results. Most children had mild voice deviation, with strain, instability, and breathiness as predominant voice qualities. F_0 measures correlate with strain to phonate. Shimmer and GNE correlate with general degree of voice deviation and with the roughness, breathiness, and instability parameters. GNE and F_0 mean in connected speech were the only measures that distinguished voices regarding severity of voice deviation.

Conclusions. There was a correlation between perceptual and acoustic measures from these children's voices. Children with high-pitched voices had higher voice deviations. GNE is a measure that reliably distinguishes the severity of voice deviation and may be useful in the screening and evaluation of children's voices.

Key Words: Voice–Voice quality–Dysphonia–Perceptual evaluation–Acoustic–Children.

INTRODUCTION

Through life, voice development follows and represents organic, psychological, and social changes in the person. The child's larynx has a higher position on the neck for the purposes of breathing and protecting the lower airways.[1]

Dysphonia may have a negative impact on a child's general health, the effectiveness of his/her communication, his/her social and educational development, self-esteem, self-image, and even participation in social environments. Both parents and peers may judge dysphonic children more negatively than the other children with healthy voices regarding personality characteristics and physical and cognitive abilities.[2]

There have been few epidemiologic studies on child dysphonia. One main difficulty is the definitions of dysphonia and its changes during this period of life.

An important challenge is to determine the severity of voice deviation and categorize vocal output as normal or deviated (deviant) in relation to age-based criteria in different domains, such as perceptual, acoustic, aerodynamic, laryngeal, and self-perception.[3]

Prevalence rates of dysphonia among children available in the literature vary from 0.5% to 80%.[3–7] Although the prevalence of dysphonia in children has been found to be high, only 8.3% of published articles on voice have had children as subjects. In addition, the evidence levels for children in these articles were lower than those for the adult population.[8]

Besides those articles, clinical research on voice complaints among pediatric populations does not have many highlights or much visibility in the field of voice research.[8]

The shortage of studies on the impact of voice on quality of life among children may also reflect the general thought that juvenile dysphonia improves once the patients reach puberty. Actually, literature data report that larynx deviations and voice complaints from childhood are still present during the teenage years in at least 21% of cases.[9]

Children's susceptibility to the development of dysphonia is related to recurrent lower airway infection, social determinants, and anatomic and behavioral characteristics.[4,10–12]

The majority of the aspects of adult voice function may be considered in child evaluations. Voice multimodality experiments demand the evaluation of perceptual, acoustic, aerodynamic, laryngeal, and self-perception measures, mapping the majority of these aspects and correlating them to establish a global and true cause of voice deviation.[2,4,8,13–17]

Both scientists and clinicians strive to develop methods of objective voice evaluation, which is predominantly an impressionistic technique. Perturbation and noise measures have emerged as robust measurements that are useful basic parameters of voice quality (these measures include general severity of voice deviation, roughness, and breathiness), although there is no consensus about their power to distinguish deviated voices from normal voices.[17,18]

It is even more important to establish whether there are correlations between perceptual evaluations and the measured acoustic parameters in determining the severity of voice

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deviation, understanding how acoustic measures reflect on perceptual analysis and *vice versa*.[19]

Within this context, the purposes of this research were to (1) verify whether there are correlations between the abilities of perceptual evaluations and acoustic measurements to determine the severity of voice deviation and (2) find which measures are more useful in distinguishing the severity of voice deviation among children.

METHODS

Study design

This was a quantitative, exploratory field and cross-sectional study. It was evaluated and approved by the Ethical Committee in Research of Academic Hospital Lauro Wanderley of the Universidade Federal da Paraíba (UFPB), protocol number 775/10.

Subjects

The study's participants were 71 children of both sexes (29 females and 42 males) aged 3–9 years, all students of the Day Care Center at the UFPB.

The exclusion criteria dismissed children who did not fulfill the required speech tasks, had cognitive disorders, or had airway disturbance at the time of the study. Inclusion criteria were age of 3–9 years and written informed consent bearing the signature of a parent or legal representative.

Materials

All voices were recorded (at a sampling rate of 44 100 Hz) using an HP notebook (Hewlett-Packard Development Company, Palo Alto, CA); a Logitech headset with a microphone (Logitech, Fremont, CA); and the *PRAAT*, Version 5.1.44 software package (P. Boersma and D. Weenink, University of Amsterdam, The Netherlands).

Procedures

Before collecting the data, a field visit was made to select a silent environment with noise background registering lower than 50-dB sound pressure level (SPL). Day care directors gave their authorization for the study after receiving an explanation of the procedures and purposes, and the informed consent forms were sent to the children's parents.

Once parents had signed the informed consent forms, the researchers returned to the day care center to record the children's voices at times scheduled with the school supervisor. The children were directed one by one to the recording environment during their first class period in the morning and afternoon shifts, which lasted from 08:00 to 10:00 AM and from 01:00 to 03:00 PM, respectively.

Voice recording lasted 5 minutes for each child, starting with a maximum phonation time task for the sustained vowel /ɛ/; this was followed by counting numbers from one to 10. Although many studies use the vowel /a/ for acoustic and perceptual analysis, the vowel /ɛ/ was used because of a recommendation regarding analysis in the software manual. Data were collected from March until October of 2011.

The voices were edited using the *Sound Forge*, Version 10.0 software package (Sony, Tokyo, Japan): the first and last 2 seconds of each recording were eliminated because of their higher irregularity, but we preserved a minimum time of 3 seconds for each emission. A normalization process was completed on both sustained (vowel sound) and connected (counting) speech using the "normalize" function of *Sound Forge* with peak levels set between -6 and 6 dB.

For perceptual analysis of the voices, a visual analog scale (VAS) ranging from 0 to 100 mm was used to indicate the general degree of dysphonia, roughness grade (RG), breathiness grade (BG), strain grade (SG), and instability grade (IG). Values closer to 0 represent lower voice deviations, and those closer to 100 represent higher ones. This evaluation was made by consensus of three speech therapists, experts on perceptual voice evaluation.

The perceptual evaluation session was performed in a silent environment; each sample was presented three times using speakers adjusted to a self-reported comfortable sound pressure level, and then voice parameters were evaluated using VAS.

Numeric correspondences between the VASs[20] were categorized as grade 1 (0–35.5 mm), normal variability of voice quality (NVVQ) or absence of deviation; grade 2 (35.6–50.5 mm), mild deviation; grade 3 (50.6–90.5 mm), moderate deviation; or grade 4 (90.6–100 mm), intense deviation.

The use of NVVQ captures acceptable variations that may express vocal style, preference for voice usage, professional characterization, or small voice problems.[20]

The predominant voice characteristic in each emission was defined as the characteristic with the highest value on VAS between the RG, BG, SG, and IG parameters for that emission.

The acoustic analysis was performed using voice analysis and voice quality modes in the *VoxMetria* Version 4.5 software package (CTS, Parana, Brazil). The acoustic analysis extracted the following values: the means and standard deviations (SDs) of fundamental frequency (F_0), jitter, shimmer, and glottal-to-noise excitation (GNE) ratio from sustained vowels and mean and variability of F_0 during connected speech (counting).

Jitter, shimmer, and GNE values were not compared with normative data because there are no established patterns in this age group with the software used, but the values were correlated with perceptual analysis.

Data analysis

Descriptive statistical analysis was performed and Spearman correlation tests were used on all studied variables to correlate the severity of voice deviation (NVVQ, mild, or moderate) with the acoustic measures. Kruskal-Wallis tests were used to compare the acoustic measures and the severity of voice deviation.

The statistical analysis was performed using the *STATISTICA*, Version 6.0 software package (StatSoft Inc, Tulsa, OK). The threshold for statistical significance was set at $P < 0.05$.

RESULTS

The general grade of VAS measure of voice deviation was used to categorize children's voices as normal (NVVQ) when the global severity of voice deviation (general grade [GG]) was in category 1 (0–35.5 mm) or deviated when the GG was in category 2 or greater (35.6 mm and higher) (Table 1).

The prevalence rate of deviated voices, as defined by perceptual analysis of sustained vowels, was 87.31% (n = 62); the deviations were considered to be mild (84.50%) and moderate (2.81%) (Table 1). None of the children had intense deviation of voice quality. The mean GG was equal to 42.18 mm (SD = 5.30) on the VAS (Table 2).

Most children had mild deviation in terms of instability (47.88%, n = 34), roughness (45.07%, n = 32), and strain (40.84%, n = 29) (Table 1), with mean scores of 42.14 mm (SD = 14.86), 41.01 mm (SD = 15.43), and 46.33 mm (SD = 11.44) on the VAS, respectively (Table 2). There were no significant differences between the absence of deviation and mild deviation in terms of BG; the average value of BG was 35.21 mm (SD = 20.75) on the VAS, within the NVVQ interval (Table 2).

Strain (32.26%, n = 20) was the parameter that measured voice deviation in children most accurately, followed by instability (29.03%, n = 18), breathiness (24.20%, n = 15), and roughness (14.51%, n = 9) (Table 3).

Considering perceptual and acoustic data, higher GG severity was correlated with higher shimmer value ($P = 0.003$), higher F_0 mean value ($P = 0.001$) and SD ($P = 0.02$), and lower GNE value ($P < 0.0001$) (Table 4).

Voices with higher RG had higher values of shimmer ($P = 0.003$) and F_0 SD ($P = 0.01$) and lower GNE values ($P < 0.0001$). There was also a correlation between GG and F_0 mean ($P = 0.02$) for connected speech because children with rougher voices had higher F_0 values during speech (Table 4).

Voices with higher deviation in BG had higher shimmer values ($P < 0.0001$) and lower GNE ($P < 0.0001$) (Table 4).

There was a positive correlation between the SG and F_0 measures. Children with more strained voices had to use higher pitches for sustained vowels ($P < 0.0001$) and connected speech ($P < 0.0001$) and had higher F_0 variability during speech ($P = 0.01$). F_0 SD was also higher in strained voices ($P = 0.04$) (Table 4).

Voices with elevated IG had higher shimmer measures ($P = 0.02$), F_0 SDs ($P = 0.004$), and lower GNE values ($P = 0.005$). Children with more unstable voices used higher F_0 ($P = 0.003$) and had more F_0 variability ($P = 0.01$) in connected speech (Table 4).

Of the acoustic measures of perturbation (jitter, shimmer, and GNE), GNE was the only one able to distinguish GG ($P = 0.02$) (Table 5).

Another comparison was made between F_0 and GG, indicating that F_0 is also able to distinguish voices according to severity of voice deviation ($P = 0.04$); higher F_0 values indicate higher severity of deviation (Table 5).

TABLE 1.
Occurrence of Voice Deviation Severity by VAS

	Voice Deviation Severity, n (%)		
Variable	NVVQ	Mild	Moderate
GG	9 (12.67)	60 (84.50)	2 (2.81)
RG	17 (23.94)	32 (45.07)	22 (30.98)
BG	28 (39.43)	27 (38.02)	16 (22.53)
SG	22 (30.98)	29 (40.84)	20 (28.16)
IG	11 (15.49)	34 (47.88)	26 (36.61)

Abbreviations: VAS, visual analog scale; NVVQ, normal variability of voice quality; GG, general grade; RG, roughness grade; BG, breathiness grade; SG, strain grade; IG, instability grade.

TABLE 2.
Mean and SD of Voice Deviation Severity by VAS

Variable	VAS Mean	NC Mean
GG	42.18 ± 5.30	1.90 ± 0.38
RG	41.01 ± 15.43	2.06 ± 0.73
BG	35.21 ± 20.75	1.83 ± 0.76
SG	42.14 ± 14.86	1.97 ± 0.76
IG	46.33 ± 11.44	1.19 ± 0.68

Abbreviations: VAS, visual analog scale; NC, numeric correspondence of VAS; GG, general grade; RG, roughness grade; BG, breathiness grade; SG, strain grade; IG, instability grade.

DISCUSSION

Perceptual analysis conducted by VAS was established as the criterion to distinguish between children with and without voice quality deviation. The overall prevalence rate of deviation was 87.3%: 84.5% of children had mild deviation and 2.8% had moderate deviation.

The largest epidemiologic study conducted in Brazil collected data from parents' interviews and perceptual, acoustic, and laryngeal analysis of 2000 children.[3] According to the parents' judgment, the prevalence of dysphonia was 6.15%; in perceptual analysis performed by speech language pathologists using the grade, roughness, brethiness, asthenia, strain, and instability (GRBASI) scale, the prevalence was 11.4%. Most children had mild dysphonia (53.3%); the others had an absence of deviation (35.3%) or moderate deviation (11.4%).

In this study, a predominance of strain, breathiness, and unstable voices was found in perceptual analysis; these attributes are reported in the literature as expected of children's voices.[6,11,12,21]

These qualities arise because of the anatomical properties of the larynx, which is likely to incur phonotrauma, and they are

TABLE 3.
Kinds of Predominant Voice in Children With General Degree Equal or Higher to 1

Voice Kinds	n (%)
Roughness	9 (14.51)
Breathiness	15 (24.20)
Strain	20 (32.26)
Instability	18 (29.03)
Total	62 (100)

TABLE 4.
Voice Deviation Severity and Acoustic Measures Correlation in Children Voices

	Voice Deviation Severity									
	GG		RG		BG		SG		IG	
Variables	Correlation	*P* Value	Correlation	*P* Value	Correlation	*P* Value	Correlation	*P* Value	Correlation	*P* Value
F_0 sustained vowel	0.15	0.33	−0.01	0.88	−0.04	0.70	0.45	<0.0001*	0.09	0.44
F_0 SD	0.27	0.02*	0.28	0.01*	0.07	0.53	0.23	0.04*	0.33	0.004*
F_0 mean counting	0.39	0.001*	0.25	0.02*	0.09	0.40	0.41	<0.0001*	0.34	0.003*
F_0 var counting	0.27	0.02*	0.14	0.23	0.09	0.43	0.29	0.01*	0.30	0.01*
Jitter	0.19	0.10	0.11	0.35	0.28	0.15	0.10	0.39	0.11	0.32
Shimmer	0.34	0.003*	0.34	0.003*	0.49	<0.0001*	0.01	0.90	0.27	0.02*
GNE	−0.46	<0.0001*	−0.45	<0.0001*	−0.62	<0.0001*	0.01	0.90	−0.32	0.005*

*Significant values ($P < 0.05$)—Spearman correlation.
Abbreviations: GG, general grade; RG, roughness grade; BG, breathiness grade; SG, strain grade; IG, instability grade; F_0, fundamental frequency; F_0 SD, F_0 standard deviation; F_0 var, F_0 variability; GNE, glottal-to-noise excitation.

associated with behavioral factors and personality structure, both of which play important roles in the etiology of voice deviation in childhood.[22]

F_0 mean during the pronunciation of a sustained vowel was directly correlated with severity of strain to phonate; this may be physiologically justified, as strained voices have more longitudinally tense (stretched) vocal folds and/or higher subglottis pressure.[23] Other research has also observed that children with strained voices had high F_0 values.[24]

The results of this research diverge from a previous study that observed a decrease in F_0 among female children with mild dysphonia compared with the ones without voice deviation. However, in that study, there was no correlation between strain and voice deviation, different from the results of the present study.[3]

Considering only normality of laryngeal perspective, other studies have contended that F_0 mean was not significant to distinguish between groups with and without laryngeal lesions.[11]

Regarding the data from connected speech, children with high-pitched voices had higher roughness, strain, instability, and general degrees of deviation. Children with richer tone scales had higher GGs of voice deviation, higher strain, and higher phonatory instability.[12]

Research comparing children with and without vocal fold nodules observed that children with lesions had higher numbers of friends, spent more time with them, met them more frequently, and were more involved in organizations. Expansive people tend to have higher amounts of voice usage and use a larger F_0 variation during communication, justifying the correlation between this parameter and higher GG in the present study.[22]

In this research, the SD of F_0 was correlated with the GGs of voice deviation, roughness, strain, and instability. It was expected that there would be a direct relationship between perceptual parameters and sound signal aperiodicity, that is, roughness and phonatory instability.

F_0 SD is also a good measure to predict the perceived GG of dysphonia; this pattern may exist because many of the subjects with voice disturbance had predominant aperiodicity components such as roughness and instability (43.54%); SDs were sensible measures of these parameters.

Shimmer values were higher in children with higher GGs of voice deviation and more roughness, breathiness, and instability. Jitter did not show correlations with any of the perceptual parameters.[11,22]

Research involving jitter and shimmer measures has not shown a consensus regarding the use of these parameters to

TABLE 5.
Mean and SD of the Jitter, Shimmer, GNE, and F_0 Measures in the Different Degrees of Voice Deviation

	NVVQ		Mild		Moderate		
Variables	Mean	SD	Mean	SD	Mean	SD	*P* Value
Jitter	0.64	1.39	0.73	1.32	0.73	0.22	0.05
Shimmer	5.34	3.21	7.00	3.61	9.60	0.50	0.06
GNE	0.90	0.08	0.80	0.18	0.5	0.20	0.02*
Mean F_0 counting, Hz	241.50	59.80	261.26	31.01	320.05	4.91	0.04*

*Significant values ($P < 0.05$)—Kruskal-Wallis test.
Abbreviations: SD, standard deviation; GNE, glottal-to-noise excitation; F_0, fundamental frequency; NVVQ, normal variability of voice quality.

predict perceived voice quality, but they are still the most trustable measures indicating the severity of voice deviation.[25–32]

In the context of screening, there is not a single unique characteristic that is able to distinguish between normal and deviated voices because voice disturbances tend to combine different types of perturbations. Few studies have evaluated the discrimination capabilities of acoustic parameters.

Research correlating laryngeal (videostroboscopy), acoustic, and perceptual parameters in children showed significant correlations between the vibration quality of mucosa wave and perceptual evaluation and between acoustic and perceptual evaluation.[3,27] The acoustic data were not correlated with those from laryngostroboscopy. The improvements in voice production produced by changes in the three parameters showed themselves to be independent.

Jitter and shimmer may be strong predictors of voice disturbance: they detect small voice deviations that may not be perceived in perceptual or visual (laryngeal) analysis.[28,33–35]

Research on children with vocal nodules has also shown a significant correlation between the judged severity of voice deviation and the jitter and shimmer measures.[3,12] Children have higher jitter and shimmer values and lower noise-to-hormonics ratio values than do adults; in that study, the jitter and shimmer values were even higher in children with voice disturbances than in subjects of the same age without voice deviation.

Considering the larynx dynamics of children, it is pertinent to correlate the shimmer and voice parameters. In this study, the predominant voice characteristic of 24 children was roughness or breathiness.

An important result is that the jitter and shimmer parameters measure aspects of voice perturbation, whereas the perceptual analysis scales, even after correcting for inter- and intrajudge variables, integrate a combination of diverse effects.[26,32]

GNE had lower values in subjects with higher general degrees of voice deviation and more roughness, breathiness, and instability. The severity of overall voice deviation was evaluated for association with jitter, shimmer, and GNE; of these, only GNE had a significant ability to distinguish between groups with and without voice deviation.

GNE measures additional sound signal noise that is independent of noise modulated by the glottic mechanism. It indicates the origin of the sound signal (whether it comes from vocal fold vibrations or from the turbulent air column generated in the vocal tract). It is capable of showing different values corresponding to distinct phonatory adjustments in diverse voice disturbances.[26]

Research using a promissory methodology in which the listeners were invited to estimate jitter, shimmer, and noise measures (signal-to-noise ratio) for synthesized voices showed that the listeners responded perceptually to noise changes in voices in a coherent and principled way, as assessment of noise level is a significant and reliable method of evaluating voice quality.[25,26,36,37]

This finding is related to the present study's results confirming that GNE, a measure of noise, is a trustable parameter to identify the degree of voice deviation; it correlates with perceptual evaluation, which may distinguish between normal and deviated voices. Furthermore, GNE is directly related to the presence of roughness and breathiness, which are among the most-quoted characteristics of children's voices.

However, more research is necessary to establish normative acoustic data for this population according to sex and age. Along with this, the major challenges for future research are to understand which resource provides the best evaluation (independent of irregularity and additive noise present on deviated voices) and to establish the correlations between each measure of perceptual and physiological systems.[25,26,38]

Voice evaluation needs to use a combination of several acoustic noise measures allowing each subject's voice emission to be quantified by a unique set of parameters. However, to simplify the screening process, it would be ideal to select the best acoustic characteristics, that is, those having higher correlations with perceptual evaluations and higher power to distinguish between normal and deviated voices.[32]

CONCLUSION

Most children with voice deviation presented a mild degree of dysphonia (84.5%) with strain and instability as the predominant voice qualities. There is a correlation between the perceptual and acoustic data, reinforcing that these two types of analysis are complementary in establishing the severity of voice deviation. Children with high-pitched voices during speech have more intense voice disturbances. GNE was the only measure of aperiodicity that was able to distinguish the severity of voice deviation among groups; it may be used as a trustable measure in the screening and evaluation of children's voices.

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