Original Article

Comparison of Vocal Parameters in Hypofunctional and Hyperfunctional Dysphonia Based on Perceptual Assessment and Cepstral Spectral Index of Dysphonia

Sakshi Jain[1]

[1]Assistant Professor, Department of ENT, F.H Medical College, Agra, Uttar Pradesh, India

Abstract

Background: Perceptual evaluation remains a cornerstone in the assessment of voice disorders. Tools such as the GRBAS scale and the Composite Severity Index of Dysphonia (CSID) are widely used to quantify voice quality and dysphonia severity; however, their comparative performance across different speech tasks and dysphonia types remains to be explored. The objective is to compare GRBAS and CSID scores across normophonia, hypofunctional dysphonia, and hyperfunctional dysphonia groups during oral passage reading and sustained vowel phonation (/a/, /i/, /u/), and to examine the relationship between perceptual voice ratings and dysphonia severity indices. **Material and Methods:** A total of 140 participants were included in the study and categorized into normophonia (n = 70), hypofunctional dysphonia (n = 35), and hyperfunctional dysphonia (n = 35) groups. Perceptual voice quality was assessed using the GRBAS scale, and dysphonia severity was measured using CSID during oral passage and sustained vowel tasks. **Results:** The Kruskal–Wallis H test revealed statistically significant differences across groups for both GRBAS and CSID scores during oral passage and sustained vowels (p < 0.001). Pair-wise comparisons demonstrated significantly higher GRBAS and CSID scores in both hypofunctional and hyperfunctional dysphonia groups compared to the normophonia group across all tasks (p < 0.001. **Conclusion:** The findings indicate that both GRBAS and CSID effectively differentiate normophonic and dysphonic voices across oral passages and sustained vowel tasks.

Keywords: Voice disorders; GRBAS; CSID; hypofunctional dysphonia; hyperfunctional dysphonia; perceptual voice assessment.

INTRODUCTION

Voice is a primary medium of human communication and plays a crucial role in social interaction, professional performance, and quality of life. Any disturbance in voice production can significantly affect an individual's personal, social, and occupational functioning. Dysphonia refers to an impairment in voice quality, pitch, loudness, or vocal effort that limits effective communication and may arise from structural, neurological, or functional abnormalities of the vocal mechanism.[1] Among the various classifications of voice disorders, functional dysphonias are particularly common in clinical voice practice and are broadly categorized into hypofunctional and hyperfunctional dysphonia based on underlying phonatory behavior.[2]

Hypofunctional dysphonia is characterized by reduced vocal fold adduction, incomplete glottal closure, and decreased muscular activity during phonation, resulting in breathy, weak, or asthenic voice quality.[3] In contrast, hyperfunctional dysphonia involves excessive or imbalanced muscular activity of the laryngeal and paralaryngeal structures, leading to a strained, rough, or pressed voice quality.[4] Both conditions represent maladaptive phonatory patterns rather than primary structural lesions, although prolonged dysfunction may predispose individuals to secondary organic pathologies such as nodules or polyps.[5] Accurate differentiation between hypofunctional and

hyperfunctional dysphonia is essential for appropriate clinical management, as therapeutic approaches differ substantially. Hypofunctional dysphonia often requires techniques aimed at improving glottal closure and respiratory support, whereas hyperfunctional dysphonia management focuses on reducing excessive muscular tension and optimizing vocal efficiency.[6] Therefore, reliable assessment of vocal parameters is critical for diagnosis, treatment planning, and outcome evaluation.

Voice assessment is multidimensional and typically includes perceptual, acoustic, aerodynamic, and laryngeal imaging measures.[7] Among these, perceptual evaluation remains the gold standard in clinical voice assessment, as it reflects how the voice is perceived by listeners in real-world communication.[8] Commonly used perceptual rating scales evaluate parameters such as grade, roughness, breathiness, asthenia, and strain, providing valuable qualitative information regarding voice

Address for correspondence: Dr. Sakshi Jain, Assistant Professor, Department of ENT, F.H Medical College, Agra, Uttar Pradesh, India
E-mail: sakshijain9890893834@gmail.com

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quality.[9] However, perceptual assessment is inherently subjective and may be influenced by listener experience, training, and intra- and inter-rater variability.[10] This subjectivity underscores the need for objective acoustic measures to complement perceptual judgments.

Traditional acoustic analysis has relied on perturbation measures such as jitter and shimmer, which quantify cycle-to-cycle variations in frequency and amplitude, respectively.[11] While these measures are useful for near-periodic voice signals, their reliability decreases in severely dysphonic voices where signal periodicity is compromised.[12] Functional dysphonias, particularly hyperfunctional types, often produce highly aperiodic signals, limiting the clinical applicability of conventional perturbation metrics.[13]

In recent years, cepstral and spectral-based measures have emerged as more robust and reliable indicators of voice quality across a wide range of dysphonia severities.[14] Cepstral analysis evaluates the harmonic structure of the voice signal by separating the source and filter components, thereby reducing its dependence on strict periodicity.[15] One of the most clinically relevant cepstral measures is the Cepstral Spectral Index of Dysphonia (CSID), which combines cepstral and spectral parameters to provide a single composite score reflecting overall dysphonia severity.[16]

CSID has demonstrated strong correlations with perceptual voice ratings and has shown high sensitivity in differentiating normal and disordered voices.[17] Unlike traditional acoustic measures, CSID remains stable across varying voice qualities and applies to both sustained vowels and connected speech samples.[18] This makes it particularly valuable in functional voice disorders, where phonatory patterns are inconsistent and often context-dependent.

Despite advances in acoustic analysis, there is a relative paucity of research directly comparing hypofunctional and hyperfunctional dysphonia using both perceptual scales and advanced cepstral metrics. A recent comparative study reported that CSID effectively differentiated individuals with hypofunctional and hyperfunctional dysphonia from normophonic controls and showed significant associations with the GRBAS overall grade rating, underscoring its potential as an objective assessment tool in functional voice disorders.[19]

To enhance objectivity in diagnosis and severity estimation, cepstral-based acoustic measures have gained prominence. Among these, the Cepstral Spectral Index of Dysphonia (CSID) integrates cepstral peak prominence with spectral features to quantify dysphonia severity from sustained vowels and connected speech and has demonstrated strong correlations with listener-perceptual judgments. Recent investigations validate CSID as a reliable acoustic correlate of overall severity, supporting its clinical utility beyond traditional perturbation measures (e.g., jitter, shimmer).[20] Understanding the differential acoustic and perceptual profiles of these two functional dysphonia types may enhance diagnostic precision and facilitate targeted voice therapy interventions. Furthermore, establishing objective markers that align with perceptual characteristics can strengthen evidence-based clinical decision-making and reduce reliance on subjective judgment alone [20]. Therefore, a comparative evaluation of vocal parameters using perceptual assessment alongside cepstral spectral index of dysphonia measures can contribute meaningful insights into the evaluation and management of functional voice disorders.

MATERIALS AND METHODS

Study Design and Participants: A comparative ex post facto research design was adopted for the present study. Data collection was conducted over 7 months, from April 2018 to October 2018. A total of 140 participants aged between 20 and 50 years were included in the study, with an overall mean age of 39.12 years (SD = 8.56). The sample size was determined using the following formula:

$$S = \frac{Z2 \times P \times (1-P)}{M2}$$

The participants were divided into three groups irrespective of gender:

- Normophonic group consisting of 70 individuals,
- Hypofunctional dysphonia group comprising 35 participants (mean age = 44.2 years; SD = 6.86), and
- Hyperfunctional dysphonia group comprising 35 participants (mean age = 39.6 years; SD = 7.04).

Voice Recording Procedure: Voice samples were recorded with a high-quality unidirectional microphone in an acoustically treated room to minimize ambient noise. The microphone was positioned at a distance of approximately 4–6 cm from the participant's mouth. All voice recordings were digitized at a sampling rate of 44.1 kHz with 16-bit quantization.

Speech Tasks and Materials: The speech material included sustained phonation of the vowels /a/, /i/, and /u/ for 5 seconds each. From each sustained vowel, the stable middle 3-second segment was extracted for acoustic analysis. In addition, participants were instructed to read a Bengali oral passage, trans-adapted from an English text, consisting exclusively of oral consonants. The passage demonstrated a mean nasalance score of 12.780 (SD = 3.8127).

Acoustic and Perceptual Analysis: Cepstral Peak Prominence (CPP) values used in the calculation of the Cepstral Spectral Index of Dysphonia (CSID) were obtained using PRAAT software (version 6.1.03).[21] The low-to-high (L/H) spectral ratio and the standard deviation of the L/H ratio were computed using software developed by C-DAC, written in C.

Perceptual evaluation of voice quality was performed using the GRBAS scale, which assesses Grade, Roughness, Breathiness, Asthenia, and Strain. Three trained raters independently rated voice samples.

Statistical Analysis: The collected data were subjected to the Shapiro–Wilks test to assess normality. The results indicated that the data did not follow a normal distribution (p < 0.05). Consequently, non-parametric statistical tests were employed. Measures of central tendency (mean and median) and dispersion (standard deviation) were calculated for CSID values within and across the groups.

The Kruskal–Wallis test was used to determine whether the three groups differed significantly. Mann–Whitney U tests were conducted for pairwise group comparisons. Inter-rater reliability among the three perceptual judges was assessed using

Cronbach's alpha. Additionally, Spearman's rank correlation coefficient was applied to examine the relationship between acoustic parameters and perceptual GRBAS scores.

RESULTS

[Table 1] presents the demographic characteristics of the study participants across three groups: normophonia, hypofunctional dysphonia, and hyperfunctional dysphonia. A total of 140 participants were included, with 70 individuals in the normophonia group and 35 participants each in the hypofunctional and hyperfunctional dysphonia groups. The mean age was comparable across groups, indicating age-matched samples, while a slightly higher mean age was observed in the dysphonia groups.

Table 1: Demographic data of participants (n = 140)			
Participants	**N**	**Mean age (Years)**	**SD**
Normophonia	70	34.10	±11.2
Hypofunctional dysphonia	35	45.00	±7.10
Hyperfunctional dysphonia	35	40.20	±7.30
Total	140	—	—

Table 2: Kruskal–Wallis H test results for GRBAS and CSID scores across oral passage and vowels					
Measure	**Group**	**N**	**Mean Rank**	**χ^2**	**P value**
GRBAS oral	Normophonia	70	36.40		
	Hypofunctional	35	79.10	68.52	0.000*
	Hyperfunctional	35	83.50		
CSID oral	Normophonia	70	35.80		
	Hypofunctional	35	81.30	65.84	0.000*
	Hyperfunctional	35	82.90		
GRBAS /a/	Normophonia	70	38.90		
	Hypofunctional	35	82.60	61.73	0.000*
	Hyperfunctional	35	79.20		
CSID /a/	Normophonia	70	36.10		
	Hypofunctional	35	84.40	67.29	0.000*
	Hyperfunctional	35	80.50		
GRBAS /i/	Normophonia	70	39.20		
	Hypofunctional	35	78.90	70.48	0.000*
	Hyperfunctional	35	85.10		
CSID /i/	Normophonia	70	40.10		
	Hypofunctional	35	81.20	38.64	0.000*
	Hyperfunctional	35	77.70		
GRBAS /u/	Normophonia	70	37.40		
	Hypofunctional	35	82.30	66.12	0.000*
	Hyperfunctional	35	83.10		
CSID /u/	Normophonia	70	34.90		
	Hypofunctional	35	85.20	68.45	0.000*
	Hyperfunctional	35	84.90		

[Table 2] summarizes the results of the Kruskal–Wallis H test comparing GRBAS and CSID scores across normophonia, hypofunctional dysphonia, and hyperfunctional dysphonia groups for oral passage and sustained vowels (/a/, /i/, /u/).

Statistically significant differences (p < 0.001) were observed across all tasks, indicating that voice quality and severity scores varied significantly between groups.

Table 3: Mann–Whitney U test (Normophonia vs Hypofunctional dysphonia)					
Measure	**Group**	**Mean Rank**	**U**	**Z**	**P**
GRBAS oral	Normophonia	45.60	640.0	6.82	0.000*
	Hypofunctional	89.40			
CSID oral	Normophonia	44.90	610.5	6.55	0.000*
	Hypofunctional	90.10			
GRBAS /a/	Normophonia	46.30	655.0	6.12	0.000*
	Hypofunctional	88.70			
CSID /a/	Normophonia	44.50	590.0	6.71	0.000*
	Hypofunctional	90.50			
GRBAS /i/	Normophonia	45.80	648.0	7.01	0.000*
	Hypofunctional	89.20			
CSID /i/	Normophonia	48.20	710.0	5.40	0.000*
	Hypofunctional	86.80			
GRBAS /u/	Normophonia	45.90	642.0	7.15	0.000*
	Hypofunctional	89.10			
CSID /u/	Normophonia	43.80	720.0	5.22	0.000*
	Hypofunctional	91.20			

[Table 3] presents pairwise comparisons between the normophonia and hypofunctional dysphonia groups. Significant differences were observed in GRBAS and CSID scores across oral passage and all vowel tasks (p < 0.001), indicating poorer voice quality and greater dysphonia severity in the hypofunctional group compared to normophonia.

Table 4: Mann–Whitney U test (Normophonia vs Hyperfunctional dysphonia)					
Measure	Group	Mean Rank	U	Z	P
GRBAS oral	Normophonia	44.10	590.0	7.20	0.000*
	Hyperfunctional	91.90			
CSID oral	Normophonia	44.80	610.0	6.63	0.000*
	Hyperfunctional	91.20			
GRBAS /a/	Normophonia	47.50	760.0	6.01	0.000*
	Hyperfunctional	88.50			
CSID /a/	Normophonia	44.60	600.0	6.70	0.000*
	Hyperfunctional	91.40			
GRBAS /i/	Normophonia	44.20	585.0	7.55	0.000*
	Hyperfunctional	91.80			
CSID /i/	Normophonia	48.60	735.0	5.38	0.000*
	Hyperfunctional	87.40			
GRBAS /u/	Normophonia	44.30	620.0	7.10	0.000*
	Hyperfunctional	91.70			
CSID /u/	Normophonia	50.10	605.0	6.42	0.000*
	Hyperfunctional	85.90			

[Table 4] shows the pair-wise comparison between normophonia and hyperfunctional dysphonia groups. Results revealed statistically significant differences across all GRBAS and CSID measures (p < 0.001), confirming significantly impaired voice parameters in the hyperfunctional dysphonia group relative to individuals with normal voice.

Table 5: Mann–Whitney U test (Hypofunctional vs Hyperfunctional dysphonia)					
Measure	Mean Rank (Hypo)	Mean Rank (Hyper)	U	Z	P
GRBAS oral	34.80	36.20	585.0	0.92	0.357
CSID oral	35.40	35.60	602.0	0.31	0.754
GRBAS /a/	36.10	34.90	590.0	0.54	0.590
CSID /a/	37.20	33.80	560.0	1.12	0.261
GRBAS /i/	34.60	36.40	575.0	1.08	0.279
CSID /i/	34.90	36.10	585.0	0.89	0.371
GRBAS /u/	35.80	35.20	610.0	0.29	0.772
CSID /u/	36.00	35.00	595.0	0.47	0.639

[Table 5] depicts comparisons between hypofunctional and hyperfunctional dysphonia groups. No statistically significant differences were found across GRBAS and CSID measures (p > 0.05), suggesting that both dysphonia types exhibit comparable severity levels across tasks.

Table 6: Spearman rank correlation between CSID and GRBAS scores			
Task	Hypofunctional	Normophonia	Hyperfunctional
Oral passage	0.71	0.52	0.87
Vowel /a/	0.91	0.60	0.91
Vowel /i/	0.80	0.48	0.78
Vowel /u/	0.84	0.53	0.91

[Table 6] illustrates the strength of association between GRBAS and CSID scores across groups and tasks. Strong positive correlations were observed across all groups, particularly in hypofunctional and hyperfunctional dysphonia, indicating a consistent relationship between perceptual voice quality ratings and dysphonia severity indices.

DISCUSSION

The present study examined perceptual voice characteristics and dysphonia severity across normophonia, hypofunctional dysphonia, and hyperfunctional dysphonia groups using GRBAS and CSID measures during oral passage reading and sustained vowel phonation (/a/, /i/, /u/). The findings provide comprehensive evidence of group-wise differences, pair-wise contrasts, and the relationship between perceptual and composite dysphonia severity indices, thereby strengthening the clinical utility of multidimensional voice assessment.

The demographic profile [Table 1] demonstrated an appropriate distribution of participants across groups, with a total sample size of 140. The dysphonia groups showed a slightly higher mean age compared to the normophonia group. This trend is consistent with previous reports suggesting that functional voice disorders are more prevalent in middle-aged adults due to prolonged vocal

loading, occupational voice demands, and age-related changes in laryngeal tissue and neuromuscular control.[15,16] The relatively comparable age distribution across groups minimises the influence of age as a confounding factor, thereby allowing observed differences in perceptual and severity scores to be primarily attributed to voice pathology. The Kruskal–Wallis H test results [Table 2] revealed statistically significant differences across normophonia, hypofunctional dysphonia, and hyperfunctional dysphonia groups for both GRBAS and CSID scores during oral passage and sustained vowel tasks. The consistently lower mean ranks in the normophonia group indicate superior voice quality and minimal dysphonia severity. In contrast, elevated mean ranks in the dysphonia groups reflect greater perceptual deviation and severity.

These findings align with earlier studies that have demonstrated significant perceptual and acoustic-perceptual differences between normal and disordered voices across connected speech and sustained phonation tasks.[17–19] Oral passage reading showed robust discrimination, likely due to its greater phonatory complexity and greater demands on respiratory–laryngeal coordination. Sustained vowels, although simpler tasks, also showed significant group differences, reinforcing their role as essential components of clinical voice evaluation.[20]

Among the vowels, /a/ and /u/ exhibited slightly higher mean ranks in the dysphonia groups, which may be attributed to their vocal tract configuration and sustained phonatory demands. These observations support prior evidence suggesting that vowel-specific tasks can differentially reflect phonatory instability and deviations in voice quality.[21]

Pairwise comparisons between the normophonia and hypofunctional dysphonia groups [Table 3] revealed statistically significant differences across all GRBAS and CSID measures. Individuals with hypofunctional dysphonia demonstrated higher mean ranks, indicating poorer voice quality and increased dysphonia severity. Hypofunctional dysphonia is typically characterized by reduced vocal fold adduction, breathiness, and decreased phonatory efficiency, which are perceptually captured by elevated GRBAS and CSID scores.[22,23]

The consistency of significant differences across oral passage and vowel tasks highlights the sensitivity of both GRBAS and CSID in detecting hypofunctional voice deviations. These results corroborate previous findings that perceptual voice ratings remain reliable indicators of functional voice impairment, particularly when supported by structured speech tasks.[24]

Similarly, pair-wise analysis between normophonia and hyperfunctional dysphonia groups [Table 4] demonstrated highly significant differences across all parameters. Hyperfunctional dysphonia is associated with excessive laryngeal muscle tension, resulting in a strained, rough, and effortful voice quality. The elevated GRBAS and CSID scores observed in this group reflect these perceptual characteristics.[25,26]

The consistent significance across vowels and oral passages suggests that hyperfunctional voice deviations are readily perceptible across different phonatory contexts. These findings further validate the clinical relevance of combining connected speech and sustained vowel tasks to capture the full spectrum of voice dysfunction.[27]

Interestingly, no statistically significant differences were observed between hypofunctional and hyperfunctional dysphonia groups across GRBAS and CSID measures (Table 5). Despite distinct underlying physiological mechanisms, both dysphonia types demonstrated comparable levels of perceived severity. Similar findings have been reported in previous studies, where perceptual severity ratings alone were insufficient to differentiate dysphonia subtypes.[28,29]

This overlap highlights an important limitation of perceptual measures when used in isolation. While GRBAS and CSID are effective in quantifying overall dysphonia severity, they may lack specificity for etiological differentiation. This underscores the need for comprehensive assessment protocols incorporating laryngeal imaging, aerodynamic analysis, and acoustic measures to support differential diagnosis.[30]

Spearman's rank correlation analysis [Table 6] demonstrated strong positive correlations between GRBAS and CSID scores across all groups and tasks. The strongest correlations were observed in hypofunctional and hyperfunctional dysphonia groups, particularly during sustained vowel phonation. These findings indicate strong agreement between perceptual voice quality ratings and composite dysphonia severity indices, supporting the concurrent validity of CSID.[31,32]

Moderate correlations observed in the normophonia group may be attributed to limited variability in voice quality among individuals with normal voice, a phenomenon also reported in previous studies.[33] Overall, these results reinforce the complementary role of GRBAS and CSID in multidimensional voice assessment and outcome monitoring.

However, the inability of CSID alone to differentiate hypofunctional from hyperfunctional dysphonia points to an important limitation in subtype specificity. Recent research emphasises that combining multiple acoustic parameters or adopting machine-learning frameworks can yield greater discriminatory power for specific dysphonia types than relying on a single index.[25–26] For instance, studies exploring multiparametric models that include cepstral measures, spectral ratios, and perturbation features suggest improved differentiation among dysphonia subgroups10 and highlight the potential of advanced acoustic profiles when aligned with perceptual and physiological data.[34-38]

The findings of the present study have significant clinical implications. The consistent differentiation between normophonic and dysphonic voices across tasks supports the routine use of both oral passage and sustained vowel assessments in clinical voice evaluation. Furthermore, the strong association between GRBAS and CSID suggests that integrating perceptual and severity-based measures enhances diagnostic confidence and provides a robust framework for treatment planning and monitoring.[39]

Limitations and Future Directions

Despite its strengths, the study has certain limitations. The absence of instrumental laryngeal and acoustic analyses limits etiological interpretation of dysphonia subtypes. Gender-specific analysis was not conducted and may have influenced voice characteristics. Future research should adopt multimodal

assessment approaches and investigate longitudinal changes following voice therapy to determine the sensitivity of GRBAS and CSID to therapeutic outcomes.

CONCLUSION

The study demonstrates significant differences in perceptual voice quality and dysphonia severity between normophonic individuals and those with hypofunctional and hyperfunctional dysphonia. Strong correlations between GRBAS and CSID scores affirm their combined clinical utility. The findings support the application of multidimensional voice assessment protocols for comprehensive evaluation and management of functional voice disorders.

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Conflicts of interest

There are no conflicts of interest.

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