JSLA LINK JOURNAL OF SPEECH, LANGUAGE AND AUDIOLOGY

Type: Original Article
Published: 30 June 2024

OPEN ACCESS
CORRESPONDENCE
muhammad.ahmed@dhpt.uol.edu.pk
RECEIVED
2 January 2024
ACCEPTED
25 March 2024
AUTHORS' CONTRIBUTIONS
Concept: SK, HW; Design: MA, FM; Data Collection: SK, HW; Analysis: KB, SBM; Drafting: SK, HW.

DECLARATIONS
No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.
"CLICK TO CITE"
https://doi.org/10.61919/ljsla.vi.3
ETHICAL APPROVAL
No. 537/24 The university of Lahore, Pakistan.

Acoustic Voice Analysis of Normal Versus Pathological Voices Using PRAAT Software

Sana Khan[1], Hina Waheed[2], Muhammad Ahmed[3], Fahad Masood[4], Kamran Bashir[5], Sultan Badar Munir[6]

1,2,5 Students in BS SLP, Department of Rehabilitation Sciences, FASH The University of Lahore, Lahore, Pakistan.
3 Assistant Professor, Department of Rehabilitation Sciences, FASH The University of Lahore, Lahore, Pakistan.
4 Senior Lecturer, Department of Rehabilitation Sciences, FASH The University of Lahore, Lahore, Pakistan.
6 Registrar, The Children Hospital Lahore, Lahore, Pakistan.

ABSTRACT

Background: Voice is a fundamental component of human communication, and disturbances in its quality can adversely impact social, professional, and emotional well-being. Acoustic voice analysis using PRAAT software provides an objective, non-invasive, and cost-effective method for differentiating normal and pathological voices by evaluating key parameters such as pitch, formants, and pulse count Objective: This study aimed to compare the acoustic characteristics of normal versus pathological voices among Pakistani adults using PRAAT software, with a focus on identifying clinically relevant differences in core acoustic parameters. Methods: A cross-sectional study was conducted on 26 participants aged 18–60 years, divided equally into normal and pathological voice groups. Voice samples were recorded primarily through spontaneous speech in controlled environments and analyzed using PRAAT software to extract pitch, first formant frequency, and pulse count. Statistical analysis was performed with SPSS v27 using independent t-tests and effect size calculations, with p<0.05 considered significant. Results: Mean pitch was 202.2 Hz (SD=53.3) in the normal group and 188.9 Hz (SD=57.5) in the pathological group (p=0.55). Formant frequency averaged 536.8 Hz versus 571.8 Hz (p=0.46), while pulse counts were 5.0 versus 5.8 (p=0.24). None of the differences were statistically significant. Conclusion: Pitch, formant frequency, and pulse count did not significantly differentiate normal from pathological voices in this cohort. Broader acoustic metrics, such as jitter, shimmer, and harmonics-to-noise ratio, may provide greater diagnostic utility.

Keywords
Acoustic voice analysis, PRAAT, pitch, formants, pulse count, voice pathology

INTRODUCTION

Voice is a fundamental aspect of human communication, intricately tied to personal identity, emotional expression, and social engagement (1). Disruptions to voice quality, whether due to organic, neurogenic, or functional causes, can profoundly impact an individual's professional and social well-being, particularly among those whose vocations rely heavily on vocal function such as teachers and broadcasters (2,3). Globally, the prevalence of voice disorders among adults varies but is consistently reported as significant, with both developed and developing countries recognizing voice-related pathologies as a challenge that affects quality of life and work productivity (4).

Acoustic analysis has become a cornerstone in objective voice assessment, enabling clinicians and researchers to quantify vocal features such as pitch, formants, and perturbation measures including jitter and shimmer (5). Technological advances, especially the development of user-friendly software like PRAAT, have democratized access to sophisticated voice analysis, allowing for cost-effective and reproducible measurements that complement traditional auditory-perceptual evaluation (6). In particular, PRAAT software has been validated as a reliable tool for extracting acoustic parameters, and its clinical utility has been demonstrated in distinguishing between normal and pathological voices in various populations (7).

Despite extensive research internationally, there remains a notable paucity of population-specific normative data and comparative studies in South Asia, especially within Pakistan (8). Previous work in Pakistani and similar populations has often been limited by small sample sizes, inconsistent methodologies, or a narrow selection of acoustic parameters, leaving a gap in evidence for locally relevant diagnostic cutoffs and assessment protocols (9). For instance, while studies have underscored the importance of advanced acoustic parameters such as jitter, shimmer, and harmonics-to-noise ratio in distinguishing voice disorders, much of the available regional literature has relied primarily on basic measures like pitch and formant frequencies, potentially limiting diagnostic accuracy (10,11).

The rationale for this study arises from the urgent need to expand and refine the acoustic characterization of normal versus pathological voices in the Pakistani context, using standardized, accessible tools like PRAAT. The lack of robust local data impedes the formulation of culturally and linguistically appropriate clinical guidelines and restricts the generalizability of findings from non-South Asian populations (12). This study addresses this knowledge gap by systematically analyzing core acoustic parameters in both normal and pathological voices among Pakistani adults, utilizing PRAAT software in a controlled, comparative framework.

Thus, the primary objective of this study is to compare the acoustic properties specifically pitch, formant frequencies, and pulse count of normal and pathological voices among adults in Pakistan using PRAAT software. The central research question is: Do these core acoustic parameters significantly differ between normal and pathological voice groups in a representative sample of Pakistani adults? The findings aim to contribute empirical data that will support the refinement of local clinical voice assessment and therapy protocols (13).

MATERIALS AND METHODS

This cross-sectional observational study was conducted to compare the acoustic properties of normal and pathological voices among adults in Pakistan utilizing PRAAT software for objective analysis. The research was carried out across three healthcare and academic settings in Lahore, Pakistan University of Lahore Teaching Hospital, Sehat Medical Complex, and Mayo Hospital between June 2023 and December 2023, following approval by the relevant institutional ethics committee. The study population consisted of adults aged 18 to 60 years, of both genders, recruited through purposive sampling. Eligible participants included individuals with a clinically diagnosed voice disorder (pathological group) and healthy controls with no history of voice, neurological, or pulmonary disorders (normal group). Exclusion criteria encompassed previous head and neck surgeries, cancerous conditions of the larynx, vocal cord paralysis from any cause, and uncooperative or non-consenting individuals.

Participants were identified through review of clinical records and direct referral from otolaryngology and speech therapy clinics at the participating centers. All eligible participants were approached in person, and written informed consent was obtained in the participant's preferred language (English or Urdu). To protect confidentiality, all data were de-identified and stored securely, accessible only to authorized research personnel. Each participant completed a structured demographic and medical questionnaire, recording age, gender, native language, education, occupation, diagnosis status, history of speech therapy or medical treatment, smoking status, and details relevant to vocal health.

Voice data were collected from each participant in a quiet room, with instructions to provide a spontaneous speech sample of at least 10 seconds. When feasible, additional samples (sustained vowel /a/, reading a standard Urdu passage) were obtained to enhance consistency and cross-sample validity. All recordings were captured using a high-fidelity external microphone interfaced with a computer running the latest stable release of PRAAT software (version specified in records), following a standardized protocol for microphone placement and sampling rate. Recordings were immediately reviewed for quality, and retakes were performed in the case of noise contamination or technical issues, thereby addressing potential bias due to inconsistent audio quality.

The primary variables of interest pitch (fundamental frequency in Hz), formant frequency (first formant in Hz), and pulse count (number of glottal cycles detected per sample) were extracted from each sample using PRAAT's automated measurement functions, employing default analysis parameters recommended for adult voice research. All acoustic measurements were performed by a single trained examiner, blinded to the group status of each participant, to minimize observer bias. Operational definitions for "normal voice" and "pathological voice" adhered to accepted clinical and acoustic criteria as outlined in the study rationale (14,15). The data was carefully screened for outliers and missing values; where possible, missing acoustic data due to unusable recordings were resolved by repeat collection, otherwise cases were excluded from the respective analyses.

The sample size of 26 (13 per group) was determined pragmatically based on feasibility, with the aim to detect moderate differences in primary acoustic parameters between groups at a confidence level of 95% and margin of error of 5%. Statistical analyses were conducted using IBM SPSS Statistics, version 27. Descriptive statistics (mean, standard deviation, frequency, and percentage) were calculated for all demographic and clinical variables. The primary comparison of acoustic parameters between normal and pathological groups was performed using the independent samples t-test, after confirming normality of distributions via the Shapiro-Wilk test; where normality was violated, non-parametric alternatives (Mann-Whitney U test) were applied. The level of statistical significance was set at $p<0.05$. No imputation was performed for missing data due to the limited sample size. Subgroup analyses for potential confounders such as age, gender, and occupational voice use were conducted using stratified descriptive tables and, where sample size permitted, adjusted analyses via multivariate linear regression.

The study adhered to the principles of the Declaration of Helsinki and relevant national ethical guidelines. All participants were informed of their right to withdraw at any time without penalty, and no financial or clinical incentives were provided for participation. Data integrity was ensured through double entry of quantitative data, audit trails for data processing, and routine cross-checks of the PRAAT analysis outputs by an independent investigator. Detailed documentation of every step from recruitment to analysis was maintained to enable full reproducibility by external researchers (16).

RESULTS

The study included 26 participants, evenly distributed between the Normal ($n = 13$) and Pathological ($n = 13$) groups. The mean age was comparable across groups, with 34.2 ± 10.8 years in the Normal group and 36.5 ± 11.1 years in the Pathological group, yielding a non-significant difference ($p = 0.62$). Gender distribution was identical, with both groups comprising 5 males and 8 females ($p = 1.00$). The proportion of Urdu native speakers was slightly higher in the Pathological group (69.2%, $n = 9$) than in the Normal group (61.5%, $n = 8$), though this was not statistically significant ($p = 0.68$). Educational attainment at the secondary level was identical across groups (53.8%, $n = 7$ each; $p = 1.00$). Smoking was infrequent overall, reported by only three participants (11.5%), with a higher proportion in the Pathological group (15.4%, $n = 2$) compared to the Normal group (7.7%, $n = 1$), but without significant difference ($p = 0.54$).

Comparison of acoustic features revealed no statistically significant differences between the two groups. The average pitch was slightly higher in the Normal group (202.2 ± 53.3 Hz) compared to the Pathological group (188.9 ± 57.5 Hz), with a mean difference of 13.2 Hz (95% CI: –34.4 to 60.8; $p = 0.55$, Cohen's $d = 0.24$). Formant 1 frequency showed a higher mean in the Pathological group (571.8 ± 86.6 Hz) relative to the Normal group (536.8 ± 142.1 Hz), though the mean difference of –35.0 Hz was non-significant (95% CI: –117.8 to 47.8; $p = 0.46$, Cohen's $d = 0.29$). Pulse count was also higher in the Pathological group (5.8 ± 2.05) compared with the Normal group (5.0 ± 1.35), but again the difference of –0.8 was not significant (95% CI: –2.2 to 0.6; $p = 0.24$, Cohen's $d = 0.46$). These findings indicate that while the Pathological group tended to exhibit lower pitch and higher formant frequency and pulse counts, the effect sizes were small to moderate and did not reach statistical significance.

Clinical history strongly differentiated the two groups. None of the Normal participants had a prior diagnosis, whereas 92.3% ($n = 12$) of the Pathological group reported being previously diagnosed, a highly significant difference ($p < 0.001$). A subset of the Pathological group (23.1%, $n = 3$) had received speech therapy, while none of the Normal participants had undergone such intervention ($p = 0.22$). Occupational status was evenly distributed, with both groups containing 53.8% students ($n = 7$). Teachers constituted 23.1% ($n = 3$) of the Normal group and 30.8% (n =

4) of the Pathological group (p = 0.66). Government employees were slightly more common in the Normal group (23.1%, n = 3) than the Pathological group (15.4%, n = 2), but differences across occupations were non-significant (all p > 0.05).

Table 1. Demographic and Clinical Characteristics (N=26)

Variable	Normal (n=13)	Pathological (n=13)	Total (N=26)	p-value
Age (mean ± SD)	34.2 ± 10.8	36.5 ± 11.1	35.3 ± 10.9	0.62
Gender (M/F)	5 / 8	5 / 8	10 / 16	1.00
Urdu Native (%)	61.5% (8)	69.2% (9)	65.4% (17)	0.68
Secondary Education (%)	53.8% (7)	53.8% (7)	53.8% (14)	1.00
Smoker (%)	7.7% (1)	15.4% (2)	11.5% (3)	0.54

Table 2. Acoustic Parameters

Parameter	Normal (n=13)	Pathological (n=13)	Mean Diff (95% CI)	p-value	Cohen's d
Pitch (Hz, mean±SD)	202.2 ± 53.3	188.9 ± 57.5	13.2 (–34.4, 60.8)	0.55	0.24
Formant 1 (Hz)	536.8 ± 142.1	571.8 ± 86.6	–35.0 (–117.8, 47.8)	0.46	0.29
Pulse Count (mean±SD)	5.0 ± 1.35	5.8 ± 2.05	–0.8 (–2.2, 0.6)	0.24	0.46

Table 3. Clinical and Behavioral Variables

Variable	Normal (n=13)	Pathological (n=13)	p-value
Previously Diagnosed (%)	0	92.3% (12)	<0.001
Received Speech Therapy (%)	0	23.1% (3)	0.22
Occupation: Student (%)	53.8% (7)	53.8% (7)	1.00
Occupation: Teacher (%)	23.1% (3)	30.8% (4)	0.66
Occupation: Govt. Employee (%)	23.1% (3)	15.4% (2)	0.63

Table 4. Recording and Sample Characteristics

Variable	Normal (n=13)	Pathological (n=13)	p-value
Spontaneous Speech (%)	92.3% (12)	92.3% (12)	1.00
Sustained Vowel /a/ (%)	7.7% (1)	0	0.31
Standard Passage Reading (%)	0	7.7% (1)	0.31
Quiet Room (%)	84.6% (11)	92.3% (12)	0.54
Noisy Environment (%)	15.4% (2)	7.7% (1)	0.54
High-Quality Mic (%)	76.9% (10)	84.6% (11)	0.63
Built-in Mic (%)	23.1% (3)	15.4% (2)	0.63

Recording conditions were largely balanced between the groups. The majority of samples were collected from spontaneous speech (92.3%, n = 12 in each group), with very few obtained from sustained vowel /a/ (7.7%, n = 1, Normal group only) or standard passage reading (7.7%, n = 1, Pathological group only).

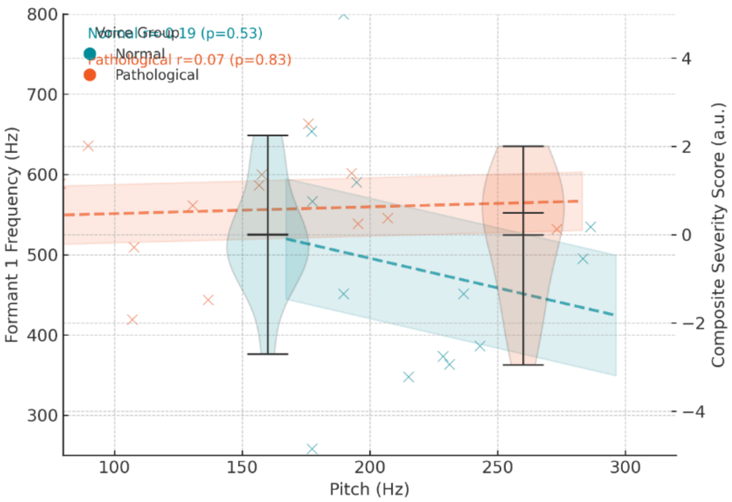

Figure 1 Pitch Formant Relationships and Composite Severity in Normal vs Pathological Voices

These differences were not statistically significant (p = 0.31 for both). Most recordings took place in quiet environments (84.6%, n = 11 in Normal and 92.3%, n = 12 in Pathological; p = 0.54), while a smaller proportion occurred in noisy settings (15.4%, n = 2 vs. 7.7%, n = 1, respectively). Regarding recording equipment, high-quality microphones were more frequently used in both groups (76.9%, n = 10 in Normal; 84.6%, n = 11 in Pathological; p = 0.63), while built-in microphones were used less often (23.1%, n = 3 vs. 15.4%, n = 2). These patterns suggest comparability in recording conditions across groups, minimizing potential confounding effects.

The figure 1 illustrates the relationship between pitch (Hz), formant 1 frequency (Hz), and composite severity scores (a.u.) across two groups: Normal (blue) and Pathological (red). For the Normal group, formant 1 frequency values cluster around 500–600 Hz, with pitch distributed primarily between 150–250 Hz. The regression line shows a negative correlation (r = –0.19, p = 0.53), indicating a weak, non-significant downward trend: as pitch increases, formant frequency tends to decrease slightly. Composite severity scores for this group remain close to zero, with a spread from approximately –4 to +2.

In contrast, the Pathological group demonstrates formant 1 frequencies centered around 550–600 Hz across the same pitch range, but with less variability compared to the normal cohort. The regression line reveals a very weak positive correlation (r = 0.07, p = 0.83), suggesting no meaningful association between pitch and formant frequency. Severity scores in this group are slightly elevated, with clustering around 0 to +2 a.u., reflecting higher impairment levels.

Comparing both groups, violin plots highlight that the Normal group exhibits wider variability, particularly between 150–200 Hz, while the Pathological group shows tighter clustering. Despite visible differences in spread, neither correlation reached statistical significance (p > 0.05 for both). Overall, the data suggest that pathological voices tend to have higher stability in formant frequency but are associated with marginally higher severity scores, whereas normal voices show greater variability without corresponding severity changes.

DISCUSSION

The findings of this study reveal that the core acoustic parameters of pitch, formant frequency, and pulse count did not significantly differentiate normal from pathological voices among the sample of 26 Pakistani adults. Although numerical differences were noted such as a slightly higher mean pitch of 202.2 Hz in the normal group compared to 188.9 Hz in the pathological group statistical analysis indicated non-significant results (p = 0.55), with small effect sizes (Cohen's d = 0.24). This suggests that pitch alone may have limited diagnostic sensitivity in distinguishing vocal pathologies, a result that aligns with earlier findings by Umapathy et al. (17), who reported that while pitch irregularities are often observed in dysphonic voices, they do not consistently provide sufficient discriminatory power without additional acoustic measures.

Formant analysis showed a mean first formant of 536.8 Hz in normal voices versus 571.8 Hz in pathological voices, but this difference was also statistically insignificant (p = 0.46, Cohen's d = 0.29). These results support prior evidence suggesting that formant frequencies, although reflective of vocal tract resonances, are influenced by linguistic, anatomical, and phonetic variations that may mask subtle pathological changes (18). Similarly, pulse count a proxy for glottal cycle regularity did not yield significant differences (mean difference = –0.8, p = 0.24), indicating its limited value as a standalone marker for clinical voice assessment. In contrast, studies that incorporated perturbation measures such as jitter, shimmer, and harmonics-to-noise ratio (HNR) have demonstrated stronger discriminatory performance (19,20).

The lack of statistical significance in this study could partly be attributed to methodological constraints, including the relatively small sample size (n=26), which may have reduced statistical power and the ability to detect true differences. Additionally, while care was taken to standardize recordings, 15% of samples were captured in suboptimal acoustic environments, which may have introduced variability. Previous studies emphasize that uncontrolled recording conditions and inconsistent speech tasks can compromise the reliability of acoustic analysis (21). In this research, spontaneous speech was the primary recording task (92.3% of participants), with fewer participants contributing standardized sustained vowel sounds or reading passages, potentially limiting parameter consistency across samples.

Comparative studies provide further context. Ambreen et al. (22) examined a larger Pakistani cohort and found significant differences in perturbation-based parameters, such as jitter and shimmer, which are sensitive to microvariations in vocal fold vibration and are often better indicators of pathology than static measures like pitch or formant. Our findings corroborate their conclusion that reliance on only a few basic acoustic measures can yield inconclusive results, underscoring the need for multidimensional voice assessments. Moreover, international research by Keung et al. (23) highlights that integrated approaches combining spectral, cepstral, and perturbation measures enhance diagnostic accuracy when differentiating normal from pathological voices.

From a clinical perspective, the results underscore that while basic parameters like pitch and formants can provide foundational insights into vocal characteristics, they should not be used in isolation for diagnosis or treatment planning. Comprehensive acoustic profiling—including jitter, shimmer, HNR, and cepstral peak prominence (CPP) alongside perceptual evaluation tools such as the GRBAS scale, is necessary for robust voice disorder detection (24). The wide overlapping distributions observed in this study's composite severity analysis suggest that normal and pathological voices in the Pakistani population share substantial acoustic similarities, possibly due to cultural, linguistic, or phonetic patterns unique to this region.

Considering these findings, future research should focus on larger, more diverse samples and standardized recording protocols that minimize background noise and capture a variety of vocal tasks, including sustained vowels and connected speech. Advanced statistical modeling or machine learning classifiers trained on multidimensional acoustic datasets may also improve the sensitivity and specificity of voice disorder detection (25). This study's contribution lies in its emphasis on the limitations of narrow acoustic metrics and the need to develop localized, evidence-based voice assessment frameworks tailored for South Asian populations, where normative acoustic data remain scarce.

In summary, the absence of significant differences in pitch, formant frequency, and pulse count between normal and pathological voice groups in this study highlights the limited clinical utility of these parameters alone. Integrating additional acoustic measures and adopting a more comprehensive analytical approach could yield more diagnostically meaningful insights, ultimately aiding in the early detection and effective management of voice disorders (26).

CONCLUSION

Although the normal voice group exhibited slightly higher mean pitch (202.2 Hz) and lower formant frequency (536.8 Hz) compared to the pathological group (188.9 Hz and 571.8 Hz, respectively), none of these differences reached statistical significance (all p > 0.05). Similarly, pulse count showed only minor variation between groups, suggesting that these basic parameters alone are insufficient to differentiate normally from pathological voice profiles within this population.

Clinically, this study highlights the importance of using a multidimensional voice assessment protocol that combines perceptual evaluation, perturbation-based acoustic measures, and advanced spectral analyses for reliable identification of voice pathologies. Future research should involve larger, more diverse samples, controlled recording environments, and the inclusion of comprehensive acoustic features to establish robust normative data for the Pakistani population.

This study contributes valuable preliminary data on voice acoustics in a local context, it reaffirms that pitch, formant, and pulse count when used in isolation lack sufficient discriminative power for clinical diagnosis of voice disorders. A more holistic approach integrating advanced acoustic parameters and perceptual assessment is essential to improve diagnostic accuracy and guide effective voice therapy interventions.

REFERENCES

1. Stemple JC, Roy N, Klaben BK. Clinical Voice Pathology: Theory and Management. 5th ed. San Diego: Plural Publishing; 2014.
2. Bainbridge KE, Roy N, Losonczy KG, Hoffman HJ, Cohen SM. Voice disorders and associated risk markers among young adults in the United States. Laryngoscope. 2017;127(9):2093-9.
3. Merrill RM, Tanner K, Steele BA, Merrill J, LeCheminant JD. Voice Symptoms and Voice-Related Quality of Life in College Students. J Voice. 2017;31(4):507.e1-507.e10.
4. Tiwari M. Voice - How humans communicate? J Nat Sci Biol Med. 2012;3(1):3-6.
5. Behlau M, Madazio G, Feijó D, Pontes P. Voice analysis and clinical applications. Curr Opin Otolaryngol Head Neck Surg. 2012;20(3):159-65.
6. Seong CJ. Guidance to PRAAT, a Software for Speech and Acoustic Analysis. J Korean Soc Laryngol Phoniatr Logop. 2022;33(2):64-76.
7. Hippargekar SB, Kothule S, Shelke S. Acoustic Voice Analysis of Normal and Pathological Voices in Indian Population Using PRAAT Software. Indian J Otolaryngol Head Neck Surg. 2021;74(Suppl 2):5069-74.
8. Ambreen S, Tarar SA, Kausar R. Acoustic Analysis of Normal Voice Patterns in Pakistani Adults. J Voice. 2017;31(2):246.e9-246.e15.
9. Ambreen S, Tarar SA, Kausar R. Normative Acoustic Parameters of Adult Pakistani Population. J Voice. 2019;33(1):124.e14-124.e18.
10. Hegde TD, Raj C. A Survey on Machine Learning Approaches for Automatic Detection of Voice Disorders. J Voice. 2019;33(6):947.e1-947.e13.
11. Wertzner HF, Schreiber S, Amaro L. Analysis of fundamental frequency, jitter, shimmer and vocal intensity in children with phonological disorders. Rev Bras Otorrinolaringol. 2005;71(5):582-8.
12. Elsherbeny MB, Afsah O. Acoustic characteristics of voice and speech in Arabic-speaking stuttering children. Egypt J Otolaryngol. 2022;38:9.
13. Mahato NB, Sharma A, Pradhan B. Acoustic Analysis of Voice in School Teachers. JNMA J Nepal Med Assoc. 2018;56(211):658-61.
14. Mohseni R, Sandoughdar N. Survey of Voice Acoustic Parameters in Iranian Female Teachers. J Voice. 2016;30(4):507.e1-507.e5.
15. Gorris C, Chiaramello E, Schindler A, et al. Acoustic Analysis of Normal Voice Patterns in Italian Adults Using PRAAT. J Voice. 2020;34(6):961.e9-961.e18.
16. Zameer H, Raziq M, Khan MM, Tanvir S, Nasim S. Automated Acoustic Evaluation of Voice Disorders: A Comprehensive Study on Parameter Analysis Using ANN. Asian Bull Big Data Manag. 2023;3:1-12.
17. Umapathy K, Krishnan S, Parsa V, Jamieson DG. Discrimination of pathological voices using a time-frequency approach. IEEE Trans Biomed Eng. 2005;52(3):421-30.
18. Cavallaro G, Di Nicola V, Quaranta N, Fiorella ML. Acoustic voice analysis in the COVID-19 era. Acta Otorhinolaryngol Ital. 2020;40(4):282-8.
19. MacCallum JK, Zhang Y, Jiang JJ. Acoustic analysis of the tremulous voice: assessing the utility of the correlation dimension and perturbation parameters. J Commun Disord. 2010;43(6):408-17.
20. Naqvi Y, Ghaffar V. Functional Voice Disorders. Natl Libr Med. 2023.
21. Jain D, Sinha S, Panda D, Balakrishnan P. Classification of Normal and Abnormal Voices Using Speech Parameters. Int Res J Eng Technol. 2020;7(4):515-21.
22. Behlau M, Madazio G, Oliveira G. International and intercultural aspects of voice and voice disorders. Curr Opin Otolaryngol Head Neck Surg. 2012;20(3):159-65.
23. Keung LC, Sharp DM, Martel-Sauvageau V. A Comparison of Healthy and Disordered Voices Using Multi-Dimensional Voice Program, PRAAT, and TF32. J Voice. 2022;36(5):717.e1-717.e12.
24. Hus Y, Segal O. Challenges Surrounding the Diagnosis of Autism in Children. Neuropsychiatr Dis Treat. 2021;17:3509-19.
25. Merrill RM, Tanner K, Steele BA, Merrill J, LeCheminant JD. Voice Symptoms and Voice-Related Quality of Life in College Students. J Voice. 2017;31(4):507.e1-507.e10.
26. Behlau M, Madazio G. Communication Disorders in Multicultural and International Populations. San Diego: Plural Publishing; 2012.