Journal Pre-proof

Relationship Between Vocal Fatigue Index and Acoustic Voice Scales in Patients with Coronavirus Infection

Nader Saki, Reyhane Nasiri, Arash Bayat, Soheila Nikakhlagh, Shokrollah Salmanzadeh, Hassan Khoramshahi

PII: S0892-1997(23)00152-2

DOI: https://doi.org/10.1016/j.jvoice.2023.04.023

Reference: YMVJ3918

To appear in: *Journal of Voice*

Received date: 3 March 2023
Revised date: 27 April 2023
Accepted date: 28 April 2023

Please cite this article as: Nader Saki, Reyhane Nasiri, Arash Bayat, Soheila Nikakhlagh, Shokrollah Salmanzadeh and Hassan Khoramshahi, Relationship Between Vocal Fatigue Index and Acoustic Voice Scales in Patients with Coronavirus Infection, *Journal of Voice,* (2023) doi:https://doi.org/10.1016/j.jvoice.2023.04.023

Relationship Between Vocal Fatigue Index and Acoustic Voice Scales in Patients with Coronavirus Infection

Relation between Vocal Fatigue index and Acoustic Voice scales in Patients with Coronavirus Infection

1.Nader Saki
Department of Otolaryngology, Head and Neck Surgery, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
Hearing Research Center, Clinical Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

2.Reyhane Nasiri
Hearing Research Center, Clinical Sciences Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

3.Arash Bayat
Department of Audiology, School of Rehabilitation Sciences, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
Hearing Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

4.Soheila Nikakhlagh
Department of Otolaryngology, Head and Neck Surgery, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

5.Shokrollah Salmanzadeh
Infectious and Tropical Diseases Research Center, Health Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

6.Hassan Khoramshahi *
Mobility Impairment Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, Iran
Department of Speech Therapy, School of Rehabilitation, Babol University of Medical Sciences, Babol, Iran

Objectives: The voice quality of patients with Coronavirus Disease 2019 (COVID-19) seems to be affected due to lower and upper respiratory involvement. Patient-based voice assessment scales are important clinical measures to diagnose voice disorders and monitor treatment outcomes in COVID-19 patients. This study compared vocal fatigue between COVID-19 patients and those with normal voices. Furthermore, the relationship between vocal fatigue and acoustic voice parameters of COVID-19 patients was evaluated.

Methods: This cross-sectional study enrolled 30 laboratory-confirmed patients with COVID-19 (18 males and 12 females) and 30 healthy individuals with normal voices (14 males and 16 females) to compare their respiratory/phonatory parameters. The Persian versions of the Consensus Auditory Perceptual Evaluation of voice (CAPE-V) and the vocal fatigue index (VFI) were conducted before and after reading the text. The Jitter, shimmer, maximum phonation time (MPT), and harmonic-to-noise ratio (HNR) were analyzed by Praat software based on the recorded voices of CAPE-V tasks. The acoustic assessment and VFI questionnaire results were compared between COVID-19 patients and the control group.

Results: There were significant differences between COVID-19 patients and their healthy counterparts in all VFI subscales ($p<0.001$). Moreover, after reading the text, we found significant differences between the two groups regarding Jitter, shimmer, and HNR of /a/ and /i/ vowels ($p<0.05$). Our findings also indicated a significant correlation between symptom improvement with rest and acoustic parameters in all tasks, except the Jitter of /a/ before reading the text.

Conclusion: Patients with COVID-19 showed significantly more vocal fatigue than people with normal voices after reading the text. Moreover, there was a significant relationship between Jitter, shimmer, and HNR and the tiredness of voice and physical discomfort subscales of VFI.

Keywords: Vocal fatigue; Acoustic; Coronavirus infection

INTRODUCTION

Coronavirus Disease 2019 (COVID-19) is a novel coronavirus disease that originated in China in December 2019 and subsequently proliferated rapidly worldwide (1-3). It has been demonstrated that COVID-19 can cause shortness of breath and exhalation difficulties, leading to insufficient energy for sufficient phonation (4, 5). Asiaee et al. (6) reported reduced airflow, increased irregularity, aperiodicity, signal perturbation, and increased noise-to-harmonics ratios in acoustic voice parameters due to laryngological and pulmonary involvements in patients with COVID-19. These patients commonly complain of cough, pharyngeal erythema, and sore throat, putting them at higher risk of voice production (7-13).

Five aspects of voice evaluation consist of auditory-perceptual, patient-based, acoustic, aerodynamic, and visual-perceptual parameters used to assess dysphonia (14-18). In recent years, patient-based voice assessment questionnaires such as vocal fatigue index (VFI), vocal tract discomfort (VTD), voice handicap index (VHI), and voice related quality of life (VRQOL) are frequently utilized for quantifying and approving patient-based or auditory-perceptual voice assessments.

The VFI is a self-report scale used in different clinical settings to identify individuals with vocal fatigue and quantify and characterize perceived fatigue levels. The VFI comprises 19 items grouped into three dimensions: physical discomfort, tiredness of voice, and symptom improvement with rest (19-20). The literature shows higher vocal fatigue in dysphonic individuals than in non-dysphonic individuals. COVID-19 patients are at risk of experiencing vocal fatigue because of dysphonia (21).

There is scarce literature data documenting vocal fatigue and its relationship with COVID-19. The current study aimed to compare signs and symptoms of vocal fatigue between COVID-19 patients and people with normal voices. Moreover, we evaluated the relationship between vocal fatigue subscales and some acoustic parameters.

Methods

This cross-sectional study enrolled 30 laboratory-confirmed patients with COVID-19 (18 males; mean age: 39.69 ± 10.42 years) admitted to our general hospital were evaluated. The inclusion criteria were an age of more than 18 years (to prevent puberty influences on voice), the possibility of vocal sampling, and native Persian speaking. The COVID-19 diagnosis was established according to the positive findings of real-time reverse transcription polymerase chain reaction (RT-PCR) assay of nasal and pharyngeal swab specimens, based on World Health Organization (WHO) guidelines. Additionally, subjects with a history of a laryngeal disorder before COVID-19 and subjects without a laboratory-confirmed COVID-19 diagnosis were excluded.

Simultaneously with sampling individuals with COVID-19, 30 gender- and age-matched healthy people (14 males; mean age: 35.69 ± 6.92 years) without COVID-19 and with a normal voice were enrolled as the control group.

All protocols of the current study were approved by the local ethics committee (ethics code: IR.AJUMS.REC.1399.766). All participants were volunteers and signed an informed consent form.

Procedure

The auditory-perceptual measurement of dysphonia was carried out using the CAPE-V scale. Two experienced SLP used the Persian version of CAPE-V to differentiate coronavirus patients with dysphonia from other patients without dysphonia and determine normal voices in the control group. Moreover, the sustained vowel tasks of CAPE-V before and after reading the standard text were used for acoustic voice assessment. The CAPE-V was introduced by the American Speech-Language and Hearing Association (ASHA) to provide a standardized approach for clinicians to analyze the voice quality of patients. The Persian version of the CAPE-V has high qualitative content validity (Cronbach α=0.95) and contains three phonatory tasks: reading six sentences, sustained vowels (/a/, /i/), and conversational speech. This tool utilizes visual analog scales (a 100-mm line) for describing the six vocal indicators, including overall roughness, severity, breathiness, strain, pitch, and loudness.

The VFI is a self-report index specifically designed to identify subjects with vocal fatigue and quantify perceived fatigue levels. The Persian version of the VFI utilized the following three factors to measure vocal fatigue: physical discomfort associated with voicing (PD, five items), tiredness of voice and voice avoidance (TV, 11 items), and symptom improvement with rest (IS, three items) (19-20). For both PD and TA subscales, higher scores corresponded to greater severity, whereas lower scores showed worse vocal fatigue for the IS subscale.

All participants performed a personal voice recording with a headset microphone (Shure Beta54) in an acoustically silent room with a background noise of less than 30 dB SPL. The voice samples were recorded and analyzed using Praat software (version 5.1.44; Phonetic Sciences, University of Amsterdam, Netherlands) installed on a laptop. Three trials were carried out for each phoneme, and the largest value was utilized in the analysis. The measures acquired from Praat software included Jitter (%), Shimmer (%), maximum phonation time (MPT) (seconds), and harmonic-to-noise ratio (HNR) (dB). Mid-2-second segments of the sustained vowels /a/ and /i/ were selected to analyze the HNR (dB) to remove the irregularities in the first and last sections of the waveforms. The Shimmer and Jitter values were analyzed based on the mean value of the qualitatively best part of both subjects' sustained vowels (22-24).

Statistical Analysis

The Kolmogorov-Smirnov test analyzed the normality of data. Quantitative variables were compared between the groups with the independent sample t or Mann-Whitney U test. The

Pearson correlation coefficient assessed the association between VFI subscales and some acoustic scales. All statistical analyses were conducted using SPSS for Windows version 22.0 (SPSS Co., Chicago, IL, USA). A significance level of 0.05 was considered in all inferential analyses.

Results

Table 1 compares the mean scores of VFI subscales between the COVID-19 and control groups. The scores of vocal fatigue symptoms in physical discomfort, tiredness of voice, and symptom improvement with rest were significantly greater in the COVID-19 group than in controls (independent sample t-test p<0.001).

Table 1: Comparison of self-perception of vocal fatigue scores according to the study group

Parameter	Group		p-value
	COVID-19	Control	
Tiredness of voice	34.80±9.852	7.50±9.913	<0.001
Physical discomfort	15.60±5.177	1.33±2.218	<0.001
Improvement of symptoms with rest	10.47±2.980	3.63±4.937	<0.001

Table 2 shows the mean vocal parameters for /i/ and /a/ vowels "before reading" and "after reading" conditions. Multivariate ANOVA results showed significantly different Jitter, shimmer, and MPT values between COVID-19 patients and controls. The Jitter and shimmer values were higher in the "after reading" condition than in the "before reading" condition, but MPT was lower (paired sample t-test p<0.001). However, the mean HNR in the "after reading" condition was slightly lower than that in the "before reading" condition in both study groups (paired sample t-test p>0.05).

Table 2: Mean (±SD) of vocal parameters according to study group

Parameter		COVID-19				Control			
		Jitter	Shimmer	HNR	MPT	Jitter	Shimmer	HNR	MPT
/a/ vowel	Before reading	0.55±0.858	3.19±2.261	21.03±6.85	6.11±1.80	0.31±0.132	2.81±1.492	24.12±3.302	14.12±3.50
	After reading	0.75±1.234	4.02±2.423	19.72±6.852	3.80±1.5	0.40±0.105	2.76±1.072	23.63±2272	13.83±3.60
/i/ vowel	Before reading	0.55±0.467	3.19±1.916	23.97±4.050	6.20±1.90	0.38±0.165	2.35±0.646	26.29±2.576	14.30±3.60
	After reading	0.99±1.339	4.14±2.480	21.16±5.409	4.10±2.10	0.45±0/270	2.40±0.630	25.60±3.385	14.09±3.49

SD: Standard Deviation; HNR: Harmonic-to-noise Ratio; Maximum Phonation Time

We found a significant correlation between the tiredness of voice and shimmer of the /i/ vowel "before reading" the text and the HNR of both /a/ and /i/ vowels in "before reading" and "after reading" conditions (Table 3). A significant correlation was observed between the physical discomfort and Jitter, shimmer, and HNR of the /i/ vowel "after reading" the text. Furthermore, all the correlations were significant between symptom improvement with rest and acoustic parameters in all tasks, except Jitter of /a/ in the "before reading" condition.

Table 3: Pearson correlation results between VFI and acoustic parameters

	Jitter		Shimmer		HNR	
Parameter	/a/ vowel	/i/ vowel	/a/ vowel	/i/ vowel	/a/ vowel	/i/ vowel
Tiredness of voice	.227	.178	0.202	.359*	-.31*	-0.389**
Physical discomfort	.217	.259*	0.224	.309*	-.253	-0.304*
Improvement of symptoms with rest	. 219	.257*	0.263*	.313*	-.293*	-0.339**

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Discussion

The VFI scale can reliably identify subjects with general voice complaints related to vocal fatigue using three parameters: tiredness of voice, physical discomfort, and improvement with rest. This study compared the VFI subscale scores of patients with COVID-19 and normal people before and after reading the text. Furthermore, the relationship between the VFI subscales and some acoustic parameters was assessed.

There was a significant difference between the groups after reading the text regarding vocal fatigue in coronaviruses in patients with COVID-19 (5-7, 25-27). Moreover, recurrent cough related to breathiness (28-33) in these patients may lead to partial vocal folds closure, causing tiredness of voice and physical discomfort.

Our findings indicated significant differences between COVID-19 patients and controls after reading the text in acoustical analysis. It has been demonstrated that COVID-19 patients may show irregularity and aperiodicity in vocal fold vibration, increased Jitter and shimmer, and decreased HNR parameters (5, 6).

Tremor and insufficient control over laryngeal muscles in COVID-19 patients can increase jitter and shimmer values. The irregular weighting of the vocal folds, which occurs due to inflammation or degeneration of vocal fold tissues, could also explain the higher Jitter and shimmer values in the experimental group from tremor and insufficient control over laryngeal muscles in the experimental group.

The present study also revealed lower HNR and CPP values in COVID-19 patients than in controls. A decrease in these acoustic features indicates increased spectral noise in patients' voices, leading to breathier voices in the COVID-19 group (34- 35).

According to our findings, the MPT value was significantly below the normative level in the patient group. The phonation duration is strongly correlated with lung volume. It has been shown that COVID-19 has noticeable impacts on the lungs, which accordingly cause airflow insufficiency for the continuation of voice. Moreover, the inadequate closure of vocal folds in the pathological larynx generally reduces MPT due to the value of the leakage through the glottis (25, 27).

The occurrence of voice breaks was rare in healthy participants. However, patients with COVID-19 have an increased incidence of voice breaks. This finding also confirms the voice dysfunction and the possible injury in vocal folds (6,27,28).

The present study showed a significant correlation between the tiredness of voice and physical discomfort and Jitter, shimmer, and HNR parameters in the "after reading" condition. The breathiness in pathological voices causes air leakage and incomplete vocal fold closure, which may result from the trauma of vocal folds during recurrent coughing (29-33).

Noise-related parameters such as Jitter, shimmer, and HNR were higher in the COVID-19 group than in the controls because of breathiness. This study also observed a significant relationship between the VFI subscales and noise-related acoustic parameters. All the correlations were significant between symptom improvement with rest and acoustic parameters in all tasks. The nature of the third factor of the VFI scale (improvement with rest) is challenging and unrelated to vocal fatigue indices. Therefore, the findings related to improvement with rest differ from other subscales of VFI and are not well definitive.

Conclusion

Patients with COVID-19 had more vocal fatigue than the controls. Furthermore, changes in noise-related acoustic parameters such as Jitter, shimmer, and HNR were related to changes in the tiredness of voice and physical discomfort subscales of VFI.

References

1. Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, Hu Y, et al. A new coronavirus associated with human respiratory disease in China. Nature. 2020; 579: 265–269.

2. Burkert FR, Lanser L, Bellmann-Weiler R, Weiss G. Coronavirus Disease 2019: clinics, treatment, and prevention. Front Microbiol. 2021; 12: 761887.

3. Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. J Autoimmun. 2020; 109: 102433.

4. Castillo-Allendes A, Contreras-Ruston F, Cantor-Cutiva LC, Codino J, Guzman M, Malebran C, et al. Voice Therapy in the Con- text of the COVID-19 Pandemic: Guidelines for Clinical Practice. J Voice. 2020; S0892-1997(20)30287-3.

5. Tohidast SA, Mansuri B, Bagheri R, Azimi H. Provision of speech-language pathology services for the treatment of speech and language disorders in children during the COVID-19 pandemic: problems, concerns, and solutions. Int J Pediatr Otorhinolaryngol. 2020; 138: 110262.

6. Asiaee M, Vahedian-Azimi A, Atashi SS, Keramatfar A, Nourbakhsh M. Voice quality evaluation in patients with COVID-19: an acoustic analysis. J Voice. 2022; 36(6): 879.e13-879.e19

7. Saki N, Zamani P, Bayat A, Nikakhlagh S, Moghateli N, Salmanzadeh S. Auditory-perceptual evaluation of vocal characteristics in patients with the new coronavirus disease. Folia Phoniatrica Logop. 2022; 74(3): 230-237.

8. Zhao S, Lin Q, Ran J, et al. Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: a data-driven analysis in the early phase of the outbreak. Int J Infect Dis. 2020; 92: 214–217.

9.Yuki K, Fujiogi M, Koutsogiannaki S. COVID-19 pathophysiology: a review. Clin Immunol. 2020; 215: 108427.

10. Özçelik Korkmaz M, Eğilmez OK, Özçelik MA, Güven M. Otolaryngological manifestations of hospitalised patients with confirmed COVID-19 infection. Eur Arch Otorhinolaryngol. 2021; 278(5): 1675-1685.

11. Saniasiaya J, Kulasegarah J, Narayanan P. New-onset dysphonia: a silent manifestation of COVID-19. Los Angeles, CA: SAGE Publications Sage CA; 2021.

12. El-Anwar MW, Elzayat S, Fouad YA. ENT manifestation in COVID-19 patients. Auris Nasus Larynx. 2020; 47: 559-564.

13. Watson NA, Karagama Y, Burnay V, Boztepe S, Warner S, Chevretton EB. Effects of coronavirus disease-2019 on voice: our experience of laryngeal complications following mechanical ventilation in severe coronavirus disease-2019 pneumonitis and review of current literature. Curr Opin Otolaryngol Head Neck Surg. 2021; 29(6): 437-444.

14. Dejonckere PH, Clemente P, Cornut G, et al. A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Eur Arch Otorhinolaryngol. 2001; 258: 77-82.

15. Kreiman J, Gerratt BR, Kempster GB, Erman A, Berke GS. Perceptual evaluation of voice quality: review, tutorial, and a framework for future research. J Speech Hear Res. 1993; 36: 31–32.

16. Helou LB, Solomon NP, Henry LR, et al. The role of listener experience on Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) ratings of post-thyroidectomy voice. Am J Speech Lang Pathol. 2010; 19: 249–253.

17. Zraick RI, Kempster GB, Connor NP, et al. Establishing validity of the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V). Am J Speech Lang Pathol. 2011; 20: 16–17.

18. Karnell MP, Melton SD, Childes JM, et al. Documentation of voice disorders. J Voice. 2006; 21: 576–590.

19- Nanjundeswaran C, Jacobson BH, Gartner-Schmidt J, Abbott KV. Vocal fatigue index (VFI): development and validation. J Voice. 2015; 29(4): 433-40.

20- Naderifar E, Moradi N, Farzadi F, Tahmasebi N, Soltani M, Latifi SM, Nanjundeswaran C. Cross-cultural adaptation and validation of the vocal fatigue index into Persian. J Voice. 2019; 33(6): 947-e35.

21. de Oliveira Lemos I, Picanço Marchand DL, Oliveira Cunha E, Alves Silvério KC, Cassol M. What are the symptoms that characterize the clinical condition of vocal fatigue? a scoping review and meta-Analysis. J Voice. 2023; S0892-1997(22)00419-2.

22.Stemple JC, Roy N, Klaben BK. Clinical Voice Pathology. 5th ed. Plural Publication; 2014.

23. Manfredi C, Giordano A, Schoentgen J, et al. Validity of jitter measures in non-quasi-periodic voices. Part II: the effect of noise. Logoped Phoniatr Vocol. 2011; 36: 78–89.

24. Deliyski DD, Shaw HS, Evans MK. Influence of sampling rate on accuracy and reliability of acoustic voice analysis. Logoped Phoniatr Vocol. 2005; 30: 55–62.

25.Ortega J, Cassinello N, Dorcaratto D, Leopaldi E. Computerized acoustic voice analysis and subjective scaled evaluation of the voice can avoid the need for laryngoscopy after thyroid surgery. Surgery. 145(3): 265-271.

26.Yanagihara N, Koike Y, Von Leden H. Phonation and respiration. Function study in normal subjects. Folia Phoniatr (Basel). 1966; 18: 323–340.

27. Rusz J, Klempíř J, Baborová E, Tykalová T, Majerová V, Cmejla R. Objective acoustic quantification of phonatory dysfunction in Huntington's disease. PLoS One. 2013; 8(6): e65881.
28.Karlsen T, Sandvik L, Heimdal JH, Aarstad HJ. Acoustic voice analysis and maximum phonation time in relation to voice handicap index score and larynx disease. J Voice. 2020; 34(1): 161.e27-161.e35.
29. Klatt DH, Klatt LC. Analysis, synthesis, and perception of voice quality variations among female and male talkers. J Acoust Soc Am. 1990; 87(2): 820-57.
30. Bickley C. Acoustic analysis and perception of breathy vowels. MIT Res Lab Electron Speech Commun Gr Work Pap. 1982; 1: 71-81.
31. Krom G. Some spectral correlates of pathological breathy and rough voice quality for different types of vowel fragments. J Speech Hear Res. 1995; 38: 794-811.
32. Dogan M, Eryuksel E, Kocak I. Subjective and objective evaluation of voice quality in patients with asthma. 2007; 21: 224-230.
33.Fraile R, Godino-llorente JI. Cepstral peak prominence: a comprehensive analysis. Biomed Signal Process Contorl. 2014; 14: 42–54.
34. Hartl DM, Hans S, Vaissière J, Riquet M, Brasnu DF. Objective voice quality analysis before and after onset of unilateral vocal fold paralysis. J Voice. 2001; 15: 351–361.
35. Moghtader M, Soltani M, Mehravar M, ShaterzadehYazdi MJ, Dastoorpoor M, Moradi N. The relationship between vocal fatigue index and voice handicap index in university pofessors with and without voice complaint. J Voice. 2020; 34(5): 809.e1-809.e5