

Research Paper

Investigating the Relationship Between the Dysphonia Severity Index and the Speech and Voice Severity of Parkinson Disease Patients



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ABSTRACT

Objectives: This study aims to investigate the relationship between dysphonia severity index (DSI), speech disease and voice severity of Parkinson disease (PD) patients.

Methods: This was a cross-sectional study, carried out on 45 randomly selected PD patients with the age range of 50 to 75 years. The Hoehn and Yahr scale (H.Y scale) was employed to measure the severity of PD. To measure the DSI, we required detecting the acoustic features of the voice, such as shimmer (dB), vital capacity (VC), semitone range (STR), and voice onset time (VOT); therefore, the participants were asked to produce the vowel /a/ three times for calculating the variables, i.e., STR, VOT, fundamental frequency (F0), second formant (F2), and shimmer (dB). Their voices were analyzed by the Praat software (version 6.0.23). F0 and F2 were utilized to calculate the STR. The VOT was assessed by analyzing the spectrograph of the syllable /pa/. The Kruskal-Wallis test was used to understand the correlation between DSI scores and the stage of PD (Y.H scale); the P value of less than 0.05 was considered significant.

Results: A significant relationship was detected between severe DSI and the stage of PD. Meanwhile, the DSI score was statistically significant compared to the scores of the other four groups ($P < 0.05$).

Discussion: There was a significant relationship between the severity of voice changes in PD patients by DSI and the stage of their disease. Further studies in this field are needed considering that such information may be of cardinal importance for voice professionals to take early interventions, appropriate to the stage of PD.

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Highlights

- There was a significant relationship between the severity of voice changes in Parkinson disease patients by dysphonia severity index and the patient's stage.
- The severity of Parkinson disease during different stages as well as the amount of dysphonia severity index increased significantly.

Plain Language Summary

Voice disorders in adults are assessed by the dysphonia severity index, which is one of the valid and reliable standard reference values for such disorders. This study aims to investigate the relationship between DSI and the severity of Parkinson disease. According to the findings of the present study, as the severity of Parkinson disease increases during different stages, the amount of dysphonia severity index increases significantly as well.

1. Introduction

Parkinson disease (PD) is the second most common progressive neurological disorder worldwide, mainly because of the degradation of dopaminergic neurons in the basal ganglia [1]. The prevalence of this disease is 120 to 180 cases per 100 000 people in the world [1-3]. The clinical symptom of PD contains movement disorders, swallowing disorders, sleep disorders, cognitive problems, depression, and speech disorders [3-5]. Conventionally, speech disorders in PD are resulted from dopamine deficiency that lead to muscle rigidity. The electromyographic evidence confirms the hypertonicity of laryngeal muscles at rest in PD and the evidence for improved respiratory function, prosodic pitch, loudness variation, and speech intelligibility with levodopa treatment [2-5]; however, other studies have been unsuccessful to draw a causal relationship between dopamine and speech disorders in PD. It has been suggested that, in contrast to the classical motor features of PD, speech disturbances may be due to altered nondopaminergic or special dopaminergic mechanisms, which impair internal cueing, sensorimotor gating, scaling of movement parameters, and attention to action, causing poor regulation of speech initiation, amplitude, and timing [5-7]. Speech impairment in PD originates from a blend of motor and non-motor deficiencies because speech is a difficult task coordinated by complex motor and sensory neural networks [6-9]. Speech Disorders affect 75% to 95% of PD patients [10]. These patients are affected by speech disorders, such as hypokinetic dysarthria, characterized by hypophonia and dysprosody, which is intensified as the disease progress and has been revealed in more advanced stages [6-9, 11-13]. This disease has different effects on patients who will not experience all the symptoms al-

together. According to the Hoehn and Yahr scale (H.Y scale), PD has 5 stages in terms of severity. In stage 1-1.5, the patient has mild symptoms which generally does not interfere with their daily activities and does not cause tremors. In addition, other motor symptoms only occur unilaterally in the body. In stage 2 - 2.5, the symptoms worsen tremors, and stiffness and other movement symptoms occur on both sides of the body, but the person can still function independently. In stage 3, which is considered the middle stage, loss of balance and slowness of movement are the prominent features, yet the person can still function self-sufficiently. In stage 4, symptoms are severe and restrictive. Patients can stand without help but they need a walker to move and the person is not able to function autonomously. In the last stage, as the most advanced and disabling stage, stiffness in the legs may make it impossible to stand or walk [4, 9, 14].

Following progressive muscle involvement and weakness in PD patients, varying severity of voice disorders is evident. In recent years, voice disorders in PD patients have received more attention than other neurogenic speech disorders as the prevalence of voice disorders in these patients is 50% to 70% [4, 15-22]. In PD patients, the voice disorders are seen by reduced stress and pitch, inadequate voice quality, and reduced loud changes that affect the daily life of the individual and their families [5].

To date, studies have been conducted to evaluate voice disorders in PD patients. Majdi Nasab et al. examined the relationship between motor disabilities and voice disorders in PD patients [23]. They indicated that with the progression of the disease, motor disorders, such as tremors, affect the vocal system [23]. In another study, Majdi Nasab et al. examined the relationship between acoustic voice characteristics, the duration, and the severity of PD

[24]. The result showed that the duration of the disease is directly related to its severity and has negative effects on the patient's voice [24]. In a study by Slibergleit, Alice K et al., acoustic voice alterations and their association with the severity of disease were examined. They found that acoustic measurements in patients with PD differed from those at the onset of the disease [25].

In the last decade, voice specialists have tried to develop novel techniques for a thorough evaluation of the voice. In recent years, acoustic assessments have been considered to examine changes as well as the severity of voice disorders [26-30]. The dysphonia severity index (DSI) is an acoustic instrument especially useful to evaluate the therapeutic evolution of dysphonic patients [31, 32]. The psychometric features of the Persian version of the DSI formula were determined by Darouie et al. [33].

To date, no study has been carried out on the use of DSI to detect the relationship between dysphonia and PD stages. Therefore, it is essential to explore the relationship between the duration and the severity of the disease with the acoustic and other characteristics of the voice. Aghadoost et al. examined DSI in teachers with voice complaints and reported significant results [34]. Early detection of vocal problems is required to achieve appropriate therapeutic interventions that have not been performed in PD patients. Accordingly, the researchers in this study decided to investigate the relationship between DSI and speech disease and voice severity in PD patients.

2. Materials and Methods

Ethical considerations

The study protocol was approved by the Institutional Review Board, School of Para Medicine, and the Ethics Committee of Mashhad University of Medical Sci-

ences (IR.MUMS.REC.1399.558.). All patients signed the written informed consent form before participating in the study and their information was kept confidential.

Study design and participants

This cross-sectional study was carried out on 45 PD patients (30 female and 15 male) with Mean±SD age of 58.89±6.05 years (range: 50-75 years) in Mashhad City, Iran in 2020. All participants were randomly classified using the random block classification method. All patients had no other disorders, were Persian speakers (monolingual), were at least 50 years old, and at least 5 years had passed since the onset of the disease to discriminate PD from other disorders of the Parkinsonism spectrum. The patients were on medication for at least 3 months and did not have cancer or any malignant disease of the larynx or a history of laryngeal surgery, trauma, chemotherapy, or radiation to the head and neck. Patients were excluded from the study as long as they did not cooperate in the assessments and did not continue the process of assessing the severity of the voice disorder.

Diagnosis of the disease severity

The H.Y scale was used to measure the progression of PD symptoms. Meanwhile, the disability level and the H.Y stage were determined by a neurologist (Table 1) [14]. All participants were examined for 45 to 90 min and the participants' medications did not interfere with the study.

Detecting the dysphonia severity index

DSI measurements were performed 5-10 min after determining the patient's PD stage. The patients were asked to produce the vowel/a/three times (each time for 5 seconds) for calculating the acoustic variables and their voices were recorded on an external sound card

Table 1. Parkinson stages and symptoms and severity by the Hoehn and Yahr scale

Stages	Symptoms and Signs
0	No signs of disease
1	Symptoms on one side only (unilateral)
1.5	Symptoms are unilateral and also involve the neck and spine
2	Symptoms on both sides but no impairment of balance
2.5	Mild symptoms on both sides, with recovery when the "pull" test is given (the doctor stands behind the person and asks them to maintain their balance when pulled backward)
3	Balance impairment, mild to moderate disease, physically independent
4	Severe disability, but still able to walk or stand unassisted
5	Needing a wheelchair or bedridden unless assisted

(TASCAM US-122mkII, Montebello, California, USA, Teac America Inc) that was attached to laptop with a microphone AKG (AKG C410, A Harman international company, Vienna, Austria) with the frequency response from 50Hz to 20kHz. Then, a digital recorder was connected to the laptop to assign the recorded sounds. The patients were asked to produce the syllable / pa / for calculating the voice onset time (VOT) and were recorded using the Praat software recorder (version 6.0.23). The mouth to microphone distance was set at 30 cm vertically to the mouth and at an angle of 30 degrees. To measure the vital capacity (VC), patients were asked to take a deep breath and blow as hard as they could on a spirometer (model TB-93500 BESMED) and repeat this operation three times. The maximum amount of VC was used to determine the DSI.

We used the website www.homepages.ucl.ac.uk to convert the fundamental frequency (F0) and the second formant (F2) to calculate the semitone range (STR). All assessments were performed by a speech and language pathologist (the first author) and the variables were incorporated into multivariate DSI formula. According to the study conducted by Darouie et al. in Iran, the formula is provided as follows [33] (Equation 1):

$$1. DSI = 0.289 (\text{shimmer}) + 0.0001 (VC) - 0.059 (STR) - 13.278 (VOT/Pa/)$$

Statistical analysis

The variables were described by descriptive statistics including mean, median, SD, minimum, and maximum for quantitative variables, and frequency and percentage for categorical variables. The normality condition of the quantitative variables was investigated via the 1-sample Kolmogorov-Smirnov test. A significant value ($\alpha < 0.01$) indicates a deviation from normality; also, this is true in the case of a statistically significant difference ($P < 0.05$).

The homogeneity of groups in terms of demographic variables was assessed by the Chi-square method or the Kruskal-Wallis test. The Kruskal-Wallis test was used to check the differences of variables across PD stages (Y.H scale). Meanwhile, pairwise comparisons of the stages of PD (Y.H scale) were reported. We used the Kruskal-Wallis test to find the correlation between DSI scores and the stages of PD (Y.H scale); the P value of less than 0.05 was considered significant. Statistical analysis was done via the SPSS software, v. 25.

3. Results

In this study, PD patients with Mean \pm SD age of 58.89 \pm 6.05 years (range: 50-75 years) were included. The Mean \pm SD of years passing from their disease was 10.56 \pm 4.18 (range: 5-20 years) and the Mean \pm SD of the time to use the drug was 7.91 \pm 4.03 (range: 2-18) (Table 2).

According to Table 2, out of 11 measured variables, shimmer, VC, STR, and VOT/Pa/ are the parameters that were used to calculate the DSI. They showed significant results concerning the stage of the disease (Y.H scale). Compared to the four stages, the higher volume DSI was statistically significant in comparison between the four groups ($P < 0.05$) (Table 2).

Figure 1 illustrates the results of the regression analysis for determining the factors affecting the DSI and the coefficient of PD stages. According to Figure 1, the linear relationship between DSI and PD stages (Y.H scale) is well shown, indicating a statistically significant relationship. The other findings of this study can be observed in Table 3, depicting a relationship between the disease stages (Y.H scale) with each other.

4. Discussion

In this study, the relationship between DSI and the severity of PD was investigated. According to the findings, as the severity of PD increased during different stages of the disease, the amount of DSI significantly augmented as well.

Since the very early stages of the PD, there may be indirect abnormalities in a voice that might not be perceptible to listeners and as the disease progresses, the voice impairment increases [32]; however, they could be evaluated by performing acoustic analysis on recorded voices. DSI is a multiparametric acoustic evaluation method in which there is at least one parameter in the model from each evaluation; that is, one component remains in the aerodynamic evaluations, two components in the acoustic evaluations, and one in the voice range profile evaluations. This indicates that one type of evaluation or a single component cannot show the perceptual quality of voice and that the multidimensional nature of voice increases the need for performing multiparametric evaluations [33].

Table 2. Demographic and baseline characteristics of the participants

Stage of PD (Hoehn and Yahr Scale)	Statistics	DSI	F0 (Hz)	Jitter (%)	Shimmer (dB)	NHR (dB)	VOT-pa(s)	MPT (s)
1	Mean±SD	1.71±0.21	113.65±45.04	0.47±.26	12.59±3.18	0.91±0.11)	0.07±0.03	14.60±3.65
	Median (interquartile range)	1.63 (.38)	90.99 (66.20)	.31 (.41)	10.82 (6.05)	.97 (.16)	.06 (.04)	15.00 (6.00)
2	Mean±SD	2.58±0.26	165.59±50.35	0.86±0.58	14.71±2.02	0.90±0.03	0.08±0.03	17.17±5.15
	Median (interquartile range)	2.52 (.37)	175.50 (71.42)	.64 (1.01)	14.29 (2.85)	.92 (.03)	.07 (.05)	17.50 (7.50)
3	Mean±SD	3.63±0.33	139.26±43.79	0.91±1.04	17.33±1.60	0.87±0.07	0.06±0.01	14.71±3.22
	Median (interquartile range)	3.67 (.51)	137.28 (82.48)	.63 (.59)	17.69 (1.71)	.87 (.12)	.06 (.02)	15.00 (7.50)
4	Mean±SD	4.45±0.32	210.40±34.18	1.89±1.58	19.97±2.31	0.87±0.07	0.07±0.03	14.86±3.51
	Median (interquartile range)	4.46 (.66)	217.79 (45.44)	1.08 (1.60)	19.22 (4.42)	.87 (.12)	.06 (.05)	15.00 (6.25)
Kruskal-Wallis Test	P	.000	.430	.030	.001	.040	.210	.070

Stage of PD (Hoehn and Yahr Scale)	Statistics	STR (Hz)	VC (ml)	Age (Year)	Number of Years After the Disease	Number of Years From Starting to Take Drugs	Gender
1	Mean±SD	15.74±2.12	4100±430.12	64.40±9.71	14.20±4.66	7.60±3.36	F: 3 (6.7)
	Median (interquartile range)	16.10 (3.62)	4100 (700.00)	67.00 (17.50)	15.00 (7.00)	10.00 (6.00)	M: :2 (4.4) T: 5 (11.1)
2	Mean±SD	14.95 (2.96)	4141±702.54	56.33±4.36	8.75±2.63	6.50±3.26	F: 8 (17.8)
	Median (interquartile range)	14.34 (5.43)	4500 (1275.00)	55.50 (9.25)	9.50 (4.75)	5.50 (4.50)	M: 4 (8.9) T: 12 (26.7)
3	Mean±SD	15.55±1.50	3692±574.41	58.43±4.78	10.57±4.03	8.64±4.11	F: 11 (24.4)
	Median (interquartile range)	16.06 (2.14)	3750 (850.00)	57.00 (4.78)	10.00 (8.25)	8.00 (7.00)	M: 3 (6.7) T: 14 (31.1)
4	Mean±SD	14.62±2.16	3750±562.62	59.57±6.12	10.79±4.71	8.50±4.77	F: 8 (17.8)
	Median (interquartile range)	14.19 (4.10)	3800 (725.00)	60.00 (6.25)	10.50 (9.00)	7.50 (9.00)	M: 6 (13.3) T: 14 (31.1)
Kruskal-Wallis Test	P	.101	.080	.199	.202	.063	.666

DSI: dysphonia severity index; F0: fundamental frequency; NHR: harmonics-to-noise ratio; VOT: voice onset time; MPT: maximum phonation time; STR: semitone range; VC: vital capacity; SD: standard deviation; T: total.

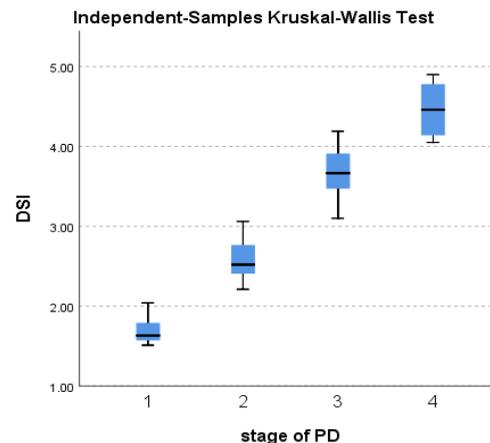


Figure 1. Relationship between disease stages with dysphonia severity index

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PD has different stages and not all of these patients showed the same degree of voice damage. In the present study, we detected a statistically significant relationship. The DSI score indicated the overall severity of dysphonia of the voice disorders [33] and based on the findings of this study, with an increase in PD stages, the severity of the voice disorder also increases. These results could be a base for more practical studies.

Majdi Nasab et al. examined the relationship between motor disabilities and voice disorders in PD patients. They found that the patients report handicaps because of voice disorders as a result of PD [24]. As mentioned above, with an increase in the stages of the disease, motor disabilities are also intensified in patients [14, 24]; therefore, it is possible that voice problems also increase, as we demonstrated in this study. The result of our study was consistent with the study conducted by Majdi Nasab et al. in that with increasing the severity and stage of the disease, voice problems in PD patients augmented. Also, Majdi Nasab et al. assessed the voice of Iranian PD patients and considered the relationship between movement disabilities and acoustic voice fac-

tors as speech motor components. They determined that with the progress of the disease, movement disorders in these patients affect their vocal system [23] which was in line with our study showing that with increasing the stage of the disease, the voice characteristics of these patients are affected. Silbergleit et al. hypothesized that quantified acoustic changes of the voice might correlate with the disease severity in PD patients. They concluded that acoustic analysis of the voice, particularly the frequency range, may provide a quantifiable correlation of the disease progression in PD which was in line with the result of our study [25].

Mansouri et al. examined the relationship between voice-related quality of life and DSI from the perspective of primary school teachers with voice complaints. They found that a low DSI, reflecting poor laryngeal function, is associated with lower voice-related quality of life [35]. Also, Ostadi et al. calculated the correlation between total scores of the Persian versions of the voice handicap index and the voice-related quality of life scales on a school teacher with voice disorders [36]. It is likely that with increasing DSI as the severity of PD dur-

Table 3. Pairwise comparisons of Parkinson disease stages

Sample 1-Sample 2/Stages	Test Statistic	Sig.
1-2	-8.500	1.000
1-3	-21.786	0.009
1-4	-35.214	0.000
2-3	-13.286	0.061
2-4	-26.714	0.000
3-4	-13.429	0.041

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ing different stages of the disease increases, the quality of life of PD patients will be affected. This issue can be considered for future studies.

Aghadoost et al. examined the DSI in teachers with voice complaints. Their results indicated that teachers with voice complaints have more voice problems than teachers without voice complaints [34]. The results of these studies were in line with our study in PD patients indicating that by increasing voice problems, the DSI is affected. In a study by Katia Nemr et al. the DSI in 66 Brazilians with voice disorders or without were evaluated and the DSI's correlation with sex and auditory-perceptual evaluation of the voice, obtained via the consensus auditory-perceptual evaluation of voice (CAPE-V) protocol, was investigated and a statistically significant relationship was detected between the DSI score and the CAPE-V [37]. In this study, we also divided the gender of PD patients (Table 2).

As far as the relationship between the severity of PD and the severity of dysphonia is concerned, no direct study has been found to examine such a relationship in patients. Therefore, the findings of the present study can be used as an accurate predictor for estimating the severity of voice disorder in different stages of PD. To investigate the relationship between DSI and the severity of PD more accurately, it is strongly suggested that the relationship in larger groups at different ages be considered. The effect of these variables would be related to reflect in future studies. The authors also propose that further research on this topic could focus on people with another voice pathology.

5. Conclusion

In this study, we tried to find the relationship between DSI and voice disorders with the stage of PD. We found that there was a significant relationship between the severity of voice changes in PD patients by DSI and the stage of the patients with this disease. Although more studies warranted finding the relationship between DSI and the severity of PD, it seems that with the increase in the severity of PD during different stages of the disease, the amount of DSI significantly increased. PD affects the voice of this patient and this information may be significant for voice professionals, and speech and language pathology to advise PD patients with voice complaints and manage them.

Ethical Considerations

Compliance with ethical guidelines

All participants had given their written consent to participate in the study, and the data collection procedure was approved by the Ethics Committee of Mashhad University of Medical Sciences (IR.MUMS.REC.1399.558.). All data generated or analyzed in this study are included in this article and or its supplementary material files. Further inquiries can be directed to the corresponding author.

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Authors' contributions

Designed the study and wrote the manuscript, performed the acoustic analysis, and made the research: Hamideh Ghaemi and Shamim Ghazi; Clinical assessments: Mohammad Taghi Farzadfard; Edited the manuscript: Hamed Ghaemi and Jamshid Jamali; Executed the statistical analysis: Jamshid Jamali.

Conflict of interest

The authors declare no conflict of interest.

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