https://doi.org/10.23925/2176-2724.2025v37i2e69771

Immediate vocal effect under phonatory effort and semi-occluded vocal tract with high resistance tube in patients with Parkinson's disease

Efeito vocal imediato sob esforço fonatório e trato vocal semiocluído com tubo de alta resistência em pacientes com Doença de Parkinson

Efecto vocal inmediato bajo esfuerzo fonatorio y tracto vocal semiocluido con tubo de alta resistencia en pacientes con enfermedad de Parkinson

Renata Serrano de Andrade Pinheiro[1]
Nelson Torro Alves[1]
Anna Alice de Figueirêdo Almeida[1]

Abstract

Introduction: Parkinson's disease (PD) is characterized by the presence of involuntary trembling movements, decreased muscle strength, and changes in gait, voice, and speech. **Objective:** to compare the immediate effect of phonatory effort exercises and semi-occluded vocal tract with a high-resistance tube on vocal parameters of patients with Parkinson's disease. **Methods:** 20 patients with PD, both sexes, 10 in the Semi-occluded Vocal Tract Exercise (SOVTE) group, and 10 in the Phonatory Effort Exercise (PEE) group. Voice was assessed in terms of perceptual parameters and acoustic analysis of the voice. Statistics were used to compare the groups and the moments before and after the exercise. **Results:** the

[1] Universidade Federal da Paraíba - UFPB, João Pessoa, PB, Brazil.

Authors´ contributions:
RSAP, AAFA: study design; data collection; and/or data analysis/interpretation; drafting or reviewing the manuscript; approval of the final version of the manuscript for publication; responsibility for the accuracy and integrity of all aspects of the research.
NTA: drafting or reviewing the manuscript; approval of the final version of the manuscript for publication; responsibility for the accuracy and integrity of all aspects of the research.

Email for correspondence: reserranoap@gmail.com
Received: 12/29/2024
Accepted: 05/13/2025

auditory-perceptual evaluation showed improvement after the exercise with gain in the immediate effect for the general degree and roughness in both groups; for breathiness and instability, there was a decrease in the gain after the exercise for the SOVTE and PEE groups. In the acoustic analysis, the gain after exercise showed a slight decrease in f0 for SOVTE, associated with decreased tension and adjustments in the vocal tract, and in the EPS there was an increase in f0, related to hyperactivity of the vocal fold tensor muscles. Intensity showed an increase for both groups, due to the increase in subglottic air pressure and improvement in vocal fold adduction. **Conclusion:** a similar benefit was recorded for vocal parameters analyzed both after EPS and SOVTE, in patients with PD.

Keywords: Parkinson's disease; Voice; Voice training; Speech acoustics; Dysphonia.

Resumo

Introdução: a Doença de Parkinson (DP) é caracterizada pela presença de movimentos tremulantes involuntários, diminuição da força muscular e alterações na marcha, voz e fala. **Objetivo:** comparar o efeito imediato de exercícios de esforço fonatório e trato vocal semiocluído com tubo de alta resistência em parâmetros vocais de pacientes com Doença de Parkinson. **Métodos:** 20 pacientes com DP, ambos os sexos, 10 no grupo de Exercício do Trato Vocal Semiocluído (ETVSO), e 10 no grupo com Exercício de Esforço Fonatório (EEF). Foi realizada a avaliação da voz nos aspectos de parâmetros perceptuais e análise acústica da voz. A estatística foi utilizada para comparar os grupos e os momentos pré e pós a execução do exercício. **Resultados:** a avaliação perceptivo-auditiva evidenciou melhora no pós exercício com ganho no efeito imediato para o grau geral e a rugosidade nos dois grupos; para a soprosidade e a instabilidade, houve diminuição do ganho pós exercício para os grupos ETVSO e EEF. Na análise acústica, o ganho no pós exercício mostrou uma discreta diminuição para o ETVSO no que se refere a f0, associado à diminuição da tensão e aos ajustes no trato vocal, e no EEF houve um aumento de f0, relacionado à hiperatividade da musculatura tensora das pregas vocais. Na intensidade mostrou-se aumento para ambos os grupos, devido à elevação da pressão aérea subglótica e a melhora da adução das pregas vocais. **Conclusão:** foi registrado benefício semelhante para parâmetros vocais analisados tanto após a realização de EEF quanto ETVSO, em pacientes com DP.

Palavras-chave: Doença de Parkinson; Voz; Treinamento vocal; Acústica da fala; Disfonia.

Resumen

Introducción: La enfermedad de Parkinson (EP) se caracteriza por la presencia de movimientos involuntarios de sacudidas, disminución de la fuerza muscular y alteraciones en la marcha, voz y habla. **Objetivo:** comparar el efecto inmediato de ejercicios de esfuerzo fonatorio y tracto vocal semiocluido con tubo de alta resistencia sobre los parámetros vocales de pacientes con enfermedad de Parkinson. **Métodos:** 20 pacientes con EP, de ambos sexos, 10 en el grupo de Ejercicio del Tracto Vocal Semiocluido (SOVTE) y 10 en el grupo de Ejercicio de Esfuerzo Fonatorio (PEE). La voz se evaluó en términos de parámetros perceptuales y análisis acústico de la voz. **Resultados:** la evaluación auditivo-perceptual mostró mejoría después del ejercicio con una ganancia en el efecto inmediato para el grado general y rugosidad en ambos grupos; En cuanto a la respiración y la inestabilidad, hubo una disminución en la ganancia posterior al ejercicio para los grupos SOVTE y EEF. En el análisis acústico, la ganancia post ejercicio mostró una ligera disminución para el SOVTE en relación a f0, asociada a la disminución de la tensión y ajustes en el tracto vocal, y en el EEF hubo un aumento de f0, relacionado a la hiperactividad de los músculos tensores de las cuerdas vocales. La intensidad aumentó en ambos grupos, debido a elevación de presión del aire subglótico y a mejora en la aducción de las cuerdas vocales. **Conclusión:** se registró un beneficio similar para parámetros vocales analizados tanto después de realizar EPS como SOVTE en pacientes con EP.

Palabras clave: Enfermedad de Parkinson; Voz; Entrenamiento vocal; Acústica del habla; Disfonía.

Introduction

Parkinson's disease (PD) is one of the most common degenerative diseases of the central nervous system, whose main characteristic is hypokinesia, a decrease in movement. The main symptoms include slow movements (bradykinesia), difficulty initiating voluntary motor activities (akinesia), increased muscle tone (rigidity) and tremors of the hands and jaw, which are more prominent at rest[1]. Although not as clinically relevant, non-motor symptoms can also occur as the disease progresses, such as depression, sleep disorders, cognitive changes and autonomic disorders[2].

The organic basis of PD is the degeneration of afferents from the substantia nigra to the striatum. These afferents use the neurotransmitter dopamine (DA), which facilitates the direct motor loop by activating cells in the putamen. DA depletion closes the funnel that feeds activity in the supplementary motor area via the basal ganglia and ventrolateral nucleus[1].

In the early stages of the disease, slight changes in voice quality and articulation may be observed, but they do not constitute limiting symptoms that impair oral communication. However, as PD progresses, voice production and articulation become compromised and oral communication may become significantly impaired[2].

In relation to the speech-language signs and/or symptoms of PD, changes in vocal quality are reported in the perceptive-auditory form: hoarse, breathy, rough, monotonous, tremulous, unstable, pasty voice; reduced loudness; low pitch; resonance changes, generally related to nasality; and acoustic changes: reduction in fundamental frequency (f0) and sound pressure levels (SP), increases in measurements related to turbulence, tremor, subharmonic components, vocal breaks, unvoiced segments, jitter, shimmer and harmonic-to-noise ratio. In addition to imprecision and slowness of articulation; respiratory dysfunctions characteristic of PD, such as respiratory muscle weakness, ventilation/perfusion restriction, and lack of coordination between lungs and speech and dysphagia in more advanced cases[3].

Currently, there are several methods and techniques for treating PD. In vocal rehabilitation, the literature shows level I evidence for the Lee Silverman Voice Treatment® (LSVT®) method, developed by Ramig et al.[4], which focuses on the laryngeal level for the treatment of voice and speech disorders in individuals with PD, based on phonatory effort, and can even improve the patient's swallowing.

Several aspects of the original LSVT® program are probably responsible for successful results, including the intensity and frequency of treatment. It has high-effort sessions, lasting 60 minutes, 4 times a week, for 4 weeks, with a sensory focus, recognizing the appropriate effort and sound intensity level; and motor training, with the use of greater effort and intensity[4,5].

However, those responsible for the LSVT® program, and other authors, have acknowledged that the treatment schedule may limit the number of speech-language pathologists who can provide treatment. Thus, the intense schedule may be limiting if individuals with PD depend on others to transport them to the treatment location[6].

Based on these difficulties, some authors[7] conducted a study adapting the LSVT® Method for group application, with the following sequence: 90-minute sessions, once a week, for 8 consecutive weeks, resulting in 720 minutes of therapy. Each week, participants received activities that should be performed daily. They demonstrated the use of the LSVT® method adapted to the group format, and after making some modifications, they concluded that it was effective, showing favorable changes in vocal behaviors. Thus, the adapted LSVT® method offers an alternative that is more accessible to patients, facilitating its application to a certain extent.

Among the phonatory competence methods are semi-occluded vocal tract exercises (SOVTE), with the objective of promoting primary muscle adjustment, through the adequate position of the vocal folds, and stretching corresponding to the voice frequency and sufficient glottal resistance to counteract the force of the pulmonary air column[8].

SOVTE are exercises with partial occlusion or widening of the vocal tract. They have been widely used in spoken and sung voice therapy with the aim of producing an increase in the input impedance of the vocal tract. This type of exercise is produced by constricting the anterior part of the oral cavity and lips. Some of these techniques include the use of occlusive consonants, fricatives, lip or tongue vibration, or phonation into resonance tubes with different diameters, lengths and resistance[9].

Phonation into tubes has been used in vocal therapy in Finland since the 1960s, with application

in both dysphonia and in people with normal voice, for vocal improvement. In the therapeutic context, these tubes have been applied in cases of functional dysphonia (hyper and hypofunctional), in paralysis of the recurrent laryngeal nerve and in patients with nodules, among other vocal pathologies. The physiological and acoustic effect produced by the tubes may vary depending on the width of the tube used[10].

There have been many advances in the field of voice studies and in the assessment and treatment of voice in the elderly. However, few studies express the real extent of the impairment of elderly individuals with PD, in terms of their vocal quality. Thus, it is important to demonstrate, in a more detailed manner, the effects of the contribution of vocal techniques, such as Phonatory Effort exercises, based on the concepts of the LSVT® Method, and SOVTE with high-resistance tube, for the acquisition of better vocal performance, in search of more effective communication in this population. The hypothesis is based on the premise that the execution of the SemiOccluded Vocal Tract Exercise (SOVTE) brings benefits to the vocal behavior of elderly individuals with Parkinson's Disease when compared to the effects of Phonatory Effort exercises (PEE).

The general objective of this study is to compare the immediate effect of phonatory effort exercises (PEE) and semioccluded vocal tract exercises (SOVTE) with high-resistance tube on the vocal parameters of patients with Parkinson's Disease.

Methods

This is an experimental study with repeated measures, fieldwork and a quantitative approach. The study was evaluated and authorized by the Research Ethics Committee of the Center for Health Sciences of a higher education institution, through protocol no. 800.329/2014. The patients read and signed the informed consent form.

The target population of this study came from the Integrated Health Care Center (CAIS) and the Speech Therapy School-Clinic of the Center for Health Sciences (CCS) of a higher education institution. It was formed by convenience, of patients with Parkinson's disease, of both sexes, treated at the reference locations mentioned above. The patients were randomly allocated into 2 groups: Group based on Phonatory Effort Exercises (EEF) and Group based on the execution of Semi occluded Vocal Tract Exercise (ETVSO) with a high resistance tube, both also submitted to Speech Therapy Guidance.

Some criteria were established for participation in this research, including: both genders; over 50 years of age; diagnosis of Parkinson's disease in stage 2 or 3 (Hoehn and Yahr, 1967); and no previous speech therapy for the voice. The exclusion criteria were: presenting other associated vocal alterations, or general health, cognitive and/or psychiatric conditions that limited the understanding or performance of the tasks to be performed.

A detailed anamnesis was performed with information on general health and medical reports, as well as the application of the Mini Mental Cognitive Screening Test (MMSE) to assess the cognitive aspects of the patients.

The demographic data of the patients were collected through an individual file consisting of: age, gender and education, in order to characterize the sample. The instruments used for data collection were described according to the multidimensional assessment of the voice; and the speech therapy evaluation involving auditory perception and acoustic parameters evaluated before and after the selected vocal exercise. The emission of the sustained vowel /ɛ/ was collected at maximum phonation time. The collections were performed before and after the application of the vocal exercise.

The research data collection was performed in a silent environment, using a unidirectional cardioid microphone, from Logitech, attached to a desktop from Samsung, through a Behringer audio interface, model U-Phoria UMC 204, using the VoxMetria software for acoustic voice analysis, from CTS Informática, and the open access software Praat (Version 5.3.84) for acoustic measurements of Cepstral Peak Prominence-Smoothed (CPPS). The sampling rate was 44,100 Hz, thus preserving most of the information of the vocal signal. Care was taken to maintain the same distance between the microphone and the corner of the mouth for all participants.

After the collection, the voices were edited using *Sony Sound Forge Pro* version 10.0 software. Normalization was performed using the *Sound Forge "normalize"* control, in *peak level mode*, in order to obtain a standardized audio output between -6 and 6 dB. The first and last two seconds of the vowel emission were eliminated, due to the greater

irregularity in these sections, in order to maintain a standardized three seconds for each emission.

The auditory-perceptual evaluation is considered the "*gold standard*" in speech-language assessment of the voice, as it allows the characterization of voice quality and quantification of the intensity of vocal deviation. It is subjective and depends on the experience and auditory training of the evaluator. Choosing a scale reduces subjectivity and directs this assessment.

The auditory perception assessment was performed by three speech-language pathologist judges with over 10 years of experience, after listening to the voices randomly paired in pairs (pre- and post-exercise vocal samples or post- and pre-exercise vocal samples) three times through a speaker, at a self-reported comfortable intensity. The task was to select the best voice of the pair and evaluate each sample separately, regardless of the previous judgment. A random repetition of 10% of the vocal samples was performed to analyze the reliability of the intra-judge evaluation.

It was decided to use the visual analog scale (VAS) for the auditory perception assessment of each vocal sample. The VAS consists of a 100mm horizontal line on which the evaluator marks the amount of perceptive sensation at the time. Each millimeter corresponds to an intensity of the deviation and, therefore, the scale offers 100 possible graduations. The cutoff points show the different intensities of vocal deviations: from zero to 35.5 points for normal variability of vocal quality; from 35.5 to 50.5, mild to moderate; from 50.6 to 90.5, moderate; and from 90.6 to 100, for intense deviations. In this study, the following parameters were used to evaluate: general degree (G), roughness (R), breathiness (S), tension (T) and instability (I), which are a worldwide consensus [11].

An acoustic analysis of the sound signal was also performed. Acoustic analysis is an evaluation that uses computerized programs and provides measurements related to the shape of the vocal tract, the vibration pattern of the vocal folds and changes in time 12. For the acoustic analysis, data were obtained on the Average f0 in Hertz (Hz), Variability of f0 in Hertz (Hz), Semitones, Average Intensity in decibel (dB), Jitter in percentage (%), Shimmer in percentage (%) and Harmonic Noise Ratio (HNR).

Patients in both groups underwent vocal guidance on the topic: general concepts and speech-language pathology symptoms in Parkinson's disease. The EEF group underwent techniques belonging to the LSVT® method. The research had the collaboration of a speech-language pathologist certified in the LSVT® Method and the participation of collaborators. The selected techniques can be seen in Chart 1: the emission of the vowel /a/ sustained at increased loudness and modulated effort; ascending and descending glissandos with increased effort and loudness; sustained vowel at high and low pitch; repetition of lists of monosyllabic and disyllabic words and phrases. The other group underwent a sequence of SOVT. For this, a rigid plastic straw, 8.7 centimeters long and 1.5 millimeters in diameter, was used. The individuals held one end of the straw with their lips and supported by the index finger and thumb of their preferred hand, observing the air coming out of the other end and emitting a breath associated with the emission of the prolonged sound of the vowel /u/. The exercises began with the performance in f0, for around three minutes, with an interval between repetitions, as described in Chart 1. The posture and phonatory effort applied in the technique were controlled by the researcher.

Chart 1. Description of the exercises applied to the groups.

ETVSO	EEF
General Concepts and Symptoms of Parkinson's Disease + **SOVTE in f0** 03 minutes of repetitions of the voiced blow with emission of the prolonged sound of the vowel /u/, in a high-resistance plastic straw, at Maximum Phonation Time (MPT), with an interval between repetitions.	**General Concepts and Symptoms of Parkinson's Disease +** **Phonatory Effort Exercise (PEE)** 10 minutes of exercises with 15 repetitions of the vowel /a/ sustained at increased loudness and modulated effort; ascending and descending glissandos with increased effort and loudness (x15); vowel sustained at high pitch (15x) and low pitch (15x); repetition of 20 identical phrases for the entire group. Finally, repetition of lists of monosyllabic and disyllabic words and phrases.

Caption: ETVSO – Semioccluded Vocal Tract Exercise; f0 – Fundamental Frequency; EEF – Phonatory Effort Exercise.

The description of the procedures was divided into three stages, as follows: in the first, pre-intervention data collection was performed with a sample of the sustained vowel /ɛ/, for subsequent auditory and acoustic vocal perceptual analysis. In the second phase, the intervention consisted of the application of SOVT or EPS to the voice of patients with Parkinson's disease. The sample was randomly divided into two groups: the experimental group, composed of a group of elderly individuals with Parkinson's disease who underwent vocal guidance and intervention through Semioccluded Vocal Tract Exercises (SOVT) with a high-resistance tube; and the positive control group, composed of a group of elderly individuals with Parkinson's disease who underwent vocal guidance and intervention through Phonatory Effort Exercises (PEE). The PD group with EPS had the techniques recommended by the LSVT® Method applied, as it presents scientific evidence in the vocal rehabilitation of patients with Parkinson's disease. In the third phase of the research, the post-intervention collection, a re-evaluation was carried out with the collection of the sample of the sustained vowel /ɛ/ to carry out a new auditory and acoustic perceptive analysis of the voice after performing the vocal techniques.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software, version 21.0. The nonparametric Mann-Whitney U test was used to compare the central tendencies of two independent samples of equal size. The Wilcoxon test for paired samples was used to compare the auditory-perceptual assessment of the judges before and after the exercise of each group. Cronbach's alpha coefficient was used to estimate the reliability of the auditory-perceptual assessment, by the VAS, measuring the correlation between the judges' responses. The significance level established was a p-value less than or equal to 0.05.

Results

This study included a population of 20 patients, divided into groups of 10 patients who underwent SOVT and 10 EPS, of both sexes, affected by Parkinson's disease, with a mean age of 65.7 (±9.0) for SOVT and 63.8 (±6.25) for EPS, with a predominance of complete high school education (3 patients, 30%) for SOVT and complete higher education (4 patients, 40%) for EPS; as described in Table 1 below.

Table 1. Description of demographic data of patients with Parkinson's Disease according to groups.

VARIABLES	ETVSO		EEF	
	N	%	N	%
Sex				
Female	4	40	7	70
Male	6	60	3	30
Education				
Illiterate	1	10	0	0
Incomplete Elementary	1	10	1	10
Complete Elementary	1	10	2	20
Incomplete Middle School	2	20	0	0
Complete Middle School	3	30	3	30
Incomplete Higher Education	1	10	0	0
Complete Higher Education	1	10	4	40

Caption: ETVSO – Semioccluded Vocal Tract Exercise; EEF – Phonatory Effort Exercise.

Table 2 describes the means, standard deviation and difference in the immediate effect (DIF) of the variables evaluated in the Acoustic Analysis: fundamental frequency (f0), Jitter, Shimmer, Harmonic Noise Ratio (HNR), f0 Variability, Semitone and Intensity, pre and post exercise in the SOVT and EEF groups.

Table 2. Description of means, standard deviation and difference of immediate effect (DIF) of the Acoustic Analysis: Fundamental Frequency (f0), Jitter, Shimmer, Harmonic Noise Ratio (HNR), Semitone and Intensity, pre and post exercise in the SOVT and EEF groups.

VARIABLES	ETVSO		p-value Intragroup	DIF	EEF		p-value Intragroup	DIF	p-value Intergroup POST
	PRE	POST			PRE	POST			
f0	147.5±50.8	146.9±47.1	0.384	-0.5±14.8	176.1±51.1	180.2±44.5	0.553	4.1±21.1	0.112
Jitter	1.6±3.2	0.4±0.3	0.909	-1.3±3.3	0.8±1.1	0.4±0.6	0.144	-0.5±0.9	0.943
Shimmer	9.6±6.8	7.8±5.1	0.244	-1.8±3.2	8.2±3.8	5.9±2.3	0.100	-2.3±3.9	0.300
PHR	0.7±0.2	0.8±0.1	0.113	0.1±0.1	0.9±0.1*	0.9±0.1†	0.343	0.0±0.1	0.130
Semitone	3.7±4.0	3.3±3.9	0.343	-0.4±1.3	3.3±3.9	4.8±5.1	0.224	1.5±3.6	0.470
Intensity	81.8±4.5	82.9±1.5	0.497	1.0±4.6	83.3±2.2	84.2±2.3	0.300	1.0±2.8	0.137

Legend: F0 = Fundamental Frequency; PHR = Harmonic Noise Ratio; SOVT- Semi-occluded Vocal Tract; DIF = difference in immediate effect; EEF- Phonatory Effort Exercise
* Intergroup difference Pre vs Pre
† = Intergroup difference Post vs Post.
Wilcoxon test; Kruskal Wallis test
Significance level = p<0.05

When comparing the acoustic measurements within the groups, it was observed that there was no statistically significant difference between the pre and post exercise moments in any of the groups studied. In addition, it was also observed that in the post exercise moment, the groups presented similar acoustic measurements.

When performing the acoustic analysis of the Cepstral Measurements of the voices of the participants in the SOVTE and EEF groups, the means, standard deviation, difference in immediate effect (DIF) and p-value of the CPPS Cepstral Measurements were described, in the pre and post exercise of the SOVTE and EEF groups, as can be seen in Table 3 below.

Table 3. Description of means, standard deviation, difference in immediate effect (DIF) and p-value of Cepstral Measures (CPPS), pre and post exercise in the ETVSO and EEF groups.

VARIABLES	ETVSO		EEF		p-value
	Average	Standard Deviation	Average	Standard Deviation	
CEPSTRAL MEASURES (CPPS) PRE	13.76	3.69	15.96	3.49	0.189
CEPSTRAL MEASURES (CPPS) POST	14.61	1.46	17.32	2.56	0.012*
p-value	0.384		0.132		
DIFFERENCE	0.85	2.05	1.36	0.93	0.554

LEGEND: ETVSO- Semi-Occluded Vocal Tract; EEF- Phonatory Effort Exercise; Student's t-test for independent and paired samples; significance *p<0.05.

It was observed that the groups presented similar cepstral measurements (CPPS) in the pre moment, however, after the application of the methods, the values of the measurements presented differences between the groups (p=0.012), being higher in the EEF group than in the SOVTE. In addition, when comparing the values of the intragroup cepstral measurements, it was observed that there was no significant difference in any of the groups, SOVTE (p=0.384) and EEF (p=0.132).

Table 4 describes the means, standard deviations and DIF of the variables assessed in the Auditory Perceptual Assessment performed by three judges using VAS: general degree (G), roughness (R), breathiness (S), tension (T) and instability (I), before and after exercise in the SOVT and EEP groups.

Table 4. Description of means, standard deviation, difference in immediate effect (DIF) and Cronbach's α for voice judges in the VAS variables: general degree (G), roughness (R), breathiness (S), tension (T) and instability (I), pre and post exercise in the SOVT and EEF groups.

Variables	ETVSO		p-value Intragroup	DIF	EEF		p-value Intragroup	DIF	p-value Intergroup PRE	p-value Intergroup POST
	PRE	POST			PRE	POST				
Overall Gradel(G)	50.8±8.1	47.7±11.1	0.207	-3.2±7.4	47.6±6.6	40.1±7.8 [a]	0.036*	-7.5±9.6	0.342	0.095
Roughness(R)	41.4±14.0	39.1±14.4	0.349	-2.3±7.3	32.7±18.8	22.7±18.6	0.055	-10.0±14.3	0.256	0.041*
Breathiness(S)	36.4±10.7	30.5±13.3	0.164	-5.8±12.1	24.9±13.4	15.2±12.5 [a]	0.025*	-9.7±11.4	0.049	0.079
Tension(T)	6.1±12.2	11.4±14.0	0.448	5.2±20.9	7.2±11.0	14.7±10.9	0.125	7.5±14.0	0.835	0.557
Instability(I)	50.9±8.5	40.3±16.1 [a]	0.046*	-10.6±14.5	40.7±14.5	34.1±15.3	0.155	-6.6±13.4	0.070	0.389

Legend: VAS = Visual Analog Scale ;G = Overall Grade; R = Roughness; S = Breathiness; T = Tension; I = Instability; SOVT - Semi-occluded Vocal Tract Exercise; EEF - Phonatory Effort Exercise; DIF = difference in immediate effect Cronbach's; α = Cronbach's Alpha the intragroup difference PRE versus POST (Wilcoxon)
* Cronbach's Alpha (Internal Consistency)
Very good - alpha greater than 0.9
Good - alpha between 0.8 and 0.9
Reasonable - alpha between 0.7 and 0.8
Weak - alpha between 0.6 and 0.7
Significance level - p<0.05

When comparing the intragroup VAS parameters before and after exercise, it was observed that in the SOVT group with high resistance tube the instability parameter presented a statistically significant difference (p=0.046), with reduced values in the post-exercise moment, in relation to the pre-moment. And in the EEP group, a significant reduction was observed in the measures of general degree (p=0.036) and breathiness (p=0.025) when the moments were observed. In the intergroup comparison, it was observed that the roughness parameter was the only one that presented a difference between the SOVTE and EEF groups, at the post-therapy moment (p=0.041). The Cronbach's Alpha test was used to measure the correlation between the responses of the three judges who evaluated the voices to assess the reliability of their judgments.

In view of the above, the Cronbach's Alpha test showed a good correlation between the judges for the variables general degree, roughness, breathiness and intensity, with acceptable values of internal consistency, which varied, in the vast majority,

from 0.7 to 0.9. However, the tension parameter presented lower reliability.

Discussion

Vocal production is complex and can be affected by several circumstances, one of which is Parkinson's disease, which can cause disharmony in the voice production process and, consequently, in communication. It is estimated that by 2025, approximately 40 million people worldwide will be diagnosed with PD, affecting 1% of the population over 50 years of age. Patients with PD generally present the following vocal characteristics: reduced vocal intensity, monopitch, hoarseness, breathiness and vocal tremor[13].

Currently, there are several scientific studies that study the changes in these vocal characteristics in the population affected by PD, using different types of therapeutic techniques[14-18], however, this study compares two exercises in the voice area: the EEF, which belongs to the LSVT® method [2,4-,7], and the ETVSO [3,8-10,22-30].

Regarding the acoustic parameters of the voice, this study found a decrease in f0 for the SOVTE group, which corroborates research carried out on the immediate effect of SOVTE[24], which showed a reduction in f0 (pre = 197.59 ± 19.68 post = 192.07 ± 20.01) when comparing SOVTE with the finger kazzoo. The reduction in f0 was associated with a decrease in tension, adjustments in the vocal tract and reactance, a component of impedance that allows the storage of acoustic energy. In another study[25], the effects of constriction, vocal tract elongation and acoustic impedance were investigated in seven computerized vocal tract configurations, also showing greater impedance and a decrease in f0 when phonating with a straw.

However, for the EEF group, there was an increase in the mean value of f0, presenting a similar result in the research carried out using the LSVT® adapted for group[7] (f0 max - pre = 238 Hz / post = 281 Hz and f0 min - pre = 129 Hz / post = 148 Hz). Another study[2] of the LSVT® method, with 28 individuals, 21 male and 7 female participants, diagnosed with PD and aged between 61 and 78 years, also showed an increase in f0 for both sexes, in men from 146.3 ± 6.76 to 193.4 ± 13.58, and in women from 157.3 ± 11.85 to 195.7 ± 12.30. This increase in f0 must be related to the hyperactivity of the tensor muscles of the vocal folds.

The values of the jitter and shimmer parameters in this study decreased in both groups, that is, both the immediate effect of ETVSO and EEF showed an improvement in vocal quality related to these parameters. In another study using ETVSO9, there was also a reduction in these values when comparing before and after the exercise, with jitter values (pre=0.75±1.33 and post=0.33±0.15) and shimmer (pre=4.76±4.66 and post=2.90±1.32), indicating that the sequence of exercises applied had a positive effect on the vibratory characteristics of the vocal folds.

The harmonic noise ratio (HNR) values showed a small increase in both groups, and when comparing the moments, it was significant. Another study on the immediate effect of ETVSO9 also showed an increase from HNR=19.39±4.61 to HNR=22.67±4.18. This result reveals that ETVSO improves the degree of adduction of the vocal folds during phonation, increasing the amount of harmonics and reducing the noise component, which can generate the sensation of a more projected voice.

Regarding the semitone, a decrease in its values was observed in the SOVTE group and an increase in the EEF group. The evaluation of this parameter was found in a study comparing the immediate effect of phonation with straws and finger kazoo[24], also showing a decrease in the semitone for phonation with straws (pre=6.15±1.80 and post=5.80±2.03), also without statistical significance. Generally, in neurological vocal disorders, where there is instability in the vibration of the vocal folds, there is an increase in the number of semitones, due to the great variability of f0[10]. SOVTE proved to be effective in reducing these values.

Vocal intensity increased in the difference of the immediate effect of the exercise in both the SOVTE group and the EEF group. Other studies[2,7] of the LSVT® also corroborate these findings, such as the one adapted for groups[7], with the application of a sequence of exercises, in a 90-minute weekly meeting, for eight weeks, which showed an increase in vocal intensity after treatment, from 65.22 dB to 70.91 dB. Another study carried out with 28 individuals (21 men and 7 women), diagnosed with PD, and using the LSVT®[2] also recorded an increase in vocal intensity after treatment (pre=65±3.8 dB and post=85±2.8 dB), presenting a statistically significant difference.

The physiological effect that justifies the increase in vocal intensity is the elevation of subglottic air pressure and the improvement of vocal fold adduction[2]. For this reason, although in the studies of the SOVT analyzed, vocal intensity was not considered a parameter of choice for evaluation, in this research similar values of gain in the difference of the immediate effect of the exercise were recorded when comparing the groups, although without statistical difference. This is a relevant factor for SOVTE to be applied to this population, since loss of vocal intensity is one of the main complaints of patients with PD.

The acoustic voice signal produced at the glottic source may present periodic or aperiodic characteristics, analyzing time-based measures (jitter and shimmer), which measure the deviation from the frequency and intensity limit. This signal can also be analyzed by frequency-based measures, that is, cepstral peak prominence (CPP)[20]. Cepstral Peak Prominence-Smoothed (CPPS) is a modification to the CPP algorithm that favors an improvement in the accuracy of the analysis of altered voices, with the smoothing of the cepstrum before extracting the cepstral peak.

When glottal closure does not occur efficiently or occurs very slowly, it causes a turbulent and irregular airflow, which reduces the energy of high harmonics. Thus, when there is an increase in glottal closure, there is a decrease in the spectral slope and an increase in vocal projection[20].

Other studies analyzed CPPS and observed that in the evaluation of the intensity of vocal deviation, cepstral acoustic measurements were strong indicators of the presence and intensity of vocal deviation, in addition to contributing to the differentiation of types of vocal deviation. Cepstral measurements provide estimates of aperiodicity and/or additive noise, without needing to identify limits of individual cycles[19]. In a study comparing two types of intensive treatment (voice and articulation), acoustic and neural changes were evaluated in 19 individuals with PD, randomized into three groups (voice treatment, articulation treatment, and no treatment). The groups showed significant improvement in CPPS measurements after voice treatment, which remained for another seven months after reassessment, together with results of increased cerebral blood flow (CBF) in the left premotor cortex and bilateral auditory cortex after voice treatment and at seven months of follow-up[21].

In this study, the classification performed by the judges in the auditory perception assessment regarding the best voice, according to the SOVTE and EEF groups, in the pre- and post-exercise moments, showed a higher percentage of intra-judge agreement considering better values for vocal parameters after the application of the exercises, confirming the positive immediate effects for both groups.

Some studies[23,24] with immediate effect of SOVTE, also used this classification to judge the auditory perception assessment. Although they were not applied to the PD population, it can be used as a parameter for normal voices, or with other alterations.

In the comparative study between the finger kazoo and phonation in tubes[24], carried out with 23 speech therapists, aged between 23 and 40 years, without vocal complaints, there was a similarity in the judgment of the best voice for phonation in tubes, with 41.3% considering the pre as better, 47.8% considering the post as better and 10.9% considering them equal. For the finger kazoo exercise, 39.1% had a better voice before the exercise, 37.0% had a better voice after the exercise, and 23.9% considered them equal.

In another study[23], 48 individuals of both genders were evaluated, 40 women and 8 men; with ages ranging from 18 to 55 years; divided into two groups: 23 in the group with laryngeal injury and 25 in the group without laryngeal injury. In the group with laryngeal injury, 26.09% had an easier voice, 21.74% had a better voice, 34.78% had an easier and better voice, and 17.39% had no difference. And in the group without laryngeal injury, 28.00% had an easier voice, 8.00% had a better voice, 8.00% had an easier and better voice, and 56.00% had no difference.

In this study, the auditory perception assessment performed by three judges using VAS showed a decrease in the values in the difference between the pre- and post-time points, in the immediate effect of the exercise, for the SOVT and EEF groups in the following variables: general degree (G), roughness (R), breathiness (S) and instability (I); and an increase in tension values (T), according to the comparison of the difference in the immediate effect before and after for the two groups.

Some authors[2] agree with the data found in this study, when using LSVT®, they observed some data that were recorded in the auditory perception

assessment: no patient presented voice without alteration, most patients presented both roughness (91%) and breathiness (72%) and 40% of the patients presented only one of the two alterations. Roughness was mild to moderate and breathiness was moderate to intense.

In another study[27], in which LSVT® was applied, the auditory perception analysis of the voice was performed using the Japanese GRBASI scale. The ten patients with PD presented changes in the global degree of dysphonia (G) and instability (I); all the voices analyzed were evaluated with roughness (R) and had a reduction in the degree of change in nine patients after therapy; six patients decreased the degree of breathiness (S), resulting from the improvement in glottal closure and the increase in vocal intensity; and only three patients with PD presented asthenia (A), vocal weakness, remaining without this change after therapy. Finally, regarding tension (S), there was an increase in the degree of deviation with speech therapy in eight of the voices analyzed.

Studies conducted using ETVSO[9,10,22] show the positive effects of exercises on vocal parameters. ETVSO[9,10] has an immediate therapeutic physiological effect, observed in acoustic analysis and auditory perception assessment, with the improvement and ease in voice production obtained after exercise, due to the change in the vibration pattern of the vocal folds due to greater source-filter interaction, with the use of resonance tubes.

Another study applied ETVSO[22] to 23 healthy subjects (6 men and 10 women), analyzed electroglottography (EGG) signals with the Laryngo Graph system and performed acoustic analysis observing the difference between formants (f1 – f0). Vocal production became clearer, brighter and more sonorous, due to an effective reinforcement of vocal fold vibration, since there is a phase alignment of supraglottic acoustic pressures by the resonance of the vocal tract. A lowering of the first formant is observed, bringing it closer to the fundamental frequency and increasing the inertial reactance of the vocal tract, producing a more efficient vocal fold vibration pattern.

Recently, other authors[27-30] confirmed the results of these findings when using phonation in tubes through SOVTE. One study[27] used phonation with tubes for patients with dysphonia in a clinical setting, with significant improvement in voice quality, perceived by changes in phonation time, better jitter values, auditory perception and reduction in voice roughness. In the application of SOVTE in PD, it was observed by researchers[28] that the use of the exercise with a glass resonance tube immersed in water caused a significant improvement in vocal intensity and quality, in addition to reducing vocal symptoms and increasing voice-related quality of life.

In another study[29], authors reported its use in the elderly population in order to minimize the effects of aging on the characteristics and symptoms of Presbyphonia, that is, on age-related voice changes, the most commonly reported being: breathiness, roughness, reduced amplitude and altered fundamental frequency. Thirty-seven elderly individuals with self-perception of vocal changes were divided into two groups: an experimental group, subjected to six weekly sessions and home practice of SOVTE immersed in water, and a control group, with education on vocal hygiene. Analysis of acoustic and auditory-perceptual parameters was performed, as well as self-assessment of vocal changes before and after the intervention. The results of this study showed a reduction in phonatory or vocal effort through the use of straw phonation, inducing a positive change in functional, physical and emotional aspects of voice-related quality of life in older adults.

Finally, researchers[30] conducted a randomized clinical trial with the application of SOVTE with straw phonation combined with therapeutic singing in a group (CTG) with the aim of exploring the efficacy of this exercise on voice quality and mood in individuals with PD. Participants (n = 27) were randomly assigned to one of three groups (a) straw phonation combined with CTG (n = 10); (b) CTG only (n = 10); and (c) speech-only control group (n = 7). They performed voice recordings for acoustic measurements and responded to the Visual Analogue Mood Scale for mood analysis before and after a 30-minute intervention. The results demonstrated significant improvement in voice quality, which was evidenced by the decrease in Acoustic Voice Quality Index scores after a single session for SOVTE + CTG and CTG intervention when compared to the control group. Happiness scores improved in the experimental groups when compared to the control. The experimental groups (ETVSO + CTG, CTG) demonstrated better mean mood scores in happiness, anxiety and anger when

compared to the control group, indicating a positive psychological response to singing interventions. The authors concluded that these resources were effective and showed promise for voice quality and mood in individuals with PD.

The scientific production in the area of voice that addresses Parkinson's Disease requires the expansion of research that highlights new options for methods and techniques of treatment for the voice of patients affected by this disease, in order to promote the prevention and treatment of the effects of the disease on their communication, aiming at better expressiveness, longevity in voice quality and promotion of vocal health.

To confirm the efficiency of the application of ETVSO in the PD population with greater accuracy and veracity, it is necessary to conduct randomized clinical trials to observe the effects found through longer treatment interventions and to verify the preservation of the gains obtained by performing the exercises over time through *follow-up* of the results.

Conclusion

There was a similarity when comparing the immediate effect of the application of the Semi Occluded Vocal Tract Exercise (using a high-resistance tube) with the Phonatory Effort Exercise, analyzed in terms of the vocal parameters observed in acoustic and auditory-perceptual analysis, when applied to patients with PD. Thus, the use of SOVTE with a high-resistance tube may constitute another resource in the care of patients with PD, aiming at improving their quality of life and vocal health.

Acknowledgments

To the professors and professionals who collaborated with discussions about the research and participated with scientific contributions.

References

1. Lent R. Cem bilhões de neurônios: conceitos fundamentais de neurociências. São Paulo: Editora Atheneu, 2005.

2. Dias AE, Limongi JCP. Tratamento dos distúrbios da voz na doença de Parkinson: O método Lee Silverman. Revista Arquivos de Neuropsiquiatria; 61(1): 61-66. 2003.

3. Cielo CA, Lima JPM, Christmann MK, Brum R. Evidência Científica sobre Exercícios de Trato Vocal Semiocluído – Revisão de Literatura. In: Terapia Fonoaudiológica Baseada em Evidências. Vol.1. Ed. Barueri, SP: Pró-Fono, 2013.

4. Ramig L, Sapir S, Fox C, & Countryman S. Changes in vocal loudness following intensive voice treatment (LSVT) in individuals with Parkinson's disease: A comparison with untreated patients and normal aged-matched controls. Movement Disorders, 16, 79–83. 2001.

5. Fox C, Ramig L, Ciucci M, Sapir S, Mcfarland D, & Farley B. The science and practice of LSVT/LOUD: Neural plasticity-principled approach to treating individuals with Parkinson disease and other neurological disorders. Seminars in Speech and Language. 27, 283–299. 2006.

6. Spielman J, Ramig L, Mahler L, Halpern A, & Gavin W. Effects of an extended version of the Lee Silverman Voice Treatment on voice and speech in Parkinson's disease. American Journal of Speech-Language Pathology, 16, 95–107. 2007.

7. Searl J, Wilson K, Haring K, Dietsch A, Lyons K, Pahwa R. Feasibility of group voice therapy for individuals with Parkinson's disease. Journal of Communication Disorders. 44. 719–732. 2011.

8. Maia MEO, Maia MO, Gama ACC, Behlau M. Efeitos imediatos do exercício vocal sopro e som agudo. Jornal da Sociedade Brasileira de Fonoaudiologia. 24(1):1-6. 2012.

9. Guzman M, Higueras D, Fincheira C, Munoz D, Guajardo, C. Efectos acústicos inmediatos de una secuencia de ejercicios vocales con tubos de resonancia. Revista CEFAC. Mai-Jun; 14(3): 471-480. 2012.

10. Guzman M, Higueras D , Fincheira C. , Munoz D. , Guajardo C. & Dowdall J. Immediate acoustic effects of straw phonation exercises in subjects with dysphonic voices. Logopedics Phoniatrics Vocology, 38: 35–45, 2013.

11. Yamasaki R, Leão SHS, Madazio G, Padovani M, Azevedo R. Análise perceptivo-auditiva de vozes normais e alteradas: Escala analógica visual. XV Congresso Brasileiro de Fonoaudiologia e VII Congresso Internacional de Fonoaudiologia; out 16-20; Gramado. 2007.

12. Ferreira FV, Cielo CA, Trevisan MH. Medidas Vocais Acústicas Na Doença De Parkinson: Estudo De Casos. Revista CEFAC. Set-Out; 12(5): 889-898. 2010.

13. Bear M, Connors B, Paradiso, M. Neurociências: desvendando o Sistema Nervoso. 3. Ed. Porto Alegre: Artmed, 2008.

14. Quedas A, Duprat AC, Gasparini G. Implicações do efeito Lombard sobre a intensidade, frequência fundamental e estabilidade da voz de indivíduos com doença de Parkinson. Revista Brasileira de Otorrinolaringologia.73(5): 675-83.2007.

15. Coutinho SB, Diaféria G, Oliveira G, Behlau M. Voz e fala de Parkinsonianos durante situações de amplificação, atraso e mascaramento. Pró-Fono Revista de Atualização Científica. jul-set; 21(3): 219-24. 2009.

16. Azevedo L, Cardoso F, Reis C. Análise acústica da prosódia em mulheres com Doença de Parkinson - Efeito da Levodopa. Revista Arquivos de Neuropsiquiatria.61(4): 995-998. 2003.

17. Rosa JC, Cielo CA, Cechella C. Função Fonatória em Pacientes com Doença de Parkinson: Uso de Instrumento de Sopro. Revista CEFAC. Abr-Jun; 11(2): 305-313. 2009.

18. Olszewski AE, Shen L, Jiang J. Métodos objetivos de seleção de amostras na análise acústica da voz. Otol. Rinol. Laringol. 120, 155-161. 2011.

19. Lopes LW, Sousa ESDS, Da Silva ACF, Da Silva IM, De Paiva MAA, Vieira VJD, De Almeida AA. Medidas cepstrais na avaliação da intensidade do desvio vocal. CoDAS, 31. 2019.

20. Sujitha SP, Pebbili GK. Cepstral Analysis of Voice in Young Adults. J Voice. 2022 Jan; 36(1): 43-49. doi: 10.1016/j.jvoice.2020.03.010. Epub Apr 24. PMID: 32336570. 2020.

21. Narayana S, Franklin C, Peterson E, Hunter EJ, Robin DA, Halpern A, Spielman J, Fox PT & Ramig LO. Immediate and long-term effects of speech treatment targets and intensive dosage on Parkinson's disease dysphonia and the speech motor network: Randomized controlled trial. Human Brain Mapping, 43(7), 2328–2347. 2022.

22. Vampola T, Laukkanen AM, Horacek J, Svec JG. Vocal tract changes caused by phonation into a tube: A case study using computer tomography and finite-element modeling. Journal Acoustic. Soc. Am. 129 (1), January. 2011.

23. Costa CB, Costa LHC, Oliveira G, Behlau M. Immediate effects of the phonation into a straw exercise. Brazilian Journal Otorhinolaryngology. 77(4): 461-5. 2011.

24. Sampaio M, Oliveira G, Behlau M. Investigação de efeitos imediatos de dois exercícios de trato vocal semi-ocluído. Pró-Fono Revista de Atualização Científica. 2008.

25. Andrade PA, Wood G, Ratcliffe P, Epstein R, Pijper A, Svec JG.Electroglottographic Study of Seven Semi-Occluded Exercises: LaxVox, Straw, Lip-Trill, Tongue-Trill, Humming, Hand-Over-Mouth, and Tongue-Trill Combined With Hand-Over-Mouth. Journal of Voice, 592 Vol. 28, No. 5, 2014.

26. Vicco DC, Santo SMA, Gonçalves LHT. Análise acústica e perceptivo-auditiva da voz em pacientes parkinsonianos pré e pós-terapia fonoaudiológica. Cienc Cuid Saude 2009 Jul/Set; 8(3): 313-320.

27. Meerschman, I., Lierde, K., Ketels, J., Coppieters, C., Claeys, S., & D'haeseleer, E. Efeito de três programas de terapia do trato vocal semi-ocluído na fonação de pacientes com disfonia: Lip Trill, terapia de resistência à água e Straw Phonation. International Journal of Language & Communication Disorders, 54(1), 50–61. 2018.

28. Dos Santos, AP, Troche, MS, Berretin-Felix, G., Barbieri, FA, Brasolotto, AG, & Silverio, KC. Efeitos da terapia vocal com tubo de ressonância na doença de Parkinson: ensaio clínico. Journal of Voice: Official Journal of the Voice Foundation, S0892-1997(22)00126-6. 2022.

29. Wu, C.-H., & Chan, RW. Efeitos de um programa de exercícios de fonação com canudo na água por 6 semanas no envelhecimento da voz. Journal of Speech, Language, and Hearing Research: JSLHR, 63(4), 1018–1032. 2020.

30. Sun Joo Lee, Abbey L Dvorak, Jeremy N Manternach, Therapeutic Singing and Semi-Occluded Vocal Tract Exercises for Individuals with Parkinson's Disease: A Randomized Controlled Trial of a Single Session Intervention, Journal of Music Therapy, Volume 61, Issue 2, Pages 132–167. 2024.