A comparison of vowel production after two speech therapy approaches

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ABSTRACT

The purpose of this study was to compare the impact of a speech therapy program based on oral/laryngeal motor exercises versus a combined approach with respiratory and oral/laryngeal motor exercises, on vowel production. Two groups constituted by eight male subjects diagnosed with Parkinson's disease were randomly assigned to one of the treatment groups: oral and laryngeal exercises or respiratory plus oral and laryngeal exercises. Both treatment approaches were applied throughout one month, five sessions per week. The data consisted of words, containing seven Brazilian Portuguese vowels, embedded on a carrier phase. Analyses were performed on the following parameters: (a) Formant Centralization Rate (FCR); (b) Triangular Vowel Area; (c) Vowel Working Space Area and (d) F1 and F2 values. Pre and post-treatment comparisons showed statistical significance on FCR and vowel area only for respiratory plus oral and laryngeal exercises. The effort needed to execute respiratory maneuvers may contribute on jaw and tongue movements amplitude and motor coordination, impacting positively on articulatory vowel working space.

Keywords: vowel production, speech therapy , dysarthria, Parkinson's disease

INTRODUCTION

It is well documented that individual's with Parkinson's disease (PD) have speech and swallowing disturbances [1,2,3,4]. Motors symptoms can affect respiratory, phonatory, resonance and articulatory systems [2,3,4]. Imprecise articulation has been described as an important feature of hypokinetic dysarthria [1, 2,3,4,5]. For decades, analysis of vowel production has been used to access the motor performance, control of speech and intelligibility [6,7,8,9,10]. Vowel space area is a metric used to quantify vowel articulatory space. This metric can be applied to all vowels, resulting in polygon area [7,9,11,12] or considering only the extreme articulatory vowels /a, i, u/, in that case, referred as triangular area [13,14,15].

The compression of vowel space area in subjects with PD is pointed in many studies [15,16,17,18,19] but some of them have not statistically proven the phenomenon through a comparison with a control group of subjects without neurological disorders [18,19]. For this reason, some critiques have been made on the use of static metrics based on mean values [11,14,20,21]. Sapir (2010) proposed a centralization metric, Formant Centralization Rate (FCR), arguing that measurement could be more sensitive to examine the vowel space area. FCR is a ratio that reflects compression of vowel working area. The value around zero expresses no compression [20].

There is no strong evidence that pharmacological or surgical treatments have a positive impact on speech, respiratory or swallowing functions for subjects with PD [22]. The speech therapy approach remains the best way to improve those demands. Many speech therapy approaches have been designed to address the speech functions. Remarkably Lee Silverman Voice Treatment (LSVT) has been proved effective to improve parkinsonian speech communication [15,22]. Some methods have been designed specifically to address swallowing functions. These methods are based on oral exercises to improve movements and control of the oral phase of swallowing associated with maneuvers to improve the protection of the larynx's mechanisms [23]. On the same direction, respiratory

training has been proposed to improve the respiratory function [24, 25] and the mechanism of larynx's protection [24]. Despite the main purpose of these approaches is addressed to swallow or respiratory function, it is reasonable to suppose some improvement in speech, after all, the same organs play a role on speech. In fact, some studies show a positive impact of respiratory training on speech and voice functions [24], while the speech approach pointed improvement on swallow function [26].

Based on these premises the main objective of this study was to investigate the impact of non-speech related exercises, driven by two different therapeutic approaches on vowel production.

Our hypotheses were:

(i) Oral and laryngeal motor exercises could increase movement amplitude of the tongue and jaw, and increase working vowel space.

(ii) The combination of oral, laryngeal and respiratory exercises could increase working vowel space.

2. METHODS

The present study investigated the impact of two different therapeutic approaches on production of vowels in subjects with PD. It was a blind randomized clinical trial, registered on www.ensaiosclinicos.gov.br plataform.

2.1. Clinical trial

Eighteen male subjects, diagnosed with Idiopathic Parkinson's Disease, with dysarthria and swallowing complaints participated in this study. They were randomly assigned to join one of the therapeutic groups. The main purpose of both therapeutic approaches was to address the subject's swallowing complaints. The following approaches were offered: (i) Oral and laryngeal exercises (Group **A**) and (ii) Oral and laryngeal exercises plus expiratory muscle strength training (Group **B**).

All therapeutic sessions were carried out during one month, five sessions per week. The oral and laryngeal exercises were applied by a speech therapist and the expiratory muscle strength treatment (EMST) by a physiotherapist. All professionals were trained and followed the same exercise protocol for each treatment group. Patients should practice the assigned exercises at home. All participants in each group received the same instructions and followed the same exercise protocol [27].

2.2. Speech Data

2.2.1. Recording Data

Speech stimuli were recorded as part of a larger investigation and obtained during one session of approximately thirty minutes long. Participants were fitted with a head-mounted microphone, seated in a sound-attenuating booth and instructed to repeat a target word embedded on a carrier phrase. Recordings were made using software Audacity [28], M-audio fast track audio recording interface (sampling rate = 44.1 kHz) and files were saved directly to a computer. The participants were asked to speak thirty-five sentences, containing seven vowels of Brazilian Portuguese (BP) (/i/, /e/, /ɛ/, /a, /ɔ/, /o/, /u/). For each vowel, there was one target word, which was repeated five times. All target words were disyllabic and the target vowel was on strong position.

Table 1: Show the words that composed the corpus

/i/	/piʃo/
/e/	/pezo/
/ɛ/	/pɛso/
/a/	/paso/
/ɔ/	/pɔso/
/o/	/poʃa/
/u/	/puʃo/

2.2.2. Data analysis

Acoustic analysis was carried out on Praat software [29]. The first two formants - F1 and F2 - were extracted from vowel midpoint. For every vowel, the average formant values of F1 and F2 were calculated based on the five separate measurements. These average values were transformed into Bark and taken for the calculation of tree indexes: (i) Vowel space area, computing all seven vowels (VSA); (ii) Triangular space area (TVSA), computing /i/,/a/ and /u/ vowels and (iii) Formant Centralization Rate (FCR).

2.2.2. Statistic analysis

For statistic analysis software SOFA [30] was used to perform Wilcoxon Signed Ranks Test for comparing groups.

3. RESULTS

Three hundred and sixty samples containing the seven vowels of BP were analyzed. Two investigators double checked fifty percent of all vowel segmentation. First and second formants were extracted by automatic script, values were inspected and outliers were checked by hand.
Vowel Space Area increases after treatment for most of the participants, on both groups. However, only group **B** had significant differences between pre and post treatment (*p-value 0,001*, W 1).
The data of triangular vowel space area showed no significant differences between pre and post-treatment. An intrasubject data inspection revealed inconsistent results between participants. On group **A**, four participants had increased, two participants had decreased and two had no change on TVSA. On group **B** five participants showed decrease TVSA and three had increase TVSA.
The Formant Central Rate data show a decrease of compression on vowel articulation significantly different between pre and post-treatment conditions, for group **B** (*p value 0,001*, W 1). An intrasubject data inspection points for group **B** that all participants decrease FCR values, wich means less compression on vowel articulation.

However, for group A three participants increased FCR values, with means more articulatory compression, and other five decreased values.

Table 2 - Show Wilcoxon Signed Ranks Test results for group A and B, pre and post-treatment comparison, for Vowel Space Area, Triangular Vowel Space Area and Formant Centralization Rate.

	GROUP A	GROUP B
VSA	0,674, W 15	*0,001, W 1*
TVAS	0,315, W 8	0,88, W17
FCR	0,262, W 10	*0,001, W 0*

4. DISCUSSION

Analysis of vowel production was performed in order to verify the impact of non-speech exercises (oral, laryngeal and respiratory) on hypokinetic dysarthric speech. Three indexes were calculated to explore the working vowel space. The metrics applied were: VSA; TVSA and FCR, in Bark.
Vowel space area is a metric that represents space of a polygon formed by the plot of F1 and F2 average. Triangular space area computes only three corner vowels (i,a,u). FCR is a ratio that reflects compression of vowel working area.
The results showed significant differences between conditions pre and post-treatment for the group that received oral and laryngeal plus respiratory training (group **B)** in two metrics: VSA and FCR. Group **B** showed increase on VSA values and decrease on FCR values, indicating that change has been achieved on amplitude movements of tongue and jaw during speech function. Our data did not find consistent change on speech after traditional motor oral and laryngeal training. However, when associated with respiratory training these non-speech exercises produced positive impact on vowel

articulation. What changes? We propose some hypothesis to explain it. (i) One is concerned with the amount of training, in a simple way, the group **B** made a greater amount of exercises during the therapy sessions and at home. Could the amount of training have influenced the results? The speech therapy field doesn't have strong knowledge about the amount of motor training to answer that question. (ii) Two, expiratory muscle strength training focus on maximal effort, so patients are constantly challenging to reach a target and improving it [24,25]. At the same direction, Lee Silverment Voice Treatment (LSVT) is based on loud voice, triggering great effort. LSVT is the speech approach that shows greater scientific evidences on improve dysatrhric speech [15,22,26]. We could suppose that "effort" can play an important role on this kind of speech approach. (iii) Three, oral and laryngeal exercises are disconected with speech function, the bases rely on strength, force and control of movements [3,23]. At other hand, EMST trains trough respiratory function [24,25]. Could the respiratory function be the key that expands the gain through speech function? In other words, functional training could be more efficient that isolated muscular training? Literature has been exploring the impacts of EMST on speech, the studies focus more on voice improvement, control of loudness and respiratory phonatory coordination, and has been showing positive results [24].

Surprisingly TVSA didn't follow the other metrics and didn't show significant differences between pre and post-treatment condition for any of the groups. In order to understand why TVSA couldn't reflect the articulatory modifications like VSA we checked the highest and lower values of F1 and F2 to correlate with respective vowel. The findings showed that the corner vowels (/i, u, a/) do not always represent the extreme vowels on our data. So, triangular vowel space area could be underestimated because the extreme vowels are not consistent represented by /a, i, u/. In that sense, VSA shows to be strongest in reflect working vowel space area, at least for dysatrhric speech [19].

It is import to recognize that this data is small, only eight participants per group, and it is not enough to understand the complexity of dysarthria behavior. Despite this shortages it is important for speech therapy approaches to understand when and which approaches can be useful for more than one goal, especially with neurologic population. Management of swallowing, speech and respiratory disturbances could be a big challenge for the clinician. The knowledge that a specific approach can have secondary effects on other function can be a very important tool for the care professionals.

5. CONCLUSION

The main findings of this paper are:
(i)Association of expiratory muscle strength training to oral and laryngeal exercises impact positively vowel articulatory increasing vowel working space.
(ii) Non-speech exercises do not consistent impact vowel articulatory
(iii) Vowel Space Area is more sensitive to detect changes in vowel space comparing to Triangular Vowel Space Area on hypokinetic dysarthric speech.

6. ACKNOWLEDMENTS

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