SPEECH DISORDERS IN PARKINSON'S DISEASE PATIENTS WITH MILD FORM OF FREEZING OF GAIT

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Abstract: This paper deals with the description of speech disorders present in the mild stage of freezing of gait (FOG) in patients with Parkinson's disease (PD). Experimental dataset consisted of 48 PD patients and 52 healthy controls (HC). We used freezing of gait questionnaire (FOG-Q) to characterize FOG in PD. Using one-way analysis of variance, we found loosely adducted vocal folds during phonation ($p = 0.0027$), increased acoustic noise ($p = 0.0294$), reduced variability of pitch ($p = 0.0440$), and reduced mobility of articulatory organs ($p = 0.0157$) significantly statistically different in PD patients in comparison with HC.

Keywords: Parkinson's disease, hypokinetic dysarthria, freezing of gait, analysis of variance

1 INTRODUCTION

Parkinson's disease (PD) is a frequent neurodegenerative disorder [1] with the unknown aetiology characterized by substantial reduction of dopaminergic neurons especially in *substancia nigra pars compacta* [2] but also in other regions of the brain [3]. PD affects approximately 1.5 % of people aged over 65 years [4]. Its clinical symptoms comprise a variety of motor and non-motor deficits [2] including speech disorders [5] and freezing of gait [6].

Speech disorders associated with PD are referred to as hypokinetic dysarthria (HD) [5]. HD is manifested in the area of phonation, articulation, prosody, speech fluency and faciokinesis [7, 8]. Increased acoustic noise, reduced voice intensity, harsh breathy voice quality, increased voice nasality, reduced variability of pitch and loudness combined with speech rate abnormalities, imprecise consonant articulation, unintentional introduction of pauses, rapid repetition of words or syllables, sudden deceleration/acceleration in speech has been observed [8].

Freezing of gait (FOG) in PD is characterized by the inability to initiate or continue normal gait [6, 9]. To assess FOG in PD, clinicians use a specialized six-item Likert-scale (5-point scale where a score of 0 indicates absence of the symptom, while a score of 4 indicates the most severe stage) questionnaire: Freezing Of Gait questionnaire (FOG-Q) [10]. Although, FOG is frequent in PD [11], it is still not clear which speech disorders are prevalent in mild stages of FOG (FOG mild) in PD.

The aim of this work is to investigate the presence of HD in mild stages of FOG in PD. For this purpose, wide range of speech features quantifying HD are computed. To compare the features between PD patients with FOG (mild) and healthy speakers, one-way analzsis of variance (ANOVA) is employed. The rest of this paper is organized as follows. Section 2 presents the dataset and the methodology. Experimental results are presented in section 3, and section 4 provides discussion and some conclusions.

Table 1: Freezing Of Gait Questionnaire template [10]

points	description
	Q1: *During your worst state – do you walk:*
0	Normally
1	Almost normally – somewhat slow
2	Slow but fully independent
3	Need assistance or walking aid
4	Unable to walk
	Q2: *Are your gait difficulties affecting your daily activities and independence?*
0	Not at all
1	Mildly
2	Moderately
3	Severely
4	Unable to walk
	Q3: *Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking?*
0	Never
1	Very rarely – about once a month
2	Rarely – about once a week
3	Often – about once a day
4	Always – whenever walking
	Q4: *How long is your longest freezing episode?*
0	Never happened
1	1 – 2 s
2	3 – 10 s
3	11 – 30 s
4	Unable to walk for more than 30 s
	Q5: *How long is your typical start hesitation episode (freezing when initiating the first step)?*
0	None
1	Takes longer than 1 s to start walking
2	Takes longer than 3 s to start walking
3	Takes longer than 10 s to start walking
4	Takes longer than 30 s to start walking
	Q6: *How long is your typical turning hesitation episode (freezing when turning)?*
0	None
1	Resume turning in 1 – 2 s
2	Resume turning in 3 – 10 s
3	Resume turning in 11 – 30 s
4	Unable to resume turning for more than 30 s

2 MATERIALS AND METHODS

In total, 100 Czech native speakers were examined in this work. The group of speakers consisted of 48 (22 women, 26 men) patients with idiopathic PD (mean $\pm$ std): age $= 67.44 \pm 9.07$, disease duration $= 5.90 \pm 3.51$ years, UPDRS III [12] $= 20.81 \pm 10.83$, FOG-Q [10] $= 2.42 \pm 2.16$ and 52 (26 women, 26 men) healthy controls (mean $\pm$ std): age $= 63.59 \pm 9.15$. All patients were enrolled at the First Department of Neurology, St. Anne's University Hospital in Brno, Czech Republic. The healthy participants had no history or presence of speech disorders or brain diseases, including neurological and psychiatric illnesses. The patients were examined approximately 1 hour after their regular dopaminergic medication. All patients signed an informed consent form that has been approved by the local ethics committee.

The assessment of FOG-Q [10] was conducted by a movement disorders specialist. Template of the questionnaire can be seen in Table 1. The speech data acquisition consisted of a reading tasks composed of 135 words (717 characters). To objectively assess HD, we extracted the following speech features [13, 8, 14]: mean of soft phonation index (SPI) – loosely adducted vocal folds during phonation [15], mean of harmonics-to-noise ratio (HNR) – increased acoustic noise in speech (hoarse and breathy voice/dysphonia) [16], standard deviation of the fundamental frequency (F0) – reduced variability of pitch (flat speech melody/monopitch) [14], and formant periodicity correlation of the first formant frequency (F1PC) – reduced mobility of the articulatory organs (imprecise articulation) [17]. To assess the difference between the speech features for HC and FOG (mild) PD patients, one-way analysis of variance (ANOVA) was used. The significance level $\alpha = 0.05$ was selected.

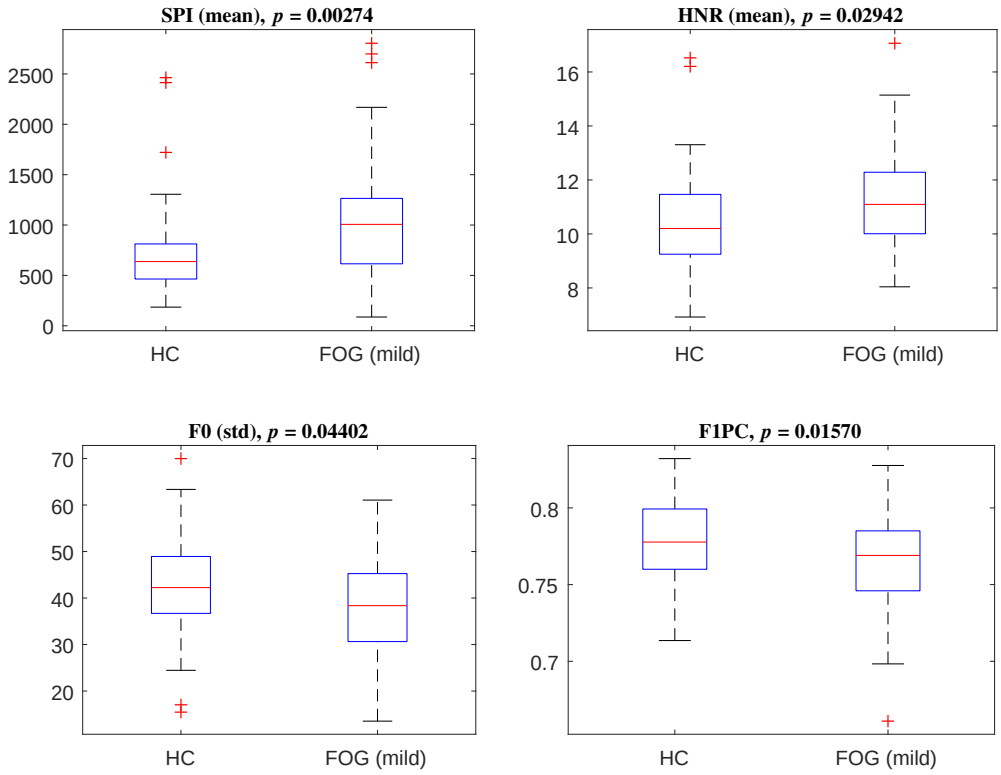

Figure 1: Box plots visualizing the distribution of the speech feature values computed for HC and FOG-Q (mild) PD patients. SPI (mean) – mean of soft phonation index, HNR (mean) – mean of harmonics-to-noise ratio, F0 (std) – standard deviation of the fundamental frequency, F1PC – formant periodicity correlation of the first formant frequency, p – significance value computed for one-way ANOVA ($\alpha = 0.05$).

3 RESULTS

The results of one-way ANOVA can be summarized as follows: SPI (mean) – $F(1,98) = 9.4470$, $p = 0.0027$, mean $\pm$ std (HC) $= 725.93 \pm 455.08$, (FOG mild) $= 1077.60 \pm 675.71$; HNR (mean) – $F(1,98) = 4.8846$, $p = 0.0294$, mean $\pm$ std (HC) $= 10.39 \pm 1.98$, (FOG mild) $= 11.22 \pm 1.77$; F0 (std) – $F(1,98) = 4.1626$, $p = 0.0440$, mean $\pm$ std (HC) $= 42.23 \pm 10.81$, (FOG mild) $= 37.90 \pm 10.35$; F1PC – $F(1,98) = 6.0452$, $p = 0.0157$, mean $\pm$ std (HC) $= 0.78 \pm 0.03$, (FOG mild) $= 0.76 \pm 0.03$. As can be seen, there were statistically significant differences between group means as determined by one-way ANOVA in the case of all speech features. The box plots visualizing the distribution of the speech feature values computed for HC and FOG (mild) PD patients can be seen in Figure 1. Clinical consclusions regarding the results are made in the subsequent section.

4 CONCLUSION

In this work, we investigated the presence of HD in a set of patients with PD suffering from a mild form of FOG. Specifically, we quantified four commonly occuring speech disorders in HD: loosely adducted vocal folds during phonation, increased acoustic noise in speech, reduced variability of pitch, and reduced mobility of the articulatory organs. Using one-way ANOVA, we found these aspects of HD statistically different for FOG (mild) PD patients in comparison with healthy speakers.

PD patients showed increased values of SPI (mean) indicating that PD has a detrimental impact on the mobility of the vocal folds resulting into loose adduction of the vocal folds during phonation. Furthermore, PD patients showed lower values of F0 (std) indicating that PD patients exhibit reduced variability of the vocal folds' vibration pattern leading to flat speech melody lacking intonation. These results are in accordance with the previous studies [8, 14]. Interestingly, higher values of HNR (mean) was observed in the case of PD patients compared to HC, which is in contradiction with the hypothesis that incomplete closure of the vocal folds leads to an increased level of acoustic noise in speech and therefore lower values of HNR. Finally, imprecise articulation was observed in PD patients quantified by F1PC.

In summary, the results of this work show that a mild form of FOG is likely to be related with deterioration of the mobility of the vocal folds and the articulatory ornans. It is a reasonable assumption considering the underlying pathophysiology of PD: progresive loss of dopaminergic neurons is responsible for impaired control of the mussles [2]. However, the conclusions drawn in this work are made using only one dataset and therefore need to be confirmed by subsequent studies. Nevertheless, a statistically significant difference between selected speech features computed for HC and FOG (mild) PD patients were found indicating a promissing potential of the methodology that can be used to further understand exact pathophysiological connection between HD and FOG in PD.

In our future studies we will focus on the analysis of HD in other stages of FOG in PD and also relationship between HD and other symptoms of PD such as depression, sleeping disorders, dementia, etc. in order to provide complex description of clinical status of the patient, which can be diagnosed, rated and monitored remotely using acoustic analysis of speech.

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REFERENCES

[1] M. C. de Rijk, et al., Prevalence of Parkinson's disease in Europe: a collaborative study of population-based cohorts, Neurology 54 (2000) 21–23.

[2] O. Hornykiewicz, Biochemical aspects of parkinson's disease, Neurology 51 (1998) S2–S9.

[3] P. Brodal, The Central Nervous System: Structure and Function, Oxford University Press, 3 edition, 2003.

[4] M. C. de Rijk, et al., Prevalence of parkinsonism and Parkinson's disease in europe: the europarkinson collaborative study. european community concerted action on the epidemiology of Parkinson's disease, J. Neurol. Neurosurg. Psychiatry 1 (1997) 10–5.

[5] F. L. Darley, A. E. Aronson, J. R. Brown, Differential Diagnostic Patterns of Dysarthria, J. Speech. Hear. Res. 12 (1969) 246–269.

[6] N. Giladi, R. Kao, S. Fahn, Freezing phenomenon in patients with parkinsonian syndromes, Movement Disorders 12 (1997) 302–305.

[7] J. Mekyska, Z. Smekal, M. Kostalova, M. Mrackova, S. Skutilova, I. Rektorova, Motor aspects of speech impairment in Parkinson's disease and their assessment, Cesk. Slov. Neurol. N. 74 (2011) 662–668.

[8] J. Mekyska, E. Janousova, P. Gomez-Vilda, Z. Smekal, I. Rektorova, I. Eliasova, M. Kostalova, M. Mrackova, J. B. Alonso-Hernandez, M. Faundez-Zanuy, K. L. de Ipina, Robust and complex approach of pathological speech signal analysis, Neurocomputing 167 (2015) 94–111.

[9] N. Giladi, H. Shabtai, E. Rozenberg, E. Shabtai, Gait festination in Parkinson's disease, Parkinsonism Relat. Disord. 7 (2001) 35–138.

[10] N. Giladi, H. Shabtai, E. S. Simon, S. Biran, J. Tal, S. D. Korczyn, Construction of freezing of gait questionnaire for patients with parkinsonism, Parkinsonism Relat. Disord. 6 (2000) 165–170.

[11] N. Giladi, T. A. Treves, E. S. Simon, H. Shabtai, Y. Orlov, B. Kandinov, D. Paleacu, A. D. Korczyn, Freezing of gait in patients with advanced Parkinson's disease, Journal of Neural Transmission 108 (2001) 53–61.

[12] S. Fahn, R. L. Elton, UPDRS Development Committee (1987) Unified Parkinson's disease rating scale, Recent developments in Parkinson's disease. Macmillan, Florham Park, 1987.

[13] I. Eliasova, J. Mekyska, M. Kostalova, R. Marecek, Z. Smekal, I. Rektorova, Acoustic evaluation of short-term effects of repetitive transcranial magnetic stimulation on motor aspects of speech in Parkinson's disease, J. Neural Transm. 120 (2013) 597–605.

[14] Z. Galaz, J. Mekyska, Z. Mzourek, Z. Smekal, I. Rektorova, I. Eliasova, M. Kostalova, M. Mrackova, D. Berankova, Prosodic analysis of neutral, stress-modified and rhymed speech in patients with parkinson's disease, Comput. Methods. Programs. Biomed. 127 (2016) 301–317.

[15] D. D. Deliyski, Acoustic model and evaluation of pathological voice production, in: 3rd Conference on Speech Communication and Technology EUROSPEECH'93, (1993), 1969–1972.

[16] A. Tsanas, M. A. Little, P. E. McSharry, L. O. Ramig, Nonlinear speech analysis algorithms mapped to a standard metric achieve clinically useful quantification of average Parkinson's disease symptom severity, J R Soc Interface 8 (2010) 842–855.

[17] R. Moretti, P. Torre, R. M. Antonello, L. Capus, M. Gioulis, S. Zambito Marsala, G. Cazzato, A. Bava, Speech Initiation Hesitation following Subthalamic Nucleus Stimulation in a Patient with Parkinson's Disease, Eur Neurol 49 (2003) 251–253.