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Instrumental and aerodynamic assessment of hypokinetic dysarthria in women

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► **To cite this version:**

Clara Ponchard, Alain Ghio, François Viallet, Lise Crevier-Buchman, Didier Demolin. Instrumental and aerodynamic assessment of hypokinetic dysarthria in women. International conference on Alzheimer's and Parkinson's diseases and related neurological disorders (AD/PD), 2023, Göteborg, Sweden. hal-04248382

HAL Id: hal-04248382

<https://hal.science/hal-04248382>

Submitted on 18 Oct 2023

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Introduction

Speech production is a process involving a succession of complex and highly coordinated phases that include neuromuscular phenomena, movements and aerodynamic variations. These events begin with breathing and end with the generation of an acoustic speech signal that results from a complex combination between the vocal source and the resonances of the vocal tract. The signal carries a variety of information that is not always easy to separate or that is modified by propagation in the vocal tract (the information must be retrieved indirectly). The shortcomings of using only acoustic parameters to evaluate the voice have been identified in several studies. For acoustic voice measurements to be an indicator of diagnosis, disease progression or treatment effects, there must be a significant relationship between the physiology (the cause) and the acoustic signal (the effect). Acoustic measurements by themselves have no inherent meaning in the absence of a causal relationship with speech production and/or perception [1]. It is possible to motivate acoustic measures by demonstrating a causal association between one or more acoustic measures and some aspect of speech production. However, the relationship between voice production and acoustics in Parkinson's disease has never been studied [1]. Aerophonometry provides a means of assessing and understanding aspects of voice production. The aerodynamic phase is the first step in speech production. It is through this phase that speech sounds are generated. The few studies using aerodynamic parameters in addition to acoustic measurements confirm the integration of aerodynamic measurements in the evaluation protocols at the increases the reliability of the evaluation, in particular the subglottic pressure which appeared in three studies as one of the most relevant criteria to describe speech disorders. This study proposes a model of aerodynamic speech in women.

Specific aims

What are the parameters for variation in aerodynamic measurements?

- Is age a factor of variation ?
- Do subjects under 60 have the same pressure as subjects over 60?
- Can the same trends be observed for parkinsonian subjects?
- Does L-Dopa treatment have an impact on pressure measurements?
- Is the pressure of OFF-dopa and ON-dopa are the same ?
- Is there a difference in pressure between healthy and parkinsonian subjects?

Do aerodynamic parameters allow characterization of Parkinsonian's speech?

Methodology

Our corpus consists of 40 speakers (20 parkinsonian patients + 20 control subjects) recorded in the Neurology Department of the Centre Hospitalier du Pays d'Aix in Aix-en-Provence [2]. The speakers were native French-speaking women aged 40 to 90 years. There was no significant difference in age between the two groups. We analyzed subglottic pressure measurements estimated from the peak of intraoral pressure during the production of the consonant [p] during the sentence "papa ne m'a pas parlé de beau papa". For Parkinsonian subjects, data were analyzed in the two pharmacological states: with L-DOPA (ON-DOPA) and with withdrawal (OFF-DOPA).

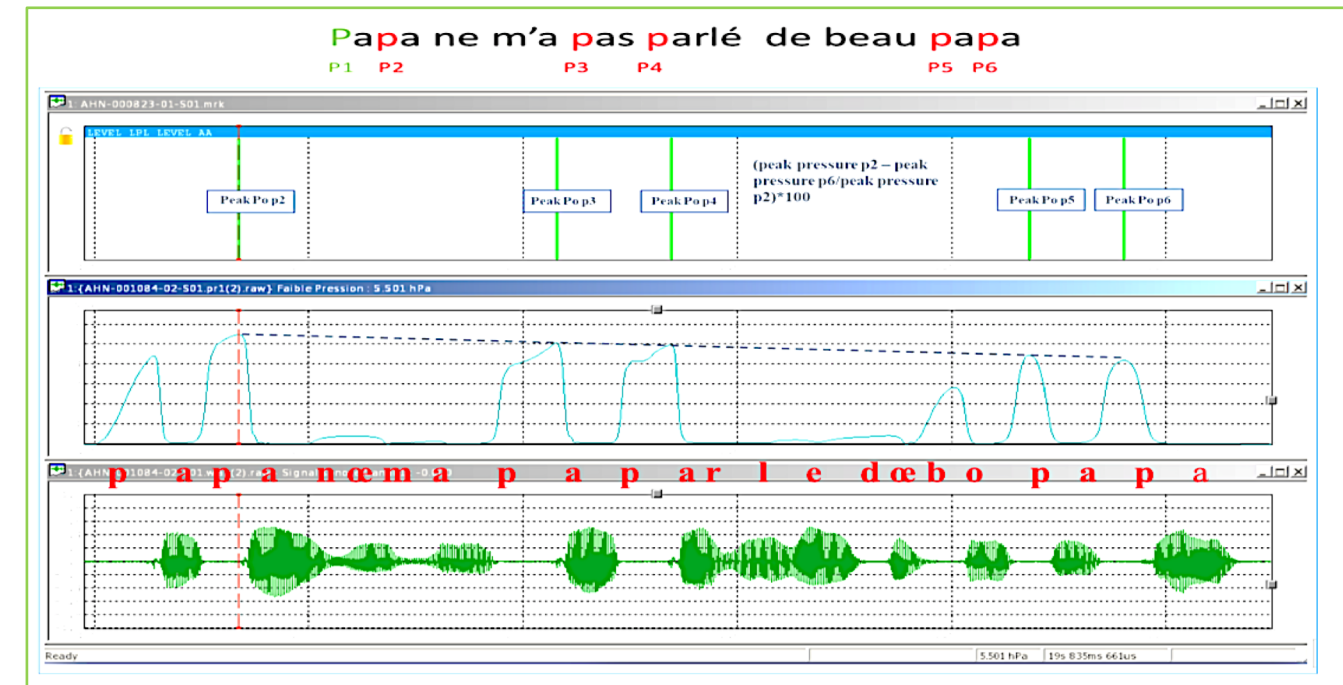


FIGURE 1: Segmentation criteria applied to intra-oral pressure peaks to estimate subglottic pressure on all the /p/ except the first of the sentence «papa ne m'a pas parlé de beau papa».

Age variation – Healthy subjects

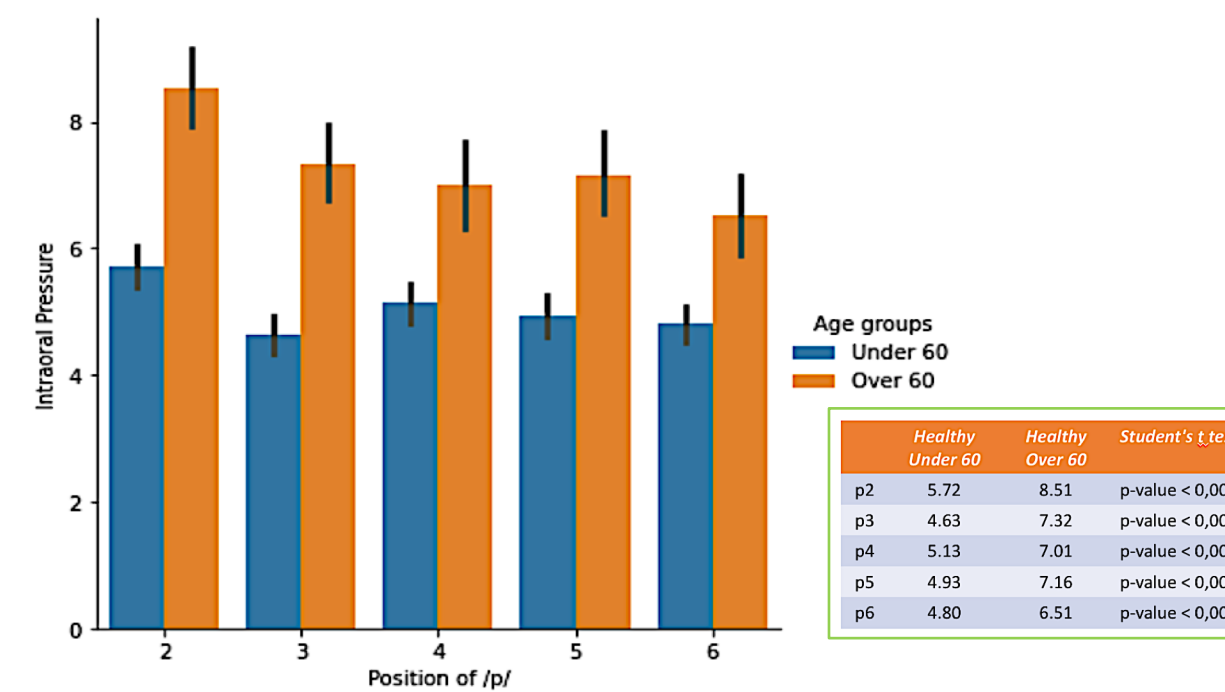


FIGURE 2: Mean estimated subglottic peak pressure of the different [p] (p2, p3, p4, p5, p6) produced in the sentence "papa ne m'a pas parlé de beau papa". In blue, the group under 60 years, in orange the group over 60 years. In the table, results of Student's t-test with mean in the different positions (p2, p3, p4, p5, p6) and p-values.

Age variation – Parkinson subjects

	Under 60			Over 60		
	OFF	ON	P-value	OFF	ON	P-value
p2	5.92	6.72	0.04*	6.92	6.74	0.69
p3	5.11	5.93	0.04*	5.64	5.34	0.49
p4	4.94	5.73	0.02*	5.1	5.73	0.95
p5	4.95	5.75	0.03*	5.81	5.98	0.63
P6	4.43	5.32	0.003**	5.30	5.02	0.31
	OFF	Témoïn	P-value	OFF	Témoïn	P-value
p2	5.92	5.72	0.47	6.92	8.51	0.0005***
p3	5.11	4.63	0.05	5.64	7.32	0.0002***
p4	4.94	5.13	0.49	5.71	7.01	0.003**
p5	4.95	4.93	0.93	5.81	7.16	0.002**
P6	4.43	4.80	0.12	5.30	6.51	0.002**
	ON	Témoïn	P-value	ON	Témoïn	P-value
p2	6.72	5.72	0.007**	6.74	8.51	0.0004***
p3	5.93	4.63	0.0009***	5.34	7.32	<0.001***
p4	5.73	5.13	0.05	5.73	7.01	0.004**
p5	5.75	4.93	0.02*	5.98	7.16	0.006**
P6	5.32	4.80	0.06	5.02	6.51	0.0002***

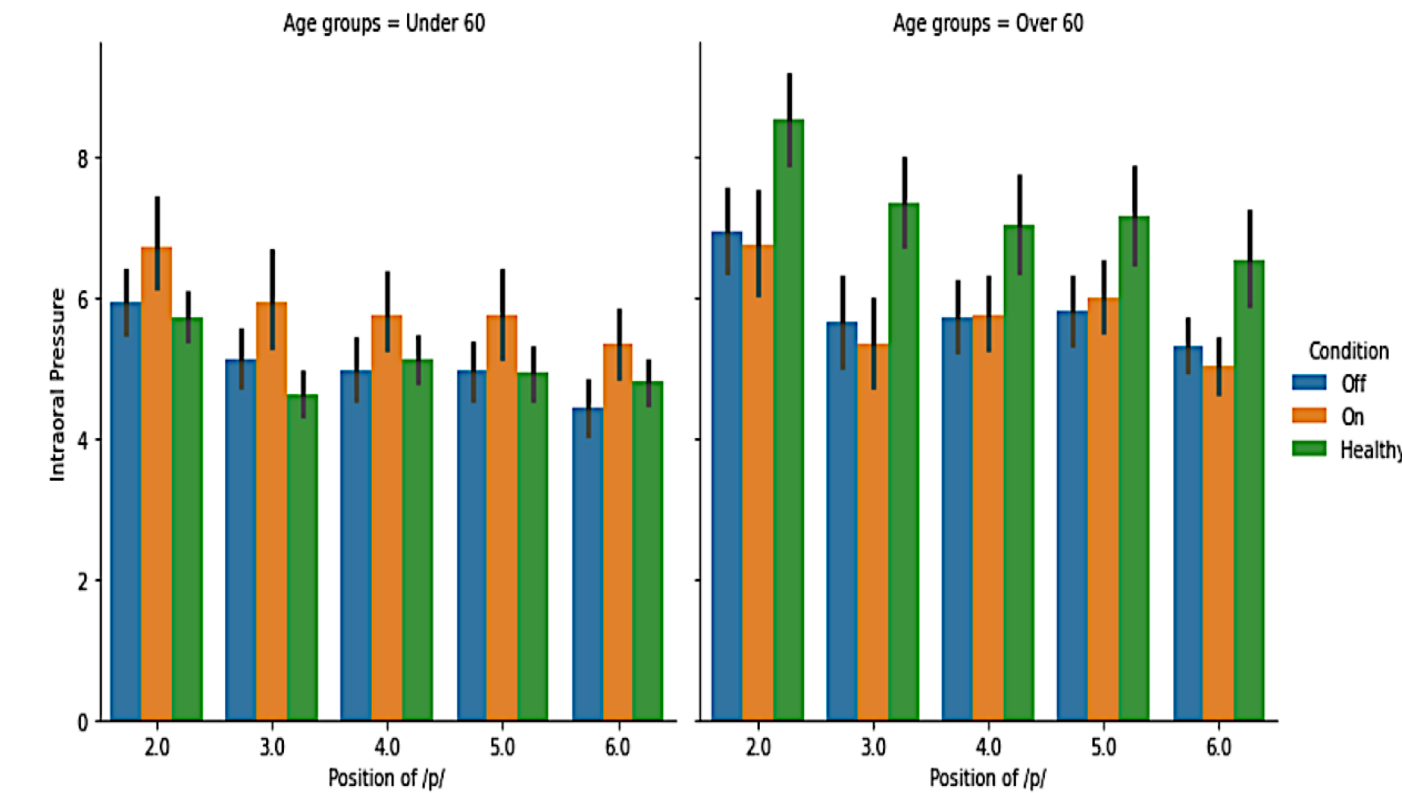


FIGURE 3 et 4: Mean estimated subglottic peak pressure of the different [p] (p2, p3, p4, p5, p6) produced in the sentence "papa ne m'a pas parlé de beau papa". In blue, the parkinsonian subjects in OFF condition, in orange the parkinsonian subjects in ON condition and in green healthy subjects. In the table, Result of Student's t test with mean intraoral pressure measurements. The p-values are shown with the significance level (* p < 0.05; ** p < 0.01; *** p < 0.001). On the left the group under 60 years old and on the right the group over 60 years old.

Machine Learning - Automatic Classification

```

Time taken to test model on training data: 0.33 seconds
=== Summary ===
Correctly Classified Instances      1643      91.2778 %
Incorrectly Classified Instances    157       8.7222 %
Kappa statistic                    0.8692
Mean absolute error                 0.1803
Root mean squared error             0.249
Relative absolute error              40.5644 %
Root relative squared error         52.8293 %
Total Number of Instances          1800

=== Detailed Accuracy By Class ===
                TP Rate  FP Rate  Precision  Recall  F-Measure  MCC      ROC Area  PRC Area  Class
                0.897   0.045   0.909      0.897   0.903      0.855   0.988     0.976   Off
                0.942   0.049   0.905      0.942   0.923      0.884   0.992     0.984   On
                0.900   0.037   0.925      0.900   0.912      0.869   0.990     0.981   Healthy
Weighted Avg. : 0.913   0.044   0.913      0.913   0.913      0.869   0.990     0.980

=== Confusion Matrix ===
  a  b  c  <-- classified as
538 32 30 | a = Off
21 565 14 | b = On
33 27 540 | c = Healthy
    
```

FIGURE 5: Performance of the Random Forest algorithm for the task of supervised automatic classification of pressure measurements into three groups: healthy, OFF and ON. The Random forest algorithm performs parallel learning on multiple randomly constructed decision trees trained on different subsets of the data.

Conclusion

- Age is a factor of variation that must be taken into account
- With age the pressure increases, older subjects have a higher pressure than younger subjects
- Before 60 years, the pressure of healthy subjects and parkinsonian subjects without treatment is the same
- After 60 years, the pressure of healthy subjects is significantly higher than the pressure of parkinsonian subjects with or without treatment
- L-Dopa treatment has an impact on pressure only in subjects under 60 years
- Pressure is a robust parameter to characterize parkinsonian speech with a 91% success rate in automatic detection

References

[1] Kreiman J., Gerratt B.R. (2020) Acoustic Analysis and Voice Quality in Parkinson Disease. In: Godino-Llorente J.I. (eds) Automatic Assessment of Parkinsonian Speech. AAPS 2019. Communications in Computer and Information Science, vol 1295. Springer, Cham. https://doi.org/10.1007/978-3-030-65654-6_1

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