An electrolaryngographic study of dysphonic Portuguese speakers

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ABSTRACT

The aims of this research were: (a) normative, to establish tentative normative data on the mean fundamental frequency (F0) for Portuguese speakers; (b) comparative, to investigate whether statistically significant differences exist between two groups of different voice conditions on the mean F0, and (c) predictive, to test for the variables that best predict the mean F0 variance. Electrolaryngographic (ELG) data was obtained from 109 subjects (52 dysphonics and 57 controls) during the production of sustained vowels, oral reading and conversation.
Results show that the normative data proved to be a valuable reference. Also, within the limitations of the study, overall the dysphonic exhibited lower F0 than controls for all speaking conditions, although this contrast was not statistically significant. Additionally, between 61 and 73 % of the mean F0 variance is explained by a combination of four or five variables for all speech tasks.

1 INTRODUCTION

There is a huge body of research devoted to normative data for fundamental frequency (F0), showing variability associated with age, gender, using a variety of speech tasks (sustained vowels, reading, conversation), different languages, studying the effects of behavioural factors (e.g. drinking and smoking), using different data gathering and analysis methods (e.g. acoustic and electrolaryngographic), and reporting different F0 measures (e.g. mean, mode, range) [1].
A synthesis of the extensive lists of previous research (cited by [1]) on F0 for 'normal' speakers during sustained vowels, reading and conversation according to gender is presented in table 1.

Data reporting F0 values for dysphonic and/or laryngeal pathology populations is still scarce and controversial [1]. Moreover, the published studies on dysphonia reflect the same methodological problems found for 'normal' samples concerning the speakers' characteristics, type of speech tasks used, analysis methods and reported measures. As would be expected, comparability between studies is often problematic.

	Women 16-52 years	Men 17-49 years
Vowel [i]	206 - 262 Hz	122 – 175 Hz
Vowel [u]	205 – 253 Hz	123 –129 Hz
Vowel [a]	199 – 215 Hz	111 – 125 Hz
Reading	180 – 242 Hz	106 – 129 Hz
Conversation	187 – 210 Hz	109 –123 Hz

Table 1 – Mean F0 for 'normal' adults

Furthermore, there is a wide range of laryngeal pathologies and dysphonia classifications (depending on who is applying it) [1]. Also, the existence of laryngeal pathology may not result in dysphonia or vice-versa because of, for example, the individual's characteristics or the demands made on his/her voice.
Standardized data on voice can then be useful to distinguish normal speakers from those with dysphonia and/or laryngeal pathology, to provide adequate baseline treatment and to demonstrate treatment efficacy.

In the present study data on the mean F0 of dysphonic speakers on performance of different speech tasks (sustained vowels, reading and conversation) will be presented. The purposes are: (1) to obtain information about F0 for Portuguese speakers; (2) to investigate whether statistically significant differences exist between the dysphonic and 'normal' speakers, and (3) to test for the variables that best predict the variance of the mean F0 data.

2 METHODOLOGY

The study presented here is a selected part of [1].

Subjects
A total of one hundred and nine subjects (who were attending a normal examination at the ENT unit of the hospital and unpaid healthy volunteers) were selected for the study.

Speakers were classified into two groups on the basis of their voice quality. A speaker was included in the

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'dysphonic' group when he/she presented with a voice problem on the day of the assessment or history of voice complaints and for which the SLT and the ENT surgeon found corroborative evidence [2].
The dysphonic group consisted of 52 subjects (39 females and 13 males) and the mean age was 44 years old. The control group consisted of 57 subjects (43 females and 14 males) and the mean age was 39 years and the mean level of education was thirteen years.

Speech sample
The speech materials used for the electrolaryngographic measurement were: (1) sustained vowels (the Portuguese vowels [a], [i] and [u]); (2) the Portuguese version of 'The Story of Arthur the Rat' (290 words) developed by [3] and, (3) conversation (3 minutes).

Experimental procedure
Individual subject data collection procedure involved nasolaryngostroboscopic examination by an ENT surgeon, case history questionnaire, auditory voice evaluation, and ELG voice recording (using Laryngograph Ltd. Laryngograph Processor) by a Speech and Language Therapist (SLT) and speakers' self-rating of psychological stress [4].
The data collection procedure involved two different phases, a pilot study (data not included in this study) and a main study.

Equipment
ELG recordings were carried out using a portable Laryngograph Processor (Laryngograph Ltd), and a portable Digital Audio Tape (DAT) recorder (Sony TCD – D8) battery powered. The EGG signal accuracy was monitored online using a Thandar, portable oscilloscope (type SC 110A).

Analysis technique
The ELG signal was displayed in real time on a computer monitor (and analysed using the Speech Studio program from Laryngograph Ltd.) subject-by-subject for each task.
Before implementing automatic analyses, in order to limit the analyses error, several procedures were performed: (1) the Lx waveforms were bandpass filtered (Kemo type VBF8 filter) between 10 Hz and 5 kHz; (2) Lx waveforms with discontinuities were not accepted for data analysis; (3) oral reading samples which contained a substantial number of mispronunciations, hesitations, part-word segmentations and dysrhythmic flow of reading, were rejected for analyses [1].

Data from the screening examinations (case history questionnaire, nasolaryngostroboscopy, auditory voice assessment and the speakers' self-rating of psychological stress) and from the speech samples were analysed subject by subject and edited in the Statistical Package for the Social Sciences (SPSS), version 10. A repeated measures analysis (ANOVA) and multiple linear regression was carried out and the probability level accepted as significant was $p<.05$.

3 RESULTS

Mean and standard deviation F0 values for all speech tasks according to the groups and gender are displayed in table 2 and 3.

It is clear from table 2 that, the mean F0 for the dysphonic females during the sustained vowels ranged between 200 Hz and 214 Hz while for the control counter partners ranged between 211 Hz and 225 Hz.
The mean F0 for the dysphonic females during the connected speech ranged between 180 Hz and 183 Hz and for the control females ranged between 187 Hz and 190 Hz.

	Dysphonic	Controls
[a]	119.5 ± 36.9	210.5 ± 33.3
[i]	212.7 ± 41.3	221 ± 36.6
[u]	214 ± 44.2	225.1 ± 37.4
Reading	183.4 ± 35.4	190.3 ± 20.9
Conversation	179.5 ± 36.1	186.6 ± 19.1

Table 2 – mean F0 for women

It is also clear from table 3 that, the mean F0 for the dysphonic males during the sustained vowels ranged between 113 Hz and 130 Hz while for the control counterpartners ranged between 118 Hz and 128 Hz. The mean F0 for the dysphonic males during the connected speech ranged between 108 Hz and 111 Hz and for the control males ranged between 109 Hz and 110 Hz.

	Dysphonic	Controls
[a]	113 ± 37.2	118.4 ± 18.4
[i]	130.2 ± 45.2	127.6 ± 37.9
[u]	128.1 ± 45.8	123 ± 21.7
Reading	111.2 ± 36.5	109.6 ± 20
Conversation	108.3 ± 27.7	109.2 ± 13.6

Table 3 – mean F0 for men

The comparative analyses show that the mean F0: (1) for the dysphonics are systematically lower than the corresponding values for the controls in the females and for the vowel [a] and conversation in the males. However, statistical testing using multiple repeated analyses between the groups revealed that the main factor of group ($F(1,79)=.032$, $p<.05$) did not exert a main significant statistical effect on the mean F0; (2) within each group (dysphonics and controls) females show mean F0 values, for all speech tasks, higher than males. This difference was found to be statistically significant ($F(1,79)=123.29$, $p<.001$); (3) within the groups, multiple comparison analysis revealed that there was a highly significant speech effect ($F(1,179)=35.27$, $p<.001$). Post hoc paired t-tests comparisons revealed

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that, firstly, there is a significant difference between all the vowels except for the pair vowel [i] versus vowel [u] for both genders. Secondly, there are significant differences between all the vowels and connected speech (reading and conversation) for all subjects. Thirdly, differences between reading and conversation were only significant for females.

The multiple regression analyses showed that a high prediction (between 61 and 73 %) for the mean F0 variance is explained by a combination of four or five variables for all speech tasks.
The variables that are associated with a lower mean F0 are: gender (male), age, number of cigarettes a day, smoker, disease and tobacco use as a cause of dysphonia, minor nose abnormalities and slight dysphonia severity.
The variables (number of coffee a day, sudden dysphonia onset, psychological factors as a cause of dysphonia, hoarse voice and total stress) are associated with a higher mean F0.
The resulting regression equations that predict the mean F0 variance for all speech tasks are respectively:
- Vowel [a] = 218.52 – 80.58 (male) – 1.49 (number of cigarettes smoked a day) + 39.14 (sudden dysphonia onset) – 18.98 (minor nose abnormalities);
- Vowel [i] = 214.87 – 81.84 (male) – 2.04 (number of cigarettes smoked a day) + 5.94 (number of coffees a day) – 25.34 (subject's reported disease as a cause of dysphonia) + 22.95 (hoarse voice);
- Vowel [u] = 223.40 – 91.06 (male) – 50.06 (tobacco use as a cause of dysphonia) – 35.68 (slight dysphonia severity) - 21.99 (smoker) +.104 (total stress);
- Reading = 217.22 – 70.38 (male) - 1.25 (number of cigarettes smoked a day) - .759 (age) + 27.65 (psychological factors as a cause of dysphonia) + 21.41 (sudden dysphonia onset);
- Conversation = 185.55 – 62.11 (male) - 1.09 (number of cigarettes smoked a day) – 26.16 (tobacco use as a cause of dysphonia) + 20.34 (psychological factors as a cause of dysphonia).

4 DISCUSSION

The mean F0 data for the control speakers (both genders) is within the limits of the published data (as shown in table1).

The results of this study failed to indicate a statistically significant difference between dysphonics and control speakers. Nevertheless, the mean F0 of the dysphonic speakers was lower than that of the control speakers for all speech tasks in the females and for the vowel [a] and conversation in the male speakers. These findings are in line with previous research (cited by [1]) wherein it was stated that mean F0 did not statistically distinguish dysphonic speakers from 'normal' speakers.

The observed F0 trends in this study showing that the dysphonic speakers have lower mean F0 than the 'normal' speakers is also in concert with some previous research (cited by [1]). And also the fact that the male dysphonics during reading show higher mean F0 than 'controls' (in the present study) is in line with the studies cited by [1].

The fact that gender had a significant effect on the mean F0 is not surprising, taking into consideration the well-known gender dimorphism and the high degree of consensus that female's F0 is generally higher than male's F0 [1].
It is also clear from the preceding results within this study that speech tasks have a highly significant effect on the mean F0. Post hoc comparisons of the results showed several trends. Firstly, the mean F0 for all the sustained vowels in this study is significantly higher compared to that in reading and conversation. Various studies (cited by [1]) that examined the speech material influence on F0 also found that a higher F0 in the sustained vowels exists compared to that in reading and conversation.
Secondly, although a significant vowel effect was found between the vowel [a] and the other two vowels [i] and [u], no significant difference was found between the vowels [i] and [u]. This data supports the previously well-established finding of the influence of vowel tongue height on the phonatory action where there is a highly significant intrinsic F0 for the high vowels (e.g. [i] and [u]) than for the low vowels such as [a] (cited by [1]).
Front and back vowel effect was not significant although the vowel [u] had a slightly higher F0 than the vowel [i] in the 'normal' female speakers. The results for 'normal' subjects are in agreement with Ewan's findings (cited by [1]).
Thirdly, a significant higher mean F0 during reading than conversation was restricted to female speakers, which is in agreement with [5]. Although the present study did not demonstrate a significant effect for the male speakers the mean F0 during oral reading is also slightly higher than during conversation and this finding is corroborated by the observations made by several researchers (cited by [1]).

The results of the multiple regression analysis show that some predictor variables (gender-male, age, number of cigarettes a day, smoker, disease and tobacco use as a cause of dysphonia, minor nose abnormalities and slight dysphonia severity) are highly associated with a lower mean F0. The gender result, meaning that males have lower mean F0 than females (as has been already mentioned) it is not surprising and corresponds to non-controversial evidence of gender F0 differences predominantly cited in the published research [1].
The second most important predictor that accounts for a lower mean F0 (in all the models) is related to smoking habit. This finding is interesting but not surprising

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because the deleterious effects of tobacco on vocal fold histology and voice quality has been frequently mentioned (cited by [1]) although statistically significant differences between the voice quality of non-smokers and smokers have been difficult to find [6]. Nevertheless, the evidence here is that the mean F0 of the smokers is lower than that of the non-smokers [6] and [7] which is in agreement with the findings in this study.
Other health related variables that are associated with a lower mean F0 are related to nasal cavity abnormalities and upper respiratory problems as aetiology of dysphonia and slight dysphonia severity. In fact, clinical experience (cited by [1]) suggests that upper respiratory tract abnormalities cause inflammation of the mucosa, alter mucosa secretions and make the mucosa more vulnerable to injury and consequently may contribute as a precipitating factor to voice quality disturbance if (a) that infection is prolonged and/or severe, (b) occurs in combination with body fatigue and/or psychological depression and (c) if the subject protects his voice by lowering his pitch and likes that type of voice. However, no experimental evidence is available about the effect of upper respiratory problems on specific voice parameters.

The study findings suggest that the variables (number of coffee a day, sudden dysphonia onset, psychological factors as a cause of dysphonia, hoarse voice and stress) are associated with a higher mean F0.
When considering how caffeine may affect the voice the major possible explanation arise from the fact of it being a central nervous stimulant and dehydrating agent and consequently affects the vocal fold vibration (cited by [1]) although experimental evidence is not available.
Psychological factors (such as emotional tension and anxiety) and stress are frequently cited as related to laryngeal tension and poor respiratory support and also potential sources of stress related to psychological factors are linked to the onset and maintenance of dysphonia [1]. Nevertheless, experimental evidence is still scarce [8], [9] and [10].

Overall, the results underline the undoubted importance even for mild dysphonia, of a multifactorial voice evaluation where the information gathered from the professionals' and speakers' perspectives would produce a better knowledge of the voice characteristics.

5 CONCLUSIONS

Results show that: (1) the mean F0 for the 'normal' speakers is within the limits of the published data; (2) mild dysphonics exhibited lower F0 than controls for all speaking conditions, although this contrast was not statistically significant; (3) between 61 and 73 % of the mean F0 variance is explained by a combination of four or five variables for all speech tasks.

However, care should be taken in the interpretation and generalization of the findings considering the exploratory nature of this study and the potential sample and methodological limitations.
In future, it may be interesting to expand the sample (speakers and larynx pathologies), to analyze (in-depth) the variables that affect the F0 to find if the results can be generalized to a large group and expand the knowledge about the relationship between F0 and the above-mentioned variables. The information gained from that will be useful in voice diagnosis, prevention and intervention by clarifying misinformation and identifying risk factors.

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REFERENCES

[1] I. Guimarães, "An electrolaryngographic study of dysphonic Portuguese speakers". London: unpublished PhD thesis, 2002.
[2] K.Verdolini, "Voice disorders," in Diagnosis in speech-language pathology, pp. 247-306. San Diego: Singular Publishing Group, 1994.
[3] D. Abercombie, *Elements of general phonetics*, Edinburgh: U.P. Edinburgh, 1967.
[4] T.H. Holmes and R.H. Rahe, "The social readjustment rating scale," *Journal of Psychosomatic research*, vol II, pp. 213-217, 1967.
[5] T. Murry, W.S. Brown and R.J. Morris, "The patterns of fundamental frequency for three types of voice samples," *Journal of Voice*, vol 3, pp. 282-289, 1995.
[6] H. Gilbert and G. Weismer, "The effects of smoking on the fundamental frequency of adult women," *Journal of Psycholinguistic Research,* vol 3, pp. 225-331, 1974.
[7] D. Sorensen and Y. Horii, "Cigarette smoking and voice fundamental frequency," *Journal of Communication Disorders,* vol 15, pp. 135-144, 1982.
[8] A.O. House and H.B. Andrews, "The psychiatric and social characteristics of patients with functional dysphonia," *Journal of Psychosomatic Research,* 31(4), pp. 483-490, 1988.
[9] J.Kinzl, W. Biebl and H. Rauchegger, "Functional aphonia: psychosomatic aspects of diagnosis and therapy," *Folia Phoniatrica,* vol 40, pp. 131-137, 1988.
[10] S.L. Goldman, J. Hargrave, R.E. Hillman, E. Holmeberg and C. Gress, "Stress, anxiety, somatic complaints, and voice use in women with vocal nodules: preliminary studies," *American Journal of Speech-Language Pathology,* vol 5, pp.44-54, 1996.