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EXPERIMENTAL INVESTIGATION OF AIR PRESSURE AND ACOUSTIC CHARACTERISTICS OF HUMAN VOICE. PART 1: MEASUREMENT *IN VIVO*

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Abstract: *This contribution is aimed to provide material that can be used to develop more realistic physical models of voice production. The experimental methodology and the results of measurement of subglottal, oral (substitute for subglottic) and acoustic air pressure (captured at a distance of 20 cm in front of the subject's mouth) are presented. The data were measured during ordinary speech production and when the acoustic impedance and mean supraglottal resistance were raised by phonating into differently sized tubes in the air and having the other end submerged under water. The results presented in time and frequency domain show the physiological ranges and limits of the measured pressures in humans for normal and extreme phonation.*

Keywords: ***Biomechanics of voice, measurement of oral pressure, voice exercises, phonation into tubes.***

1. Introduction

The study is a beginning of investigation of human voice source substitute by complex physical models of phonation. The purpose of the present contribution is to apply experimental techniques and laboratory equipment used for *in vivo* measurement and to obtain real physiological data for normal and some extreme ways of human phonation when the acoustic impedance of vocal tract was artificially increased by prolonging the vocal tract with different tubes or straws (Titze et al. 2002) and by phonation into water, which makes the phonation more difficult due to loading the human phonatory system by additional hydrodynamic pressure.

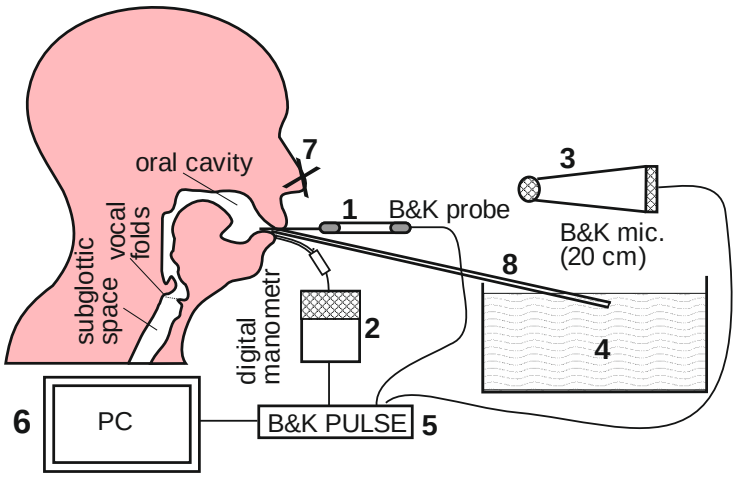

Fig. 1 – Schema of the measurement set up: 1 - B&K microphone probe 4182, 2 – digital manometer Greisinger Electronic GDH07AN, 3 – sound level meter B&K 2239, 4 – aquarium, 5 – B&K measurement system PULSE 10 with Controller Module MPE 7537 A, 6 – personal computer, 7 – clip, 8 – impedance tube.

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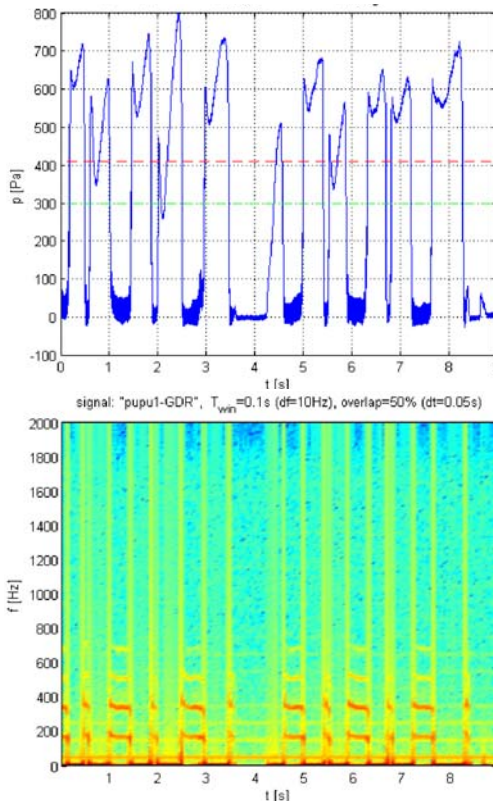

Fig. 2 – Measurement of the oral pressure and its spectrogram for phonation on [pu:pu].

One female voice trainer, phonated first in a normal way on [pa:pa], [pi:pi], [pu:pu] at comfortable pitch and loudness, and then into several plastic straws and a resonance tube in the air and with the other end submerged below water surface (Fig. 1). Air pressure was measured intraorally. The subject was keeping the lips firmly sealed around the tube or straw and two probes at the corner of the mouth to measure oral pressure. Pressure during the production of voiceless plosive [p] and manual shuttering of the other end of the tube gave an estimate of subglottic pressure. The nose was closed with a clip to prevent any leakage of air through the nose. The subglottal pressure p_{sub}, the mean air pressure p_{av}, the mean root square pressure p_{rms} inside and outside the vocal tract, the pressure spectra, the spectrograms, the fundamental voice frequencies F0 and the formant frequencies F1-F5 were analyzed for each trial from the time records of the pressure signals.

2. Results

Selected results for phonation on [pu:pu], in a stirring straw (127 mm in length, 2.5 mm inner diameter) and in a resonance glass tube (264 mm in length, 6.8 mm inner diameter) phonated into air and water are presented in Tab. 1 and one measurement example is shown in Fig. 2.

Tab. 2 – Acoustic characteristics for several ways of phonation – pressures and frequencies.

phonation	p_{sub} [Pa]	p_{av}/ p_{rms} [Pa]	$p_{rms-out}$ [Pa]	F0 [Hz]	F1 [Hz]	F2 [Hz]	F3 [Hz]	F4 [Hz]
[pu:pu]	800	15/-	0.077	170	350	660	2850	3720
stirring straw	1430	571/-	0.020	166	115	1730	2640	3830
glass tube	900	52/34	0.077	146	150	620	1300	1910
H_2O (15cm)	2450	1605/117	0.074	158	450	1000	1500	1900

3. Conclusion

According to the results for the female phonation the subglottal pressure p_{sub} varied in all cases studied between 710 Pa and 2550 Pa, the mean oral pressure p_{av} varied from 0 Pa for phonation on [a:] and [i:] to the maximum 2290 Pa for phonation into the long plastic tube (990 mm in length and 4.5 mm inner diameter) nearly up to about 23 cm under the water. The maximum root mean square pressure measured inside the oral cavity 136.4 dB. The fundamental frequency F0 varied between 146 and 172 Hz. Acoustic results show that the fundamental frequency F0 lowers with the hydrodynamic pressure for the drinking and stirring straws submerged into water, however an opposite tendency was measured for phonation into the resonance tube where F0 being the lowest for phonation into air.

Acknowledgements

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References

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