CORRELATION OF HIGH SPEED FILMS WITH OTHER CLINICAL VOICE MEASUREMENTS

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ABSTRACT

In the clinical work with patients in a medical voice clinic it is important to have a normal **updated reference** for the data used. Several new parameters have to be correlated to older traditional measures.

The older ones are (video)stroboscopy, eventually coordinated with electroglottography (EGG), the Multi-Dimensional-Voice Program and airflow rates.

Long Time Averaged Spectrograms (LTAS) and phonetograms (voice profiles) are calculating the range and dynamics of tones of the patients and area of the voice profile.

High-speed films, and updated airflow measures add information to the understanding of the glottis closure in single movements of the vocal cords.

A multivariate analysis was made to study the relation between the measures. This information can be used in many connections in the clinic , one aspect being quantitative 3D scanning related to the high speed films.

INTRODUCTION

Advanced measures for voice analysis in patients are now-a-days not evidence based for clinical use, in **randomised clinical trials as a basis for** meta-analysis.

Updated Cochrane reviews were made on voice disorders where no RCT **was found (2009 updated: 1.vocal nodules and 2.laryngo-pharyngeal reflux**). Evidence in voice research has been discussed by our group at several conferences, e.g. IFOS 2009.

The problem has to some extend been the lack of normal voice function values that can be used for **voice related medical treatment of allergology, infections of the upper airways as well as reflux, neurological-, hormonal-, emotional-, environmental-, cancer- and genetics voice disorders.**

There is established a updated approach frame of measurement references in a Danish material of amateur student singers for use in our clinic for further research.

INTRODUCTION

In the clinical situation diagnoses of voice disorders will vary, depending on the apparatus, and also on the **cooperation between medical doctors, voice pathologists, engineers and phoneticians.**

The groups are communicating **with gastroenterologists, allergologists, experts of microbiology of infections, lungs, immunology and genetics as well as neurology and environment.**

Their work is coordinated with **statisticians** and used by teachers in singing and speech and other voice related scenario of teaching and – very important especially artificial voicing.

METHODS

18 healthy amateur female singers and 12 healthy amateur male singers between 20 and 40 years of age were analysed in a stratified cohort study.

The following measurements were carried out in the duration of two days:

Multi-Dimensional-Voice-Program combined with video stroboscopy (MDVP) by the firms Key Elemetrics and Laryngograph:

A sustained note ‘ah’ and reading of a standard sentence: - ‘the blue spot is on the key again’, (advised by ASHA) and the story: ‘the Northern wind and the Sun’, (used routinely in Europe) respectively. Jitter and shimmer were measured for the sustained notes. Mean fundamental frequency, frequency- and intensity- variation percent were measured for the sentences’.

For the firm Key Elemetrics also harmonics to noise ratio and degree of voicelessness were measured, and for the firm Laryngograph, also glottal closed phase (Qx%) of the electroglottogram (EGG), and cohesion factor (irregularity)% of the fundamental frequency and the EGG.

Rutine measures were made of phonation time, maximal and minimal tone ranges.

METHODS

Long term average spectrograms (LTAS**)** measurements **up to 11.000** Hz were made with Laryngograph equipment. Calculations of harmonics were made with Key elemetris..

Phonetograms (by the firm Voice Profile Denmark) included calculations of the lowest note, the highest note, maximal dynamics and calculation of **area of voicing in semitones times decibels** (dB(A)).

Airflow measurements were made for sustained notes and consonant/vowels (Aerophone and Aerophone II by F J Electronics and Key Elemetrics), lung volume, peak flow, mean flow rate, phonation times, as well as the parameters of **adduction-abduction rates pr second as an indication of the vocal fold movements pr second, and target flow rate parameters of the mid 50% of the sampled values measured during the loudest 6dB.**

METHODS

High speed digital colour imaging , based on the apparatuses by the firm Wolf, Germany, included qualitative measurements of kymography and FFT up to 4000Hz.

Quantitatively, the opening phase between the vocal cords in front, middle and rear parts and area opening was made based on segmentation calculation in % between the vocal cords. Supplementary EGG were made on line, but till now no on line quantitative measures can be presented of comparison of the EGG and the acoustical curves.

Standard deviations and ranges were made. Multivariate correlations by pair were made and significance probabilities more than 0,5 were included. One way analysis of power (dB) was made by gender with summery of fit.

A model for spectrograms of polynomial fit degrees = 5 was used for the variety fit of power (dB) by frequency (Hz) for sustained notes. For spectrograms of reading of a text the polynomial fit degree = 6 was used for bit variety fit of power (dB) by frequency (Hz). The statistics were made in a frequency area from 0-11.000 Hz and in 3 sub groups of frequency of 200-800 Hz, 2300-2700 Hz and 9.500-11.000 Hz. (SAS institute program, JMP 7 used in the clinic).

RESULTS

The 18 female and 12 male amateur singers had normal video stroboscopies - an evaluation was made that the high speed films were normal too:

The mucosa representing normality and no reactions of e.g. infections, allergies and others.

The arytenoid regions without any oedema or other reactions e.g. related to the swallowing process.

Standard set-up for medical, clinical use

Airflow

MEAN FLOW RATE l pr second	Avera-ge	Low-est	High-est
Male	0,204	0,031	0,527
Female	0,178	0,106	0,318
VITAL CAPACITY			
Male	5,138	3,460	8,876
Female	3,723	2,615	4,219
PEAKFLOW litres pr second			
Male	10,993	8,880	19,920
Female	7,366	5,560	8,840

PHONATION TIME (in Aerophone)	Avera-ge	Lowest	Highest	S.D.
Male	15,0	5,6	23,4	4,6
Female	18,0	9,0	26,8	4,9

The mean flow rate, vital capacity, peak flow and phonation times in 12 normal Danish males and 18 females between 20-40 years of age, on a sustained tone. The average mean flow rate showed a difference between males (204 ml pr second) and females (178 ml pr second).

Standard set-up for medical, clinical use

Fundamental frequency, Jitter and Shimmer

		Range	
Average F0 (Sustained note ”ah”)	Average	Lowest	Highest
Male	140,048	116,040	169,400
Female	272,371	206,620	308,600
Jitter % (Sustained note ”ah”)			
Male	0,320	0,200	1,080
Female	0,541	0,140	2,080
Shimmer % (Sustained note ”ah”)			
Male	7,116	3,090	17,540
Female	8,227	2,010	18,690

Measure on sustained notes for 4 seconds, with jitter and shimmer by MDVP and Laryngograph Ltd. The results of the two firms were correlated.

Standard set-up for medical, clinical use

Fundamental frequency, frequency and intensity variation during reading

		Range	
Average F0 (Speech)	Average	Lowest	Highest
Male	127,898	106,560	171,050
Female	227,405	198,260	262,700
Irregularity of frequenzy (Hz,Speech)			
Male	5,469	3,040	6,770
Female	5,448	2,620	7,550
Irregularity of intensity (dB,Speech)			
Male	18,047	13,950	20,900
Female	13,389	11,460	17,030

Standard set-up for medical, clinical use

Harmonics to noise and degree of voicelessness.

Harmonics to noise ratio	Average	Lowest	Highest	S.D.
Male	0,40	0,23	0,91	0,18
Female	0,37	0,21	0,860	0,220
Degree of voiceless ness				
Male	56,0	22,640	91,340	13,600
Female	66,0	25,260	86,900	18,100

Measures were made with the MDVP program, ranges and standard deviations are presented.

Standard set-up for medical, clinical use

Laryngographic (EEG) measured closed phases (Qx%)

		Range	
Average Qx (Sustained note)	Average	Lowest	Highest
Male	47,944	39,9	63,33
Female	46,032	37,65	60,94
Average Qx (Speech)			
Male	51,248	46,07	58,55
Female	49,239	39,99	57,46

Closed phase (QX %) of the vocal cords on sustained tones ”ah” on a comfortable tone in the speaking area for 4 seconds and during reading of the standard text.

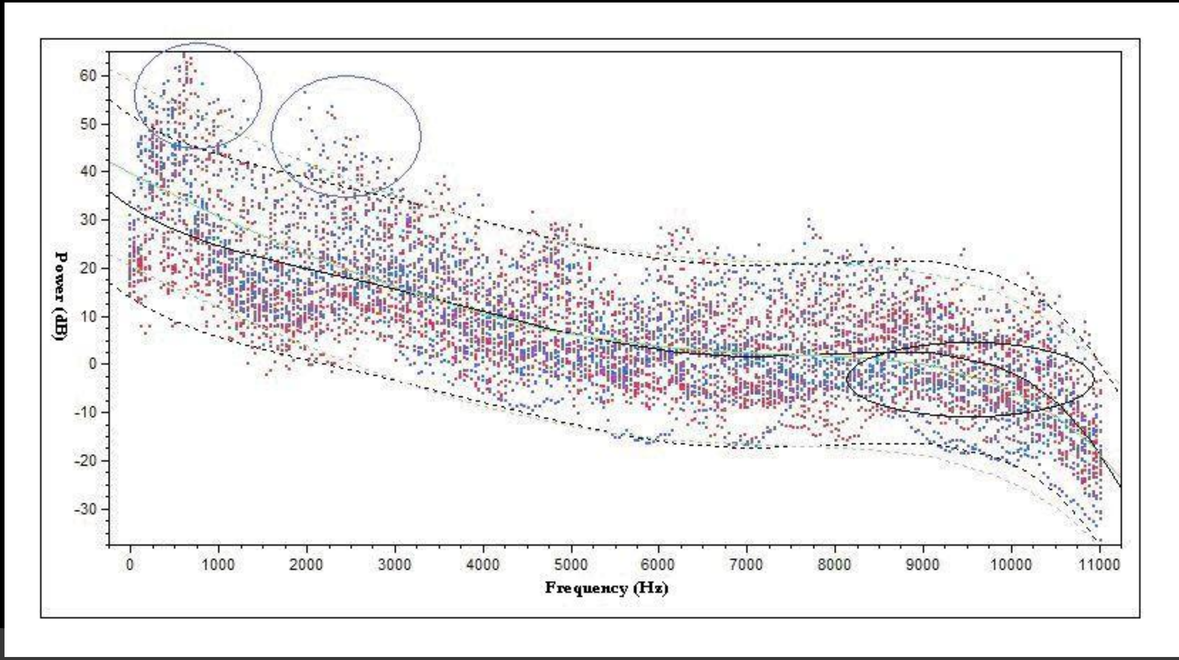
Standard set-up for medical, clinical use

No significant difference was found for fundamental frequency, frequency and intensity variation in reading and for a sustained note for the firms Key Elemetric and Laryngograph. The use of the term jitter and shimmer in reading of a standard text should be replaced by frequency and intensity variation during reading, in percent.

Suggested setup for medical, clinical use

males and females during reading of a standard text .The calculated LTAS differences (none was found for sustaned tones)

The text (Northern wind and the Sun) of both males and females were presented in polynomial fit degree=6. The normal distributions 200-800 hz and 2300-2700 hz were presented and the one way analysis of power (dB) by gender showed that the males had a larger resonance intensity than the females, 31dB versus 28 dB. No difference was found from 9500 -11000hz



Suggested setup for medical, clinical use

Lowest tone	Average	Lowest	Highest	S.D.
Male	87	73,4	98	31
Female	160	131	220	33
Highest tone				
Male	716	622	880	154,8
Female	1084	1568	1245	204,3
Maximal dynamic range				
Male	32	24	57	8,4
Female	37	20	41	9,01
Total area in semitones times decibels				
Male	714	406	1054	202
Female	822	432	1047	214

The calculated results were presented for phonetograms of the lowest tones, 87 Hz for males and 160 for females respectively, the highest tones, 716 and 1084 Hz, the maximal dynamic area 32 dB and 37 dB and the total area in semitones times decibels 714 for males and 822 for females. Ranges were also presented as well as standard deviations.

Suggested setup for medical, clinical use

Airflow	average	Highest	Lowest	S.D
Adduction –Abduction rate /sec				
Male	8,41	11,87	5,64	1,70
Female	7,59	10,37	5,1	1,56
Target flow rate (l/sec)				
Male	0,24	0,45	0,17	0,117
Female	0,17	0,21	0,08	0,05
Target SPL (dB)				
Male	82,00	89,26	77,28	3,80
Female	79,43	87,12	70,86	6,36
Real air pressure (cmH2O)				
Male	8,30	12,22	5,15	2,23
Female	7,83	9,96	4,034	1,64

Some of the important airflow parameters based on the Aerophone II by FJ Electronics included abduction/adduction rate of the vocal cords in movements per second measured during voicing of a?a?a?a? as fast as possible.

Another new measure is the target air flow rate: the average airflow rate of the mid 50% of the sampled flow values, measured during the loudest 6 db of the SPL curve, and real air pressure in cm water.

Suggested setup for medical, clinical use

High speed films, 30 normal singers.

Open quotient front	Ave-rage	Lowest	High-est	S.D.
Male	0,45	0,14	0,92	0,32
Female	0,48	0,37	1,60	0,49
Open quotient centre				
Male	0,51	0,09	1,0	0,27
Female	0,58	0,12	1,0	0,29
Open quotient rear				
Male	0,59	0,07	0,99	0,32
Female	0,48	0,00	1,00	0,31
Area between vocal cords				
Male	0,60	0,04	1,0	0,43
Female	0,68	0,13	1,0	0,30

The open quotients of the high-speed films were calculated in % on segmentation, in front, centre and rear as well as the area of the general open phase, using the equipment and software from the firm Wolf (Gmp).

Statistics related to the Multivariate Analysis with SAS JMP 7 statistical program

A multivariate statistics made with SAS JMP statistics showed correlations between the suggested measures. The clinical value of the results is that it documents the voicing as a wind instrument, to be used in the clinical setting with patients with especially mucosal and neurological disorders, where the airflow regulation is compromised.

40 significant measures were calculated in this study of normal clients, examples are

<u>High speed films or also called high speed - digital imaging (HSDI):</u>
The multivariate analysis showed in this normal material

r   .8130, and p 0.0001 for HSDI open quotient front versus HS open quotient centre.,
r   .6748, and p 0,0021 for HSDI open quotient front versus HS area between the vocal cords,
r   .7574, and p 0,0003 for HSDI open quotient centre versus HS area between the vocal cords.

A correlation of
r . 4567,and p 0,0568 was found between the high speed films area between the vocal cord and the closed phase on the electroglottogram (EGG, Qx%) during reading of a standard text.

Statistics related to the Multivariate Analysis with SAS JMP 7 statistical program

Phonetograms:

r   -.6524, and p <0,0001 for the maximal dynamic range (dB) versus the phonetogram area in semitones times decibels

r   -.6123, and p 0,0003 for the lowest tone (Hz) versus peak flow rate in litres/sec.

r   -.5800, and p 0,0008 for the lowest tone (Hz) versus the vital capacity in litres.

r   -.5743, and p 0,0017 for the highest frequency (Hz) versus the target flow rate in litres/sec.

r   -.3677, and p 0,0456 for the dynamic range in dB of the phonetogram versus the maximum phonation time in sec.

Statistics related to the Multivariate Analysis with SAS JMP 7 statistical program

Aerophone II:

r .8461, and p< 0,0001 for peak flow (litre/seconds) versus vital capacity (litre)

r .5065, and p 0,0060 for max phonation (seconds) time versus mean air flow rate (litre/sec)

r .4594, and p 0,0107 for ad/abduction rate (cps) versus phonation quotient (litre/sec)

r .5027, and p 0,0123 for target flow rate (litre/second) versus target resistance

r .-3675, and p 0,0543 for ad/abduction rate (cps) versus mean flow rate (litre/sec)

DISCUSSION

- Normal materials of voice measurement for clinical laryngological use vary with age and local language as well as with cultural language. We have earlier measured the fundamental frequency and phonetograms up to 18-19 years of age compared with hormonal development and secondary gender characteristics. (Normal development of voice Springer 2008). The same approach will be made again for the aging of the voice. The suggested air flow measures and as well as quick and easy high speed filming will make the results even more up-dated for comparison with pathology - in busy ear-nose-throat clinics.
- LTAS averaged from 1-11.000 Hz was made in our large materials on sustained tone and in reading of a standard text in 12 normal males and 18 females aged 20-40 years shows significant differences between the genders during reading. Single plots though give no information about the quality of the voice, usable in pathology related e.g. to allergy, infections of the upper airways, reflux and many other disorders, except in extreme cases. Quantitative 3D pictures of the larynx might .

DISCUSSION

- The open quotient in high speed films is interesting.
- Variations give information as a basis for quantitative diagnosis and treatment e.g. of posterior laryngitis with edema to be quatified as seen in laryngo-pharyngeal reflux,
- The open quotient in high speed films is interesting also for development of voice with changing registers, related to the newer popular singing techniques.
- Neurological disorders, e.g. dystonia patients often have reduced open phases and irregular patterns.
- Various voice related technical speaking and singing problems are illustrated with the closure in front, centre and rear part of the vocal cords. Our set up combined on line with the acoustical, electroglottographical (EGG) and kymographical signals show the clinical ear-nose-throat specialist where the disorder is located.
- We have presented statistical relations for the new measures of high speed films, LTAS, phonetograms area and the airflow related parameters. The high correlations in the SAS statistical program indicate that these measurements must be used much more in the future. This is a promising cue to further understanding of the voice as a wind instrument.

CONCLUSION

- The medical clinical tools: high speed films were evaluated in 30 amateur singers and the (normal) results were correlated with other parameters measured at the same time in a multivariate statistical analysis with SAS JMP. Measures of air function show that airflow analyses must be used much more in the future since the significant values related to voice were high.

- The aspect of air pressure measurement is a promising for clinical trials of treatment effect of upper airway disorders. For high speed films the quantitative measurements must be further developed. Till now, the measures presented in the MDVP and Laryngograph set-ups including phonetography get heavily better scientific perspectives of accuracy with high speed films and updated airflow measures for measurement of pathology usable for development of quantitative 3D measures.

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