Update of acoustical standard measures for clinical voice analysis.

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Keywords: normal voice parameters

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Pedersen M (2008). Update of acoustical standard measure for clinical voice analysis. *The 6th international conference on voice physiology and biomechanics.Tampere. (Poster)*

1. 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 (1). A number of reviews were made on voice disorders where no RCT was found (2-3). Evidence in voice research has been discussed by our group at several conferences (4-9). The problem has to some extend been the lack of normal voice function values that can be used for medical treatment (effect) of allergology, infections of the upper airways as well as reflux, emotional and environmental voice disorders. Therefore we have established a normal frame of measurement references in a Danish material. In the clinical situation diagnoses of voice disorders will vary, depending on the apparatuses, and also on the cooperation between different experts:

1. Medical doctors
2. Voice pathologists
3. Engineers
4. Phoneticians

As for the first group and the second group, there are laryngologists and voice pathologist with more pharmacological and life style related approaches, more surgery related approaches, both groups communicating with gastroenterologists, allergologists, experts of microbiology of infections, immunology and genetics as well as neurology. The work is coordinated with statisticians and used by teachers in singing and other voice related scenario of teaching.

The third group, engineers, secure correct measurement, but mostly till now engineers are not familiar with evidence based clinical approaches of pathology, which makes their priority of measurements difficult, also because their dialog with the regular ear-nose-throat specialists has been underestimated or lacking, in most parts of the world. Both the third and the fourth group seem to be aware of necessity problem solving. In the future updated evidence based voice analyses should be made regularly, for clinical use by all four groups.

2. Materials

18 healthy amateur female singers and 12 healthy amateur male singers between 20 and 40 years of age were analysed. At their inclusion a phonetogram was made which means that they could reproduce a given tone. Normal values for phonetograms as well as the appearance of the averaged phonetograms in adults are given among others in the regime of F J Electronics (13).

3. Methods

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

A. Multi-Dimensional-Voice-Program (MDVP) (10) by the firms Key Elemetrics and Laryngograph (11) including sustained tones and reading of a standard sentence: -the blue spot is on the key again, and the story: -the north win and the sun, respectively. Mean fundamental frequency, frequency and intensity variation percent were measured. For the firm Key Elemetrics also harmonics to noise ratio and degree of voiceless ness, and for the firm Laryngograph, also glottal closed phase (Qx%), and cohesion factor (irregularity)%. Long term average spectrograms (LTAS) measurements were made with Laryngograph equipment. The calculations were made on Key Elemetrics equipment.

B. Phonetograms (by the firm Voice Profile) (12) - including calculations of the lowest tone, the highest tone, maximal dynamics and calculation of area of voicing in semitones times decibels (dB(A)).

C. Airflow measurements for sustained tones and consonant/vowels (Aerophone II by F J Electronics, Denmark) (13): lung volume, peak flow, mean flow rate and more updated new parameters.
High speed films by the firm Wolf, Germany (14), which include many qualitative measurements, quantitatively of the opening phase between the vocal cords in front, middle and rear and an area opening calculation in % between the vocal cords.
Standard deviations were made. Multivariate pair wise correlations 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 of polynomial fit degrees=5 was used for bit variety fit of power (dB) by frequency (Hz) for sustained tones. For reading of a text and 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) (15)

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4. Results

The clients had normal video stroboscopies and the measurements, as analysed with statistics from the SAS Institute will be used as normal values in our clinic further on. Some results (*1a + 1b*) were already presented earlier by invitation at the XIIth Congress of the International Rhino logical Society, (round table on coughing and voice disorders in rhinitis and asthma, the role of allergy and medication, Venice 2007) (16).

Table 1
shows the mean flow rate, vital capacity and peak flow in *table 1a*, compared with jitter and shimmer as well as electroglottigraphical closed phase (Qx%) on sustained tone, a comparison was made to frequency and intensity variation and Qx% in reading of a standard text in *table 1b* in this defined normal material, *corresponding to a normal upper airway mucosa and anatomy, including a normal larynx by video stroboscopy and high speed films, of the vocal cords, the tong root, recesses of the larynx, backward region including the arytenoid cartilages and opening to the oesophagus (16).*

table 1a Range

MEAN FLOW RATE	Average	Lowest	Highest
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			
Male	10,993	8,880	19,920
Female	7,366	5,560	8,840

No significant difference was found for fundamental frequency, frequency and intensity variation in reading and for a sustained tone for the firms Key Elemetric and Laryngograph. The use of the term jitter and shimmer in reading of a standard text should be probably in the future be replaced by frequency and intensity variation in percent.
The Harmonics to Noise Ratio and degree of voiceless ness measured with the Key Elemetrics program are shown for these normal persons in *table 1c.*

table B Range

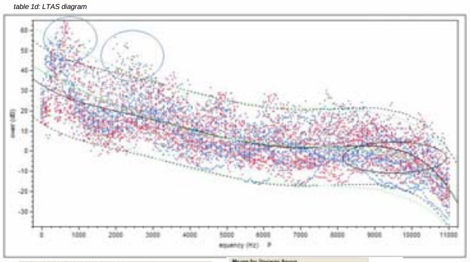
	Average	Lowest	Highest
F0			
Male	127,898	106,56	171,05
Female	227,405	198,260	262,700
Jitter (Speech)			
Male	5,469	3,04	6,77
Female	5,448	2,620	7,550
Shimmer (Speech)			
Male	18,047	13,95	20,9
Female	13,389	11,460	17,030
Average Qx (Speech)			
Male	51,248	46,07	58,55
Female	49,239	39,990	57,460
Average Fx (Sust.note)			
Male	140,048	116,04	169,4
Female	272,371	206,620	308,600
Jitter (Sust.tone)			
Male	0,32	0,2	1,08
Female	0,541	0,140	2,080
Shimmer (Sust.tone)			
Male	7,116	3,09	17,54
Female	8,227	2,010	18,690
Average Qx (Sust.tone)			
Male	47,944	39,9	63,33
Female	46,032	37,650	60,940

table 1c

HARMONICS TO NOISE ratio	Average	Range Lowest	Highest	S.D.
Male	0,40	0,23	0,91	0,18
Female	0,37	0,21	0,86	0,22
Degree of voiceless ness				
Male	56,0	22,64	91,34	13,6
Female	66,0	25,26	86,90	18,1
Irregularity% (speech) Fx				
Male	19,518	6,41	71,49	
Female	8,525	7,36	14,89	
Irregularity% (sust.note) Fx				
Male	0,788	0,22	4,06	
Female	0,415	0,09	1,00	
Irregularity% (speech) Qx				
Male	40,209	28,35	82,01	
Female	33,211	3,79	63,77	
Irregularity% (sust.note) Qx				
Male	7,987	0,40	31,03	
Female	25,218	0,46	60,73	
Phonation time (in Air Phone II)				
Male	15	5,6	23,4	4,6
Female	18	9,02	26,8	4,9

The cohesion factors or irregularity percents for all measures versus the ones were two resemble each other are presented. A division is made for reading of a standard text (the north win and the sun) and a sustained tone for 4 seconds. The phonation times are also presented.
LTAS results are presented *in table 1d*, showing significant different results of harmonics between males and females. The difference is presented specifically at the areas 200-800 Hz, 2300-2700 and 9500-11000 Hz in
table 1d,a:
a: The sustained tones of both males and females are presented in polynomial fit degree=5 areas are marked from 200-800, 2300-2700 and also 9500-11000.
With one way analysis of power by gender, a difference is found between resonance power, better for males at the area 200-800 Hz (40 vs 34 dB). At the area between 2300-2700 (23 vs 20 dB) the resonance power is also better for men. But at 9500-11000 Hz there is a slightly better result for females. Measurements from 9500-11000 Hz based on a polynomial fit degree=5 of sustained tones.

table 1d: LTAS diagram



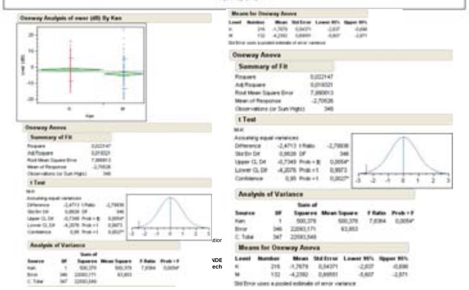
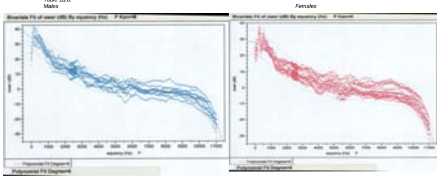


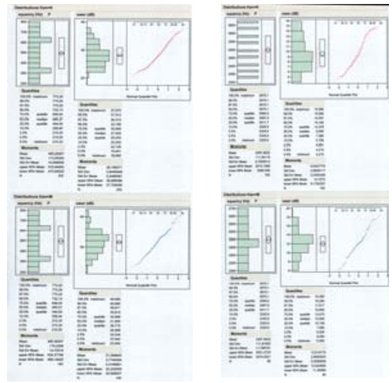
table 1d,b:
The text (north win and the sun) of both males and females are presented in polynomial fit degree=6. The normal distributions at 200-800 Hz and 2300-2700 Hz are presented and the one way analysis of power (dB) by gender showed that the males had a larger resonance than the females (31 vs 28 dB) at 200-800.

Table 1d,b:
Males *Females*



Results continued

table 1d,b continued



In *table 2* the calculated results are presented for phonetograms of the lowest-, highest tones, the maximal dynamic area and the total area in semitones times decibels for males and females.
In *table 3* an attempt has been made to select some of the most important new airflow parameters.

table 2 30 normal amateur singers
PHONETOGRAMS

	Average	Range Lowest	Highest	S.D.
Lowest Tone				
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

table 3 30 normal amateur singers
Aerophone II

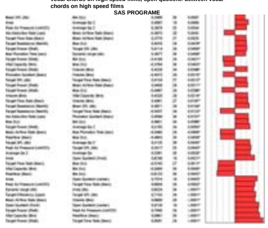
	Average	Range Highest	Lowest	S.D
Adduction – Abduction rate				
Male	8,41	11,87	5,64	1,70
Female	7,59	10,37	5,1	1,56
Target flow rate (l/sec)				
Male	0,24	0,45	0,17	0,117
Female	0,17	0,216	0,08	0,05
Target SPL (dB)				
Male	82,00	89,26	77,28	3,80
Female	79,43	87,12	70,86	6,36
Real air pressure (cmH2O)				
Male	8,30	12,22	5,15	2,23
Female	7,83	9,96	4,034	1,64

In *table 4* the open quotients of the high-speed films are presented, in front, centre and rear as well as the area calculations of the general open phase %.
A multivariate statistics made with SAS institution showed many interesting connections in *table 5.*

table 4 30 normal amateur singers
HIGH SPEED FILMS

	Average	Range Lowest	Highest	S.D.
Open quotient front				
Male	0,45	0,14	0,92	0,32
Female	0,48	0,37	1,6	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	1,0	0,31
Area between vocal cords				
Male	0,60	0,04	1,0	0,43
Female	0,68	0,13	1,0	0,30

Table 5:
STATISTICAL CONNECTIONS
MULTIVARATE ANALYSIS FOR BOTH GENDERS, Qx means electroglottographical closed phase in sustained tones, Qx2 electroglottogaphical closed phase in speech, area: between vocal chords on high speed films, open quotient: between vocal chords on high speed films
SAS PROGRAME



The clinical value of the results, document the voicing as a wind instrument with most significant connections to the Aerophone II measurements.

5. Discussion

Normal materials of voice measurement vary of course with age. We have earlier measured the fundamental frequency and phonetograms at school age up to 18-19 years of age (17) compared with hormonal development and secondary sex characteristics. The same approach has been not yet been made with aging of voice.
LTAS from 1-11.000 Hz have to be made in larger materials on sustained tone and in speech (reading?). Single plots give no information about the quality of the voice usable in pathology related e.g. to allergy, infections of the upper airways and reflux, except in extreme cases. The open quotient in high speed films is interesting, variations give information as a basis for treatment e.g. of posterior laryngitis as seen in larying-pharyngeal reflux, development of voice and various technical problems related to the closure in front, centre and rear part of the vocal cords.
We have presented statistical significant relations especially to airflow related parameters. We have not sorted out the standard deviations after mutual dependencies on Aerophone II. But the high significances for correlations 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. The documentation aspects of treating allergy, infection and reflux at the laryngeal level certainly have taken a step forward with video stroboscopy, combined with quantitative high speed films (18) and a significantly related frame of normality for physiological and acoustical measures.

6. Conclusion

The clinical usable tools: video stroboscopy and high speed films were evaluated in 30 amateur singers and the (normal) results were statistically compared with physiological and acoustical parameters measured at the same time. The results of air function must be used much more in the future since the significant values related to sound were high. The aspect of air pressure measurement is also a promising for clinical trials of treatment effect of upper airway disorders. For high speed films the quantitative measurements must be further developed.