https://doi.org/10.3176/lu.1998.3.21

JAANA SELLMAN (Espoo)

PRELIMINARY EVALUATION OF SELECTED ACOUSTIC PARAMETERS AS SENSITIVE INDICATORS OF DIFFERENCES BETWEEN WOMEN WITH AND WITHOUT VOCAL NODULES

Acoustic measures are often considered to be well-defined, objective and reliable. J. Laver, S. Hiller and J. Mackenzie Beck (1992) suggest that the possible clinical applications of acoustic analysis are screening of a given population, priority assessment of patients visiting their general practitioner, diagnostic support, monitoring to assess voice changes over time of patients receiving surgery, radiotherapy, chemotherapy, or speech therapy or to track deterioration in progressive disease.

Some of the acoustic measures that have proven to be clinically useful are mean fundamental frequency, frequency variability (F0std), frequency range, frequency perturbation, mean sound pressure level, amplitude variability, dynamic range and amplitude perturbation (Stemple 1993). Frequency (jitter) and amplitude (shimmer) perturbation are measurements of how much a given period differs from the period that immediately follows it. Measurements of jitter and shimmer serve to quantify short-term instability of the vocal signal. Jitter is believed to be a reflection of involuntary changes in frequency, as opposed to voluntary changes of pitch and intonation (Baken 1987). According to R. F. Orlikoff (1995) perturbation measures reflect a speaker's capacity to maintain ventilatory and laryngeal parameters to produce a stable vocal output.

1. Purpose of study

The purpose of this study was to examine 14 acoustic parameters to determine which acoustic variable(s) might be sensitive indicators of differences between a vocal nodule group and a control group. In addition to this correlations between the average fundamental frequency and sound pressure level and other acoustic parameters were examined.

2. Method

2.1. Subjects and speech task

Sixteen women ranging in age from 19 to 42 years with a mean age of 30 years, participated in this study. Nine of them had vocal nodules and seven had normal vocal status (= control group). Laryngeal examination was conducted by a phoniatrician for all the subjects.

The subjects were asked to produce a sustained /a/ three times for several seconds at three different pitch and three different loudness levels. For this study voice samples produced at a louder than normal comfortable loudness level was selected.

2.2. Recordings and acoustic analysis

The acoustic signal was recorded using an omnidirectional microphone (Brüel & Kjaer 4176) positioned 30 cm from the speaker's mouth. The signal was recorded on a digital tape recorder (CASIO DA-7 Portable Audio Tape Recorder). The sound pressure level meter (Brüel & Kjaer 2235) weighting was linear network ("Lin").

Three seconds of each subjects' three phonations were analysed using a Multi-Dimensional Voice Program (MDVP) in CSL by Kay Elemetrics. MDVP provides 33 acoustic parameters. In this study 14 of these were statistically analysed. The parameters selected for closer study were:

— average fundamental frequency (= F0),
— standard deviation of F0 (= F0std),
— fundamental frequency variation (= vF0),
— peak-amplitude variation (= vAm),
— noise to harmonic ratio (= NHR),
— five jitter parameters: absolute jitter (= Jita), jitter percent (= Jitt), relative average perturbation (= RAP), pitch perturbation quotient (= PPQ), smoothed pitch perturbation quotient (= sPPQ),
— four shimmer parameters: shimmer in dB (= ShdB), shimmer percent (= Shim), amplitude perturbation quotient (= APQ), smoothed amplitude perturbation quotient (= sAPQ).

The second sample of each subject's three phonations was selected for statistical analysis. The mean sound pressure level was analysed using the Computerised Speech Lab (CSL). No signal calibration was used, so the SPL values given in this study provide only information about signal loudness compared to each other and do not give any information about the absolute sound pressure level.

3. Results

To determine which acoustic parameter(s) might be sensitive indicators of differences between the vocal nodule group and the control group the mean values of 14 acoustic parameters were calculated for both groups. A two-tailed t-test was performed to determine if there was a significant group difference for those 14 parameters.

Table 1 shows the mean, standard deviation, minimum and maximum values of acoustic analysis for control and for vocal nodule groups.

3.1. Acoustic parameters discriminating among two groups

The average fundamental frequency for control group was 233 Hz and for pathologic voice group 243 Hz respectively, no statistical difference between two groups was observed. Results of t-test indicated that values of standard deviation of fundamental frequency (F0std) and fundamental frequency variation (vF0) were significantly higher ($p < .01$, $p < .05$) in the group with vocal nodules than in the control group.

The values of peak-amplitude variation (vAm) and noise to harmonic ratio (NHR) were a little lower in control group, although the results of t-test did not indicate significant differences for two groups.

Table 1

Mean, standard deviation, minimum and maximum values of acoustic analysis for the normal and vocal nodule groups

Acoustic parameter	Normal		Vocal nodules	
	Mean (sd)	**Min—max**	**Mean (sd)**	**Min—max**
F0	233 (22.19) Hz	206—266 Hz	244 (25.69) Hz	191—283 Hz
F0std	1.8 (0.48)	1.32—2.69	2.90 (0.68)	2.12—4.19
vF0	0.8 (0.25)	0.50—1.20	1.19 (0.28)	0.82—1.79
Jita	18.5 (3.71)	14.38—23.86	43.0 (23.30)	11.46—85.763
Jitt	0.43 (0.095)	0.35—0.59	1.00 (0.45)	0.33—1.64
RAP	0.25 (0.058)	0.19—0.35	0.60 (0.29)	0.18—1.00
PPQ	0.26 (0.056)	0.196—0.34	0.59 (0.26)	0.18—0.96
sPPQ	0.45 (0.14)	0.31—0.68	0.79 (0.25)	0.48—1.15
SPL	66.9 (3.08)	63—70	66.3 (3.21)	61.1—70.8
vAm	12.1 (9.99)	3.41—33.21	17.85 (7.55)	11.31—33.88
ShdB	0.25 (0.17)	0.11—0.62	0.46 (0.27)	0.18—0.93
Shim	2.74 (1.53)	1.24—6.00	5.07 (3.57)	2.08—9.21
APQ	2.65 (2.55)	0.91—8.38	4.23 (3.57)	1.51—12.99
sAPQ	5.15 (4.71)	1.54—15.29	7.60 (7.55)	2.11—27.20
NHR	0.12 (0.009)	0.11—0.14	0.14 (0.028)	0.11—0.19

Five different jitter algorithms (Jita, Jitt, RAP, PPQ, sPPQ) were calculated in this study. All of them showed a significant difference between the normal and pathologic female voice. All five average jitter values in women with vocal nodules were significantly higher than in women without vocal nodules. Absolute jitter had a somewhat lower probability ($p < .05$) than the other jitter algorithms ($p < .01$).

Altogether four shimmer algorithms (ShdB, Shim, APQ, sAPQ) were compared in this study. All the shimmer values were somewhat lower in normal female voice than in pathologic voice, but none of those showed a significant difference between the two groups in two-tailed t-test.

All the jitter values of control group were under the threshold values given by MDVP. In vocal nodule group jitter the normative threshold values were exceeded by six subjects. In the case of shimmer values the values of three normal subjects and respectively seven subjects with vocal nodules were over the normative shimmer thresholds.

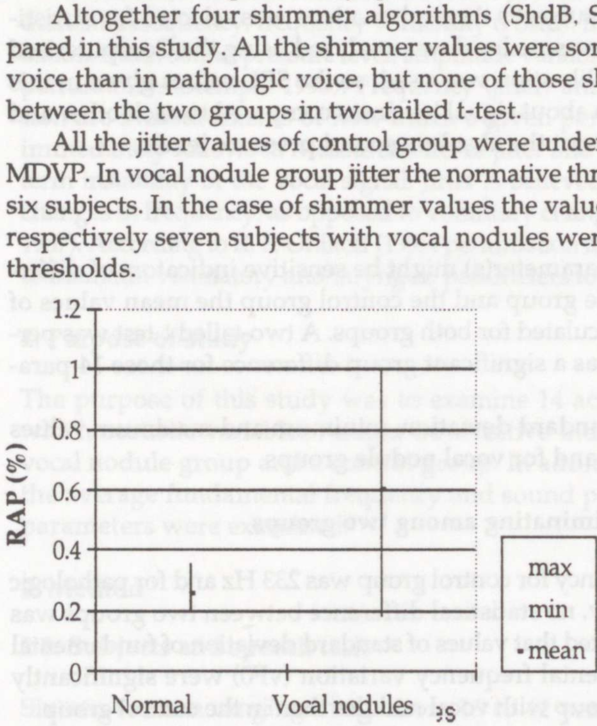

Figure 1. **Intragroup variability of relative average perturbation (= RAP) for the vocal nodule and control groups.**

Figure 1 presents an example of intragroup variability of one acoustic parameter (RAP) in both groups. It is seen in Table 1 that the intragroup variability for almost all parameters, is much larger in the pathologic than in normal group. Because of the great variability in the vocal nodule group there is overlap of the perturbation measures in normal and vocal nodule speakers.

3.2. Correlations of F0, SPL and other acoustic variables

Table 2 presents the correlation data for perturbation measures and F0 as well as SPL. Statistically significant correlations were found between the fundamental frequency and four jitter parameters in the vocal nodule group. The higher the pitch of the pathologic voice the lower the jitter value. This was, however, not true in the control group, where only the fundamental frequency and fundamental frequency variation (vF0) indicated significant correlation (–.70, $p < .05$). In the control group the correlation of F0 and vF0 indicates that the higher the pitch the lower the variation of fundamental frequency.

Table 2

Correlation coefficients of fundamental frequency (F0), sound pressure level (SPL) and other acoustic parameters (* = p < .05, ** = p < .01, *** = p < .001)

	F0			SPL		
	All n = 16	Normal n = 7	Vocal nodules n = 9	All n = 16	Normal n = 7	Vocal nodules n = 9
1. F0				.1776	–.1950	.4611
2. F0sd	.1693	–.5316	–.2653	.0492	.3666	.0766
3. vF0	–.1589	–.7012 *	–.2206	–.0256	.3562	–.1447
4. Jita	–.4229	–.0697	–.89 ***	–.318	.7008 *	–.4958
5. Jitt	–.2851	.3507	–.8028 **	–.3088	.5860	–.5077
6. RAP	–.2875	.3580	–.7907 **	–.3192	.5200	–.5095
7. PPQ	–.2950	.4432	–.8459 **	–.3205	.5979	–.5365
8. sPPQ	.0053	–.5276	–.0785	.0071	.0578	.1252
9. SPL	.1776	–.1959	.4611			
10. vAm	–.0988	–.1479	–.2355	–.5450 *	–.5725	–.5285
11. ShdB	–.1490	.1247	–.4484	–.6453 **	–.6409	–.6948 *
12. Shim	–.1732	.1274	–.4893	–.6067 **	–.6569	–.6503 *
13. APQ	–.1204	.0673	–.3106	–.6608 **	–.5589	–.7197 *
14. sAPQ	–.0675	–.0894	–.1315	–.6293 **	–.5809	–.6610 *
15. NHR	–.2374	.3802	–.5585	–.6649 **	–.8012 **	–.7409 **

When the correlations of sound pressure level and other acoustic parameters were examined, a significant correlation (.70, $p < .05$) was found between SPL and absolute jitter in the control group. Also the other jitter parameters (Jitt, RAP, PPQ) indicated some correlation with SPL, but because of the small number of subjects they did not reach statistic significance. In women with a normal voice, correlations between SPL and frequency perturbation measures were positive indicating that when the sound pressure level increased so did the jitter values. In the vocal nodule group SPL and jitter values responded in different ways compared to the control group. The correlations were negative, indicating that jitter values decreased when sound pressure level increased. Correlations in the vocal nodule group were not however statistically significant. Figure 2 presents the values of absolute jitter and fundamental frequency for the vocal nodule group and Figure 3 shows the values of absolute jitter and sound pressure level for the normal group. The results show that the higher or the louder the voices of subjects the more similar are also the jitter values of pathologic and normal voice.

Correlation between SPL and NHR was high ($r = –.80$ for normal and $r = –.74$ for pathologic voices, $p < .01$) and statistically significant for both groups indicating that the louder the voice the better the NHR value.

SPL and short-term amplitude perturbation measures correlated significantly in the pathologic group (ShdB: –.69, Shim: –.65, APQ: –.72, sAPQ: –.66; $p < .05$). SPL and the shimmer parameters responded in similar ways in the control group as in vocal nodule group, but because of the small number of subjects they did not reach statistical significance.

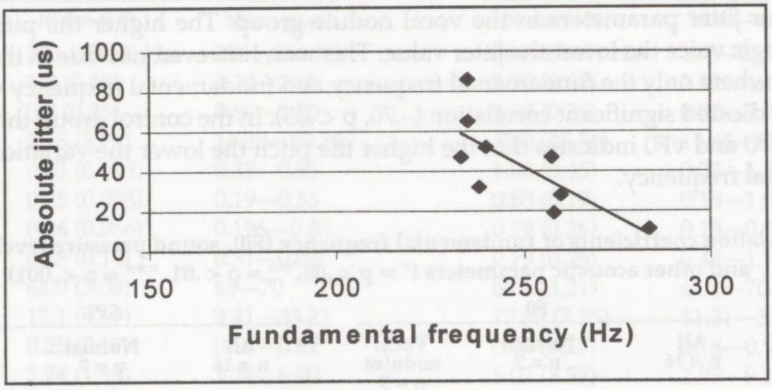

Figure 2 . **Correlation of F0 and absolute jitter in the vocal nodule group.**

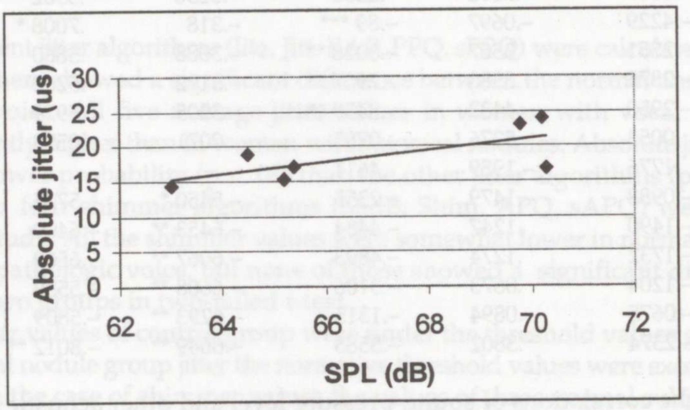

Figure 3. **Correlation of SPL and absolute jitter in the normal group.**

4. Discussion

The results of this study may indicate that certain acoustic parameters of voice may be more sensitive indicators of laryngeal pathology than others. In general, the vocal nodule group had higher and more variable perturbation scores compared to the control group. The standard deviation of fundamental frequency (F0std), fundamental frequency variation (vF0), absolute jitter (Jita), jitter percent (Jitt), relative acoustic perturbation (RAP), frequency perturbation quotient (PPQ) and smoothed frequency perturbation quotient (sPPQ) proved to be sensitive indicators of differences between women with and without vocal nodules in the Multi-Dimensional Voice Program. If the number of subjects had been bigger, the difference in shimmer values might also have reached statistical significance.

Knowing that vocal nodules increase the vibrating mass of vocal cords, it would have been expected that the mean fundamental frequency of pathologic group would have been lower than in control group. However, in this study the opposite effect was found. A possible reason for this is the phonation task. Subjects were asked to produce sustained phonation at louder than their comfortable loudness level so increased effort took place when producing the phonation. It is likely that women with vocal nodules strengthen their voice using a different technique than females with normal vocal status. The subjects with vocal nodules might have used more air pressure to get the increased mass of vocal cords in vibration. This could have led to more pressed manner of voice production and also to a higher fundamental frequency, particularly when producing loud voice.

It is known that the lower the fundamental frequency the higher is the perturbation (e.g. Lieberman 1963). The pattern of jitter parameters indicate that the least amount of fundamental frequency perturbation of voice occurred at high pitch phonations particularly in the vocal nodule group. According to A. K. Silbergleit, A. F. Johnson, B. H. Jacobson (1997) there is less room for vocal variability at a high pitch than at a comfort or low pitch. Also the size of vocal nodules might have had some effects on this correlation. It can be assumed that the anatomic dissimilarity of the vocal cords in the pathologic group is much greater than in control group. This can explain the high variability of acoustic scores, particularly in the vocal nodule group.

J. C. Stemple (1993) has claimed that the direct clinical management techniques used daily with voice disordered patients have not been tested by scientific procedures. I suppose one reason for this is the lack of valid methods and standards. Although acoustic analysis is considered objective voice analysis method some researchers (e.g. Bielamowicz, Kreiman, Gerratt, Dauer, Berke 1996) have almost given up on the possibility of using perturbation measures and their utility in analysing vocal quality. It has been claimed that jitter cannot be measured validly when voices are aperiodic, which is usually the case when dealing with pathologic voice (e.g. Bielamowicz, Kreiman, Gerratt, Dauer, Berke 1996). Also, R. C. Rabinov, J. Kreiman, B. R. Garrett, S. Bielamowicz (1995) has reported that objective methods quickly broke down as severity of voice disorder increased. Methodology-oriented studies of perturbations have led to researchers seriously considering the abandonment of jitter as a measure of pathological voice. However, in this study it has been shown that perturbation measures, especially jitter parameters are able to discriminate normal and pathologic voice. However, great caution must be exercised when giving threshold values for normal and pathological voice. A single value of jitter does not always tell whether the subject has normal or pathological vocal status.

Methodological studies will give us more information of the acoustic perturbation itself and are therefore very important. However, in order to develop more clinical applications for acoustic analysis, all clinicians and speech therapists should do more application-oriented case-studies; to evaluate the acoustic parameters as part of their assessment and monitoring. There is also a need for longitudinal studies of acoustic parameters of the voice in patients with voice disorders. Longitudinal studies would improve our knowledge of the sensitivity of acoustic variables giving us information about the pattern of vocal change as a result of voice therapy. The results of monitoring vocal changes during therapy have the potential to assist clinical decision-making of different therapy methods as well as the duration of therapy.

REFERENCES

Baken, R. J. 1987, Clinical Measurement of Speech and Voice, Boston.

Bielamowicz, S., Kreiman, J., Gerratt, B. R., Dauer, M. S., Berke, G. S. 1996, Comparison of Voice Analysis Systems for Perturbation Measurement. — Journal of Speech and Hearing Research 39, 126—134.

Laver, J., Hiller, S., Mackenzie Beck, J. 1992, Acoustic Waveform Perturbations and Voice Disorders. — Journal of Voice 6, 115—126.

Lieberman, P. 1963, Some Acoustic Measures of the Fundamental Periodicity of Normal and Pathologic Larynges. — Journal of the Acoustical Society of America 35, 344—353.

Orlikoff, R. F. 1995, Vocal Stability and Vocal Tract Configuration. An Acoustic and Electroglottographic Investigation. — Journal of Voice 9, 173—181.

Rabinov, R. C., Kreiman, J., Gerratt, B. R., Bielamowicz, S. 1995, Comparing Reliability of Perceptual Ratings of Roughness and Acoustic Measures of Jitter. — Journal of Speech and Hearing Research 38, 26—32.

Silbergleit, A. K., Johnson, A. F., Jacobson, B. H. 1997, Acoustic Analysis of Voice in Individuals with Amyotrophic Lateral Sclerosis and Perceptually Normal Vocal Quality. — Journal of Voice 11, 222—231.

Stemple, J. C. 1993, Voice Research: So What? A Clearer View of Voice Production, 25 Years of Progress; the Speaking Voice. — Journal of Voice 7, 293—300.