Acoustic and capacity analysis of voice academic teachers with diagnosed hyperfunctional dysphonia by using DiagnoScope Specialist software

Hanna Zielińska-Bliźniewska, Piotr Piekiewicz, Jarosław Miloński, Joanna Urbaniak, Jurek Olszewski

Department of Otolaryngology and Laryngological Oncology, Medical University of Łódź, Poland, Head: J. Olszewski, MD, PhD, Poland

ARTICLE INFO

Article history:
Received: 07.01.2013
Accepted: 05.02.2013
Available online: 08.02.2013

Keywords:
• Voice acoustic
• Capacity analyses
• Hyperfunctional dysphonia

OBJECTIVES: The aim of the study was to assess the acoustic and capacity analyses of voice in academic teachers with hyperfunctional dysphonia using DiagnoScope Specialist software. Material and methods: The study covered 46 female academic teachers aged 34–48 years. The women were diagnosed with hyperfunctional dysphonia (with absence of organic pathologies). Having obtained the informed consent, a primary medical history was taken, videolaryngoscopic and stroboscopic examinations were performed and diagnostic voice acoustic and capacity analyses were carried out using DiagnoScope Specialist software. Results: The acoustic analysis carried out of academic teachers with diagnosed hyperfunctional dysphonia showed enhancement in the following parameters: fundamental frequency (FO) by 1.2%; relative average perturbation (Jitter by 100.0% and RAP by 81.8%); relative amplitude perturbation quotient (APQ) by 2.9%; non-harmonic to harmonic ratio (U2H) by 16.0%; and noise to harmonic ratio (NHR) by 13.4%. A decrease of 2.5% from normal values was noted in relative amplitude perturbation (Shimmer). Formant frequencies also showed reduction (F1 by 10.7%, F2 by 5.1%, F3 by 2.2%, and F4 by 3.5%). The harmonic perturbation quotient (HPQ) was 0.8% lower and the residual harmonic perturbation quotient (RHPQ) 16.8% lower, with the residual to harmonic (R2H) decreasing by 35.1 per cent; the sub-harmonic to harmonic (S2H) by 2.4%; and the Yagishihara coefficient by 20.2%. Conclusions: The capacity analysis with the DiagnoScope Specialist software showed figures significantly lower than normal values of the following parameters: phonation time, true phonation time, phonation break coefficients, vocal capacity coefficient and mean vocal capacity.

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* Corresponding author at: Klinika Otolaryngologii i Onkologii Laryngologicznej II Katedry Otolaryngologii UM, ul. Żeromskiego 113, 90-549 Łódź, Poland. Tel.: +48 6393580; fax: +48 6393580.
E-mail address: jurek.olszewski@umed.lodz.pl (J. Olszewski).

http://dx.doi.org/10.1016/j.otpol.2013.02.001
Introduction

Functional voice disorders, known as functional dysphonia may occur in three forms, hyper-, hypo- and dysfunctional; of these the hyperfunctional form predominates. Hyperfunctional dysphonia makes up about 60 per cent of voice disorders and occurs mostly in occupational voice users [1]. Teaching appears to be the profession with a substantial vocal loading. In Poland some academic teachers are registered with certified compensable occupational disease. In general, teachers have no voice training, that is why a comprehensive diagnosis of their speech organs, including the objectivity of the research outcome in the form of voice acoustic analysis, is essential [2–4].

In their studies, Wiskirka-Woźnića et al. [5] emphasize that there is no simple relationship between the degree of acoustically-assessed dysphonia and the extent of laryngeal pathologies. However, they observed that the majority of significant relationships in their research results could be found by assessing the correlation of parameters, which define vocal folds vibrations in videostroboscopy, and acoustic parameters of generated vocal wave in the Multi-Dimensional Voice Program (MDVP). In the diagnosis of voice and speech disorders acoustic analyses have recently been more frequently applied. Their value and usefulness have also increased due to the introduction of very fast digital voice analyzers, based on the latest generation of computers with specially designed software [6, 7].

In our earlier studies [6] the parameters of acoustic and capacity analyses of voice measured in medical students and academic teachers were compared using IRIS and DiagnoScope Specialist software. They revealed that in the women the mean F0 value was 227 Hz (standard value, 212 Hz), in young female students the voice samples presented lower frequency (less sensitive to variations in timing); Shimmer – period-to-period relative variations in fundamental frequency; NHR – non-harmonic to harmonic (measure of noise and distortions); APQ – harmonic frequency amplitude equal to fundamental frequency (less sensitive to variations in timing); Shimmer – relative period-to-period amplitude perturbation quotient (harmonic frequency amplitude equal to fundamental frequency); APQ – amplitude perturbation quotient; HPQ – harmonic deviation quotient; R2H – residual to harmonic; U2H – non-harmonic to harmonic (measure of noise and distortions); NHR – noise to harmonic ratio (buzzing); Yg – Yanagihara coefficient (hoarseness scale).

In voice capacity analysis, recording took the form of an analysis interval marked at the minimum value set at the background noise level, lasted approximately 1 s. The initial voice level was recorded. In the diagnostic acoustic analysis, the sustained (approximately 1.5 s) /a:/ vowel sound, produced twice on one breath, was recorded. An interval between sounds, used to define the background noise level, lasted approximately 1 s.

The study covered 46 female academic teachers (aged 34–48; mean, 39.9 year) employed at the Medical University in Łódź. The women were diagnosed with hyperfunctional dysphonia. Having obtained the women’s informed consent, a primary medical history was taken, videolaryngoscopic and stroboscopic examinations were performed and diagnostic voice acoustic and capacity analyses were carried out with DiagnoScope Specialist software. The women were nonsmokers and have been professional voice users in the communication process for 3–15 years (mean, 11 years). Their occupational risk was associated with vocal load during obligatory teaching for 18–20 h/week.

The diagnosis of hyperfunctional dysphonia was based on medical history, the videolaryngoscopic examination and a qualitative assessment of the voice using the GRBAS scale. Hoarseness and the feeling of a lump in the throat predominated in all the academic teachers under study. Forced voice with a nasal and guttural speech and a hard vocal predisposition were revealed. In addition, excessive muscle tension in the face, neck and shoulder girdle was present, most frequently associated with abnormal, high rib and collar bone breathing.

On videolaryngoscopic examination the vocal folds were found to be rounded, tensed, slightly congested on their edges and swollen with a small amount of mucus between folds.

On stroboscopic examination diminished vibration amplitudes (vibration of vocal fold edges only) and a lack of complete closure (visible during phonation triangle) in the posterior chink were observed.

Examinations were performed in a quiet room with a sound level not exceeding 30 dB with use of a computer condenser microphone. The initial voice level was recorded. In the diagnostic acoustic analysis, the sustained (approximately 1.5 s) /a:/ vowel sound, produced twice on one breath, was recorded. An interval between sounds, used to define the background noise level, lasted approximately 1 s.

The aim of this study was to assess acoustic and capacity analyses of voice in academic teachers with diagnosed hyperfunctional dysphonia by employing DiagnoScope Specialist software.

Materials and methods

The study covered 46 female academic teachers (aged 34–48; mean, 39.9 year) employed at the Medical University in Łódź. The women were diagnosed with hyperfunctional dysphonia. Having obtained the women’s informed consent, a primary medical history was taken, videolaryngoscopic and stroboscopic examinations were performed and diagnostic voice acoustic and capacity analyses were carried out with DiagnoScope Specialist software. The women were nonsmokers and have been professional voice users in the communication process for 3–15 years (mean, 11 years). Their occupational risk was associated with vocal load during obligatory teaching for 18–20 h/week.

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The following parameters, defined in the voice capacity analysis module in the DiagnoScope Specialist software, were regarded as the most important:

- **Phonation time** – total length of all basic time intervals marked at the “analysis interval” stage;
- **True phonation time** – total length of all basic time intervals within the marked phonation-containing intervals, for which the value of the voiced parameter is not lower than the minimum value set at the “analysis interval” stage;
- **No phonation coefficient** – the ratio of total length of basic time intervals denoted as phonation and having the value of voiced parameter below minimum to phonation...
time. Phonation breaks coefficient – the ratio of the number of phonation breaks, i.e., continuous intervals with the voiced parameter value below the minimum in intervals denoted as phonation to half of the total number of fundamental time intervals, that is to the highest possible number of breaks:

- Voice efficiency coefficient – numerical parameter dependent on the voice quality expressed as the value of three short-term parameters (jitter, U2H, NHR) during true phonation and from the phonation time;
- Voice capacity – performance capacity divided by true phonation time, a measure of average voice quality expressed as the value of three short-term parameters (jitter, U2H, NHR) in the total range of true phonation.

The data obtained were analyzed and the results of the individual parameters used in the acoustic and capacity analyses were compared with the norms established by the DiagnoScope Specialist software producer. The following values were calculated: confidence interval (CI); mean value (X); standard deviation (SD); standard error (SE); minimum value (Min); and maximum value (Max). Bearing in mind that the study did not employ a control group, the statistical analysis included a comparison between the results obtained and the values taken from the database worked out by the software programmer (the value of a given parameter, obtained for each study participant, was compared with the standard value, taking account of standard deviation).

### Results

The qualitative assessment of the voice, performed with use of the GRBAS scale (Table I), showed, for individual components of the scale, the range of the severity of the voice dysfunction in the study’s participants from 0 (normal, physiological) through 1 (slight deviation) up to 2 (moderate deviation), which indicates moderate dysfunction of the voice in this group of academic teachers.

The study showed the following mean values of the analyzed voice acoustic parameters (normal values for women are given in parentheses): fundamental frequency (F0), 210.0 Hz (211.5 Hz); pitch perturbation quotient (jitter), 0.80 (0.40); RAP, 0.4 (0.22); relative amplitude perturbation (Shimmer), 4.75 (4.87); APQ, 3.59 (3.40); formant values: F1, 751.33 (831.57); F2, 1307.99 (1374.96); F3, 1373.92 (1374.96); F4, 3949.11 (3959.84); HPQ, 9.06 (9.13); RHPQ, 12.13 (14.17); R2H, 21.68 (29.3); U2H, 3.48 (3.0); S2H, 0.42 (0.43); NHR, 4.23 (3.73); and Yg coefficient, 1.04 (1.25) (Table II).

The voice acoustic and capacity analyses showed the following mean values of the parameters under study (normal values for women are given in parentheses): phonation time, 15.4 s (21.0 s); true phonation time, 15.04 s (21.0 s); no phonation coefficient, 0.023 (0.019); phonation breaks

### Table I – Evaluation of voice on the GRBAS scale in women (n = 46)

<table>
<thead>
<tr>
<th>GRBAS scale</th>
<th>X</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>1.09</td>
<td>0.16</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S</td>
<td>1.26</td>
<td>0.38</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Abbreviations: G – grade of hoarseness; R – harshness of voice; B – lavish voice, A – weak voice, S – tensed voice.

The range of the severity of the voice dysfunction: 0 – normal, physiological, 1 – slight deviance 2 – moderate deviance, 3 – severe deviance.

### Table II – Results of voice acoustic analysis parameters in women with hyperfunctional dysphonia (n = 46)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>X</th>
<th>Me</th>
<th>SD</th>
<th>SE</th>
<th>95% CI</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>214.0345</td>
<td>216.4965</td>
<td>42.8668</td>
<td>6.3204</td>
<td>201.3046–226.7644</td>
<td>111.2768</td>
<td>340.1164</td>
</tr>
<tr>
<td>Jitter</td>
<td>0.8026</td>
<td>0.6200</td>
<td>0.4296</td>
<td>0.0633</td>
<td>0.6751–0.9302</td>
<td>0.2913</td>
<td>2.2539</td>
</tr>
<tr>
<td>RAP</td>
<td>0.4698</td>
<td>0.3709</td>
<td>0.2535</td>
<td>0.0374</td>
<td>0.3946–0.5451</td>
<td>0.1559</td>
<td>1.2735</td>
</tr>
<tr>
<td>Shimmer</td>
<td>4.7562</td>
<td>4.3626</td>
<td>1.8055</td>
<td>0.2662</td>
<td>4.2200–5.2924</td>
<td>2.7085</td>
<td>12.4692</td>
</tr>
<tr>
<td>APQ</td>
<td>3.5920</td>
<td>3.4320</td>
<td>1.1591</td>
<td>0.1709</td>
<td>3.2478–3.9362</td>
<td>2.0132</td>
<td>7.6940</td>
</tr>
<tr>
<td>F1</td>
<td>751.3397</td>
<td>785.0267</td>
<td>179.8443</td>
<td>26.5166</td>
<td>697.9325–804.7469</td>
<td>9.4802</td>
<td>1030.6280</td>
</tr>
<tr>
<td>F2</td>
<td>1307.9960</td>
<td>1341.9450</td>
<td>221.9960</td>
<td>32.7315</td>
<td>1242.0710–1373.9210</td>
<td>11.2708</td>
<td>1566.3190</td>
</tr>
<tr>
<td>F3</td>
<td>2790.1380</td>
<td>2862.6180</td>
<td>470.7449</td>
<td>69.4076</td>
<td>2650.3440–2929.9320</td>
<td>20.2240</td>
<td>3431.0160</td>
</tr>
<tr>
<td>F4</td>
<td>3769.5510</td>
<td>3856.2830</td>
<td>604.6495</td>
<td>89.1507</td>
<td>3589.9930–3949.1100</td>
<td>2.8684</td>
<td>4240.5000</td>
</tr>
<tr>
<td>HPQ</td>
<td>9.0618</td>
<td>8.5743</td>
<td>3.0314</td>
<td>0.4470</td>
<td>8.1616–9.9621</td>
<td>1.7583</td>
<td>20.4823</td>
</tr>
<tr>
<td>RHPQ</td>
<td>12.1393</td>
<td>11.7030</td>
<td>3.6163</td>
<td>0.5332</td>
<td>11.0654–13.2132</td>
<td>0.5719</td>
<td>18.3117</td>
</tr>
<tr>
<td>U2H</td>
<td>3.4893</td>
<td>2.8534</td>
<td>2.4974</td>
<td>0.3682</td>
<td>2.7477–4.2310</td>
<td>0.7705</td>
<td>16.2278</td>
</tr>
<tr>
<td>S2H</td>
<td>0.4263</td>
<td>0.3174</td>
<td>0.2878</td>
<td>0.0429</td>
<td>0.3398–0.5128</td>
<td>0.2027</td>
<td>1.8419</td>
</tr>
<tr>
<td>NHR</td>
<td>4.2387</td>
<td>3.9356</td>
<td>1.7740</td>
<td>0.2645</td>
<td>3.7057–4.7716</td>
<td>1.2152</td>
<td>10.3247</td>
</tr>
<tr>
<td>Yg</td>
<td>1.0406</td>
<td>0.9830</td>
<td>0.5082</td>
<td>0.0758</td>
<td>0.8879–1.1933</td>
<td>0.4003</td>
<td>3.3066</td>
</tr>
</tbody>
</table>

X – mean value; Me – median; SD – standard deviation; SE – standard error; CI – confidence interval; min – minimum; max – maximum.

FO – fundamental frequency; Jitter – pitch perturbation quotient; RAP – relative average perturbation; Shimmer – amplitude perturbation quotient; APQ – amplitude perturbation quotient; F – formant; HPQ – harmonic perturbation quotient; RHPQ – harmonic perturbation quotient for high frequency; R2H – residual to harmonic; U2H – non-harmonic to harmonic; S2H – sub-harmonic to harmonic; NHR – noise to harmonic ratio; Yg – Yanagihara coefficient.
coefficients, 0.0007 (0.00096), voice efficiency coefficient, 11.36 (26.80); and voice capacity, 0.76 (1.26) (Table III).

Discussion

Uneconomical voice production plays an essential role in the development of hyperfunctional dysphonia, manifested by high-tension speech and considerable muscle tension [8, 9]. As depicted by Obrebowski [9], this disorder may lead to vocal cord congestion, occurrence of vocal nodules or the development of ventricular voice.

Multicenter studies have shown that in the population of Polish teachers a likelihood of dysphonia development in the group of female academic teachers is three times higher than in the control group [3]. Therefore, researchers have been attempting to find objective tests, which could contribute to better prevention and a more comprehensive diagnosis of voice disorders.

Dejonckere et al. [10], in cooperation with the Committee on Phoniatrics of the European Laryngological Society, specified the standards of a comprehensive voice examination and proposed a protocol containing five major diagnostic methods: voice self-assessment, perceptual assessment of voice, laryngovideostroboscopy, voice acoustic analysis, and aerodynamic tests.

Of all the diagnostic methods, voice acoustic analysis, objective and non-invasive methods, have gained a growing interest among specialists [7]. Already in 1998, in his habilitation thesis Świdziński [11] used the KAY Elemetrics Comp. kit with Multi Dimension Voice Program (MDVP) to define the usefulness of voice acoustic analysis in the diagnosis of organic and functional pathologies. He showed that the group of parameters concerning laryngeal tone frequency disturbances, such as Jita, Jitt, RAP, PPQ, sPPQ and vFO, were the most useful in the assessment of pathologies (over 90%) [11, 12].

Wiskirska-Woźniak [13] has also discussed the MDVP’s usefulness in the voice comprehensive evaluation in functional and organic laryngeal disorders. She also noted the correlation between the results obtained, the outcome of videostroboscopic examinations and the voice perceptual GRBAS scale.

In our own studies, carried out in a group of academic teachers with diagnosed hyperfunctional dysphonia (in the absence of any organic pathology), the voice acoustic analysis revealed the increased values of the following parameters: FO by 1.2%; relative frequency perturbations (Jitter by 100.0% and RAP by 81.8%); APQ by 2.9%; U2H by 16.0% and NHR by 13.4%. The decreased values were found in relative amplitude perturbation (Shimmer) by 2.5%; formant frequencies (F1 by 10.7%, F2 by 5.1%, F3 by 2.2% and F4 by 3.5%); harmonic perturbation quotient (HPQ by 0.8% and RHPQ by 16.8%); R2H by 35.1%; S2H by 2.4%); and y4v coefficient by 20.2%. In addition, the voice capacity analysis with use of the DiagnoScope Specialist software showed a significant decrease in almost all parameters under study (from 36.4 to 135.9%), except for no phonation coefficient that was found to be increased by 21.1%. The study results express the voice load and impaired physiological adaptation to job-related vocal effort, leading to hyperfunctional dysphonia.

The analysis of formants F1, F2, F3 and F4 serves to identify sounds and to assess the function of resonance and vocal quality manifested by the three short-term parameters (Jitter, U2H, NHR) during true phonation, and phonation time (the better the voice and the longer the phonation the higher the value).

Table III - Results of voice capacity analysis parameters in women with hyperfunctional dysphonia (n = 46)

<table>
<thead>
<tr>
<th>Voice capacity parameters</th>
<th>X</th>
<th>Me</th>
<th>SD</th>
<th>SE</th>
<th>95% CI</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonation time</td>
<td>15.4039</td>
<td>14.8080</td>
<td>5.6960</td>
<td>0.8398</td>
<td>13.7124–17.0954</td>
<td>6.0568</td>
<td>33.5252</td>
</tr>
<tr>
<td>True phonation time</td>
<td>15.0400</td>
<td>14.4498</td>
<td>5.6031</td>
<td>0.8261</td>
<td>13.3761–16.7039</td>
<td>5.9501</td>
<td>33.5252</td>
</tr>
<tr>
<td>No phonation coefficient</td>
<td>0.0238</td>
<td>0.0087</td>
<td>0.0328</td>
<td>0.0048</td>
<td>0.0141–0.0336</td>
<td>0.0000</td>
<td>0.1368</td>
</tr>
<tr>
<td>Phonation breaks coefficient</td>
<td>0.0007</td>
<td>0.0000</td>
<td>0.0014</td>
<td>0.0002</td>
<td>0.0003–0.0011</td>
<td>0.0000</td>
<td>0.0062</td>
</tr>
<tr>
<td>F0 standard deviation</td>
<td>5.4848</td>
<td>3.8832</td>
<td>4.4308</td>
<td>0.6533</td>
<td>4.1690–6.8006</td>
<td>1.8622</td>
<td>21.6014</td>
</tr>
<tr>
<td>Energy standard deviation</td>
<td>1.7000</td>
<td>1.4076</td>
<td>0.7723</td>
<td>0.1139</td>
<td>1.4706–1.9292</td>
<td>0.7478</td>
<td>4.0732</td>
</tr>
<tr>
<td>Voice capacity</td>
<td>0.7621</td>
<td>0.7559</td>
<td>0.1737</td>
<td>0.0256</td>
<td>0.7105–0.8137</td>
<td>0.4515</td>
<td>1.1316</td>
</tr>
</tbody>
</table>

Abbreviations as in Table II.
in teachers of Group II with functional dysphonia after a voice loading test. The voice acoustic analysis combined with voice loading testing of a group of female teachers who had applied for certification of occupational voice disease allowed for a precise diagnosis of work-related permanent laryngeal pathologies. The analysis also confirms the video-stroboscopic results and provides a considerable supplement to this technique. Nowadays, voice acoustic analysis has become an acknowledged gold standard tool for the diagnosis and certification of occupational disorders of the voice.

Preliminary observations concerning the voice acoustic analysis in a group of female teachers with functional dysphonia are a good sign for future use of this method in objective evaluation of voice plasticity and voice proneness to rehabilitation under phoniatric treatment [14].

The obtained data confirm this assumption, and the use of the DiagnoScope Specialist software along with voice acoustic analysis in general and voice capacity analysis in particular provide an opportunity to introduce objective methods in the disease prevention and selection of candidates for professional voice users.

Conclusions

1. In the study group of academic teachers with hyperfunctional dysphonia, voice acoustic analysis revealed abnormal values mostly in the frequency parameters, pitch perturbation quotient (jitter) and relative average perturbation, as well as in the noise to harmonic ratio and Yanagihara coefficient.

2. The voice capacity analysis with use of the DiagnoScope Specialist software showed significantly lower values of the following parameters: phonation time, true phonation time, phonation breaks coefficient, voice performance coefficient and average voice capacity.

Authors’ contributions/Wkład autorów

HZ-B – study design, acceptance of final manuscript version. JM – data collection, JO – statistical analysis. JO – data interpretation, acceptance of final manuscript version. PP – literature search.

Financial support/Finansowanie

None declared.

Conflict of interest/Konflikt interesu

None declared.

Acknowledgments/Admowa

The work described in this article have been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; EU Directive 2010/63/EU for animal experiments; Uniform Requirements for manuscripts submitted to Biomedical journals.

The own research were conducted according to the Good Clinical Practice guidelines and accepted by local Bioethics Committee, all patients agreed in writing to participation and these researches.

REFERENCES/PIŚMIENNICTWO