Factors Involved in Vocal Fatigue: A Pilot Study

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Abstract

Objective: The purpose of this retrospective study was to determine the vocal characteristics of a treatment-seeking population with the primary complaint of vocal fatigue (VF).
Methods: Forty-three men (mean age 42 years, range 19–69) and 145 women (mean age 34 years, range 18–68) were included. None of the subjects had received voice therapy or previous laryngeal surgery. A questionnaire, laryngeal and perceptual evaluations, aerodynamic and acoustic pa-rameters, and the Dysphonia Severity Index (DSI) were used to determine vocal characteristics.
Results: In 74% of the subjects, flexible laryngeal videostroboscopic evaluation revealed a vocal pathology, with vocal nodules and muscle tension dysphonia as the most frequently diagnosed pa-thologies. Vocal abuse/misuse was present in 65% of the subjects. A median DSI value of –0.4 and –0.8 was found in female and male patients, respectively. Aerodynamic and acoustic parameters and DSI scores were significantly different from normative data.
Conclusion: VF is a vocal sign with a significant need for medical consultation, especially in future professional voice users. Understanding the occurrence and the influencing variables of VF may help to close the gap between early stages of a vocal problem and the starting point of a well-established disorder.

Keywords
Vocal fatigue · Voice disorders · Dysphonia Severity Index · Laryngeal evaluation

Introduction

Vocal fatigue (VF), also called laryngeal fatigue, is a complex multifaceted clinical phenomenon. According to Solomon [1], the voice user perceives an increased sense of effort and discomfort during phonation with reduced vocal characteristics. Symptoms typically increase

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across the speaking day and improve after resting. Physiological and biomechanical mechanisms such as neuromuscular fatigue, increased vocal fold viscosity, reduced blood circulation, and nonmuscular tissue strain are hypothesized to contribute to VF [2, 3].

Most studies investigating VF used vocal loading tasks in trained and untrained voice users with normal voices. In these studies, VF was elicited with several types of vocal loading tasks [4–11]. Results are conflicting. While several authors [4, 6] found no significant change of fundamental frequency (F_0) after the vocal loading task, other authors [8, 10–12] measured a significant increase. Moreover, some mentioned no significant differences in jitter and shimmer in untrained voice users [7, 9], while others [8, 13] measured an increase in perturbation parameters. Also an increase in voice tremor [14, 15] and perceived phonatory effort [16] was measured after reading tasks. The purpose of these studies was to experimentally induce VF in subjects with normal vocal characteristics, and the studies were set in simulated workplace environments [1].

Studies assessing the pure complaint of VF are, however, rare and challenging. These few studies used a variety of assessment techniques, such as acoustic [17, 18], aerodynamic [17, 19], videostroboscopic [17, 18], electroglottographic [18], and self-rating assessments [18, 20]. The now widely used Dysphonia Severity Index (DSI) [21] was not included in the assessment protocols. However, nowadays the DSI is a preferred measure of vocal quality, as it is a robust, objective, and multiparametric approach to vocal quality which reflects the multidimensional nature of voice. The DSI is designed to establish an objective and quantitative correlate of perceived vocal quality and is a sensitive method for detecting voice problems with good interobserver and test-retest reliability [22].

Most authors [18–20] reported no significant electroglottographic, acoustic, and aerodynamic differences between subjects with and without VF. The only study assessing vocal characteristics in subjects with the primary complaint of VF was performed by Eustace et al. [17]. These authors reported acoustic, aerodynamic, and videostroboscopic measures in 88 patients with a primary complaint of VF without other laryngeal pathologies. The results revealed an abnormally high airflow rate and decreased maximum phonation time (MPT) in patients with VF. An anterior, posterior, or hourglass glottal gap was found in 61% of the subjects.

In a literature review, Welham and Maclagan [23] suggested that future research should focus on exploring the relationship between VF and other voice disorders given that it is still unclear whether VF primarily contributes to, results from, or exists independently of other voice conditions. Moreover, McCabe and Titze [24] hypothesized that maladaptive functional compensations contribute to VF and vocal tissue changes. The perceived VF is often the first complaint, but since vocal rest can improve voice, this may delay the patients' search for help.

The purpose of the current retrospective study was to determine objective and subjective vocal characteristics in a treatment-seeking population with the primary complaint of VF. In addition, the vocal characteristics of these patients were compared with normative values obtained by the Belgian Study Group of Voice Disorders [21]. Based on previous findings [17], voice parameters of the subjects with the complaint of VF were hypothesized to deviate from those normative values.

Materials and Methods

Subjects

A retrospective file review of 1,150 patients, who presented for the first time with a voice problem at the Voice Clinic of Ghent University between 2001 and 2012, was performed. Two hundred and eight patients mentioned a primary complaint of VF, i.e., laryngeal fatigue or a tired voice. These patients primarily searched for medical help to improve their voice. No central nervous system diseases, psychological or psychiatric diseases were reported in these subjects. All patients had a minimum age of 18 years. None of them received voice therapy or laryngeal surgery prior to data collection.

The vocal characteristics of these subjects were compared with a norm (control) group extracted from the database of the Belgian Study Group on Voice Disorders [21, 25]. The norm group consisted of subjects without any vocal fold pathology or any vocal complaint and was recruited at random in 4 university centers and 2 affiliated voice centers in Belgium. The methods used for data collection are described elsewhere [21, 25]. The norm group consisted of 36 women and 27 men with a mean age of 27 years (range 18–47) and 36 years (range 18–61), respectively. This group contained significantly more ($p = 0.002$) and younger ($p = 0.002$) (Mann-Whitney U test) females than the VF group. Since the variables F-high, F_0, jitter, and DSI are age dependent, the comparison with the norm group was confounded by this age effect. Therefore, in order to perform a pure comparison to investigate the pathology effect only, i.e., the VF group versus the norm group, we excluded the oldest subjects from the VF group by excluding all women aged 55 years and more. Additionally, patients with the presence of chronic obstructive pulmonary disease were excluded. This resulted in a study and norm group matched for age. Eventually, 43 men (23%) with a mean age of 42 years (range 19–69) and 145 females (77%) with a mean age of 34 years (range 18–68) were included in the VF group.

Methods

Questionnaire, Laryngeal and Perceptual Evaluation

The same standardized protocol was used for each subject of the VF and the norm group.

Questionnaire. The questionnaire was conducted by a speech-language pathologist with more than 10 years of experience. This survey addressed 3 main categories: (1) ear, nose, and throat pathologies; (2) vocal complaints; and (3) vocal care (vocal abuse/misuse, smoking) [26].

Videolaryngostroboscopy. Videolaryngostroboscopy was used to evaluate vibration patterns and the state of the larynx and was performed by an ear, nose and throat specialist with more than 10 years of experience. In addition, audio samples, which are part of a standard clinical evaluation, were collected by the speech-language pathologist.

Perceptual Evaluation. These samples of spontaneous speech (5 min) were perceptually evaluated using the GRBASI scale [27]. The GRBASI assessment consists of 5 well-defined parameters: G (overall grade), R (roughness), B (breathiness), A (asthenicity), and S (strain). A 6th parameter, I (instability), was added to the original scale [28]. A 4-point rating scale (normal [0], slight [1], moderate [2], and severe [3]) is used to score each parameter. Both judges (ear, nose and throat specialist and speech-language pathologist) first independently rated each laryngeal video and voice sample. In case of disagreement, the laryngeal video (13% of disagreement) and voice samples (17% of disagreement) were replayed and discussed until a consensus was reached.

Objective Assessment

Aerodynamic Measurement. MPT was measured for the vowel /a/, sustained at the subject's habitual intensity and pitch in free field and in sitting position. For the MPT, the procedure of Van de Heyning et al. [25] was used. The length of the sustained phonation was measured with a chronometer. The patients received verbal and visual encouragement and coaching. The best of 2 trials was retained for further analysis.

Vocal Range. Frequency and intensity range were measured using the Voice Range Profile function of the Computerized Speech Lab (Kay Elemetrics, Lincoln Park, NJ, USA, 1992). The procedure developed by Heylen et al. [29] was used. A unidirectional dynamic Shure SM-48 microphone located at a distance of 15 cm from the mouth and angled at 45° was used. The patients were instructed to inhale in a comfortable way and to produce the vowel /a/ for at least 2 s, using a habitual pitch and intensity, a minimal pitch (F-low), a minimal intensity (I-low), a maximal pitch (F-high), and a maximal intensity (I-high), respectively. Analysis was performed using Voice Range Profile with a sampling rate of 44,100 Hz.

Acoustic Analysis. For the determination of acoustic voice parameters, the Multi-Dimensional Voice Program from Computerized Speech Lab was used. The subjects were asked to sustain the vowel /a/ using their habitual tone and without unnecessary effort. A midvowel segment of 3 s duration registered with a sampling rate of 50 kHz was used for analysis. The parameters jitter (%), shimmer (%), noise-to-harmonics ratio, and fundamental frequency (F_0 in Hz) were determined. The overall objective vocal quality was measured with the DSI [21]. The DSI is based on the weighted combination of voice parameters calculated with the following equation: (0.13 × MPT) + (0.0053 × F-high) – (0.26 × I-low) – (1.18 × jitter) + 12.4. The score ranges from +5 to –5, corresponding with normal and severely dysphonic voices, respectively. All recordings and perceptual and objective evaluations were performed in a sound-treated room.

Table 1. Results of the laryngeal flexible videostroboscopy in 147 subjects with pathological vocal fatigue

	Female	Male	*n*	%
Organic vocal pathology	63	15	78	53
Vocal nodules	38	2	40	27
Paralysis	11	7	18	12
Edema	11	4	15	10
Polyp	1	1	2	1.4
Leukoplakia	0	1	1	0.7
Cyst	1	0	1	0.7
Vagal nerve schwannoma	1	0	1	0.7
Functional vocal pathology	11	20	31	21
Muscle tension dysphonia	9	20	29	20
Bowing	2	0	2	1.4
Normal	30	8	38	26

Statistical Analysis

SPSS versions 19 and 22 (SPSS Corporation, Chicago, IL, USA) were used for statistical analysis. Pearson's χ^2 test was performed to compare frequencies. Most of the variables of the VF group were non-Gaussian distributed according to the Kolmogorov-Smirnov test for normality and Q-Q plots. Therefore, the results are reported as medians and 25th and 75th percentiles. Consequently, female and male subjects of the VF group were compared separately with the norm group using the Mann-Whitney U test. The significance level was set at $\alpha = 0.05$.

Statement of Ethics

This study was approved by the Ghent University ethical committee.

Results

Subjects

The classification of Koufman and Isaacson [30] was used to subdivide the subjects according to their vocal demands during professional activities: elite vocal performers (3%, 6/188), professional voice users (43%, 81/188), future professional voice users/students (teachers) (14%, 25/188), nonvocal professionals (17%, 32/188), and nonvocal nonprofessionals (12%, 23/188). In 11% (21/188) the professional activities were unknown. The results of the questionnaire revealed variables possibly influencing the vocal quality. Vocal misuse (65%, 123/188) followed by stress (57%, 108/188), allergy (33%, 62/188), and nasal obstruction (31%, 59/188) were frequently reported by the subjects. Furthermore, 18% (34/188) of the subjects were

Table 2. Comparison between norm group females and female patients with an initial complaint of vocal fatigue

	Females				Mann-Whitney U test, *p* value
	norm group		vocal fatigue		
	median	Pc 25–75	median	Pc 25–75	
Maximum phonation time, s	17	14 to 18	14	10 to 18	*0.006*
F-low, Hz	142	123 to 170	139	123 to 156	0.29
F-high, Hz	902	830 to 988	539	415 to 698	*<0.001*
I-low, dB	50	50 to 52	62	59 to 67	*<0.001*
I-high, dB	97	92 to 103	97	91 to 103	0.54
F_0, Hz	213	199 to 228	195	184 to 208	*<0.001*
Jitter, %	0.5	0.3 to 0.8	1.3	0.8 to 2.4	*<0.001*
Shimmer, %	2.6	2.0 to 3.7	2.9	2.1 to 4.5	0.22
Noise-to-harmonics ratio	0.11	0.10 to 0.13	0.12	0.09 to 0.15	0.65
Dysphonia Severity Index	5.5	4.6 to 6.3	–0.4	–3.0 to 1.3	*<0.001*

Italics indicate statistical significance. Pc 25–75, 25th to 75th percentiles.

current or past smokers. Reflux and infection of the upper airway were present in 21% (40/188) and 16% (31/188) of the subjects, respectively. Besides VF, subjects also complained of increased laryngeal tension (71%, 133/188) followed by hoarseness (58%, 109/188), the inability to produce a loud voice (43%, 81/188), laryngeal dryness (41%, 77/188), and coughing (24%, 45/188). The reported numbers are not exclusive percentages, as the same patient may be represented in more than one category.

Vocal Characteristics

Laryngeal and Perceptual Evaluation

The results of the laryngeal flexible videostroboscopic evaluation are listed in Table 1. In 22% of the patients, the video samples of the vocal folds were not suitable for further analysis because of a gag reflex or poor quality of the saved sample of the stroboscopic recordings. The results of the laryngeal videostroboscopic evaluation showed a vocal pathology in 74% (109/147) of the patients. Fifty-three percent (78/147) had an organic voice disorder. No vocal pathology was found in 26% (26/147) of the patients. Vocal nodules (27%, 40/147), muscle tension dysphonia (MTD; 20%, 29/147), and paralysis (12%, 18/147) were the most frequently diagnosed vocal pathologies.

The median perceptual scores were G1, R1, B0, A0, S1, and I1 (consensus evaluation: 85%) for the male subjects ($n = 43$) and G1, R1, B1, A0, S1, and I1 (consensus evaluation: 81%) for the female subjects ($n = 145$). In comparison with the norm group, significantly higher scores were obtained for all parameters of the GRBASI scale by patients with VF independent of gender ($p < 0.001$).

Objective Voice Assessment

Aerodynamic and acoustic parameters and vocal range of the patient and norm group are presented in Tables 2 and 3. In both the male and female patient comparisons to the normative group, the DSI value was significantly lower in the patient group.

Discussion

The purpose of the present study was to determine the vocal characteristics in a treatment-seeking population with the primary complaint of VF. This study found a high presence of the variables vocal misuse (65%) and stress (57%) in these patients. The most frequent complaint, besides VF, was increased laryngeal tension (71%). Moreover, a vocal pathology was found in 74% of the patients. Additionally, aerodynamic and acoustic parameters and perceptual evaluation differed significantly in comparison with the normative group. A significantly lower DSI score was found in patients with the primary complaint of VF.

The present study stands out because it is based on a larger sample size ($n = 188$) than previous research. The majority of these subjects were females. Furthermore, 49% of all subjects were teachers. It is known that the majority of teachers are females and that they have about twice as many voice problems as men [31]. Women have shorter vocal folds vibrating at a higher fundamental frequency. Consequently, there is less tissue mass to dampen a larger amount of vibrations per unit time. Women are

Table 3. Comparison between norm group males and male patients with an initial complaint of vocal fatigue

	Males				Mann-Whitney U test, *p* value
	norm group		vocal fatigue		
	median	Pc 25–75	median	Pc 25–75	
Maximum phonation time, s	21	15 to 18	16	13 to 20	0.053
F-low, Hz	82	69 to 90	85	73 to 93	0.56
F-high, Hz	587	494 to 659	440	311 to 587	*<0.002*
I-low, dB	51	49 to 53	60	58 to 70	*<0.001*
I-high, dB	100	95 to 107	99	90 to 105	0.54
F_0, Hz	116	110 to 118	118	104 to 133	0.59
Jitter, %	0.5	0.4 to 1.3	1.3	0.5 to 2.3	*<0.001*
Shimmer, %	2.8	2.5 to 3.5	3.6	2.4 to 5.3	0.09
Noise-to-harmonics ratio	0.13	0.12 to 0.14	0.13	0.11 to 0.14	0.52
Dysphonia Severity Index	4.4	3.6 to 5.5	–0.8	–3.1 to 1.4	*<0.001*

Italics indicate statistical significance. Pc 25–75, 25th to 75th percentiles.

thus more vulnerable to developing voice problems [32]. Previous research already stated that women are more susceptible to VF due to an increase in viscosity of the vocal folds [1], parallel with other findings [33, 34].

Fifty-seven percent of the current subjects were (future) professional voice users, which is an alarming figure. It is unclear whether these participants received training to optimize the vocal use. Nevertheless, this should be encouraged for all professional voice users, as previous reports [8, 9, 35] stated that people who did have vocal training appeared less susceptible to VF. The impact of increased voice use in professional voice users and the use of amplification on VF should be the subject of further research.

In subjects with the complaint of VF, vocal abuse/misuse (65%) and stress (57%) were mentioned as the most frequent influencing variables on overall vocal quality. In the literature, much controversy exists about the effect of stress on vocal quality. Further research is needed to determine the possible causal relationship between stress, phonation style, and VF.

Flexible laryngeal videostroboscopic evaluation revealed a vocal pathology in 74% of the subjects, with vocal nodules and MTD diagnosed most frequently. MTD is a voice disorder caused by imbalanced/dysregulated activity of the paralaryngeal musculature [36]. Van Houtte et al. [37] found indications of more hypertonic infrahyoid muscles in patients with MTD, suggesting that there is a loss of flexibility in the laryngeal framework in these patients. An increase in VF in subjects with MTD is therefore hypothesized and is a subject for further research.

The female subjects in this study showed a median DSI value of –0.4. This corresponds to a DSI% of 46% indicating a mild dysphonia (perceptual evaluation of G1) [38]. Duffy and Hazlett [39] reported a DSI value of +4.0 (80%) in 55 student teachers (without the complaint of VF), indicating a good vocal quality. In a previous study [40] of 143 female student teachers without a complaint of VF, using the same equipment and methodology, we obtained a mean DSI value of +2.6 (corresponding to a DSI% of 76%, indicating a normal voice). The results of this study thus suggest a decreased vocal quality in subjects with the complaint of VF. In contrast, the current patient group seems to have a better voice quality than patients with vocal fold paralysis (mean DSI –4.59) [41], although a similar voice quality was observed for patients with hyperfunctional voice disorders (mean DSI –1.4) [42] and vocal fold nodules (median DSI –0.81) [43].

The absence of a self-evaluation scale of VF and of audio samples of a reading passage to perceptually evaluate voice quality are 2 limitations of this study. Moreover, because of the retrospective aspect of the study, laryngeal videostroboscopic data were not available for 22% (41/188) of the patients. As a result, the pathologies observed in the VF group should be interpreted with caution. In the future, prospective studies with a well-defined standardized videostroboscopic evaluation will provide more accurate and specific information. In addi-

tion, despite the similar primary complaint in all patients, the current patient sample was heterogeneous. In future studies, it would be interesting to compare the vocal characteristics of patients with VF with different vocal pathologies and with an age- and gender-matched control group. VF has been reported in patients with functional and organic disorders [23, 43], but the underlying physiological and biomechanical mechanisms [23] contributing to VF might be different. Fatigue is still the least understood symptom of voice disorders, despite its frequency mentioned by patients. Understanding the occurrence of VF and the influencing variables may help to close the gap between early stages of developing a vocal problem and the starting point of a well-established disorder. Further research, particularly prospective studies, should use perceptual and objective voice assessment techniques as well as self-evaluation scales to obtain a complete picture of patients with VF. Moreover, case-control studies comparing voice patients with and without VF will reveal the unique correlates of this voice pathology.

Conclusion

VF is a pathological vocal sign with a significant need for medical consultation, especially in future professional voice users. VF is frequently associated with organic or functional voice disorders. Important influencing variables are vocal misuse/abuse and stress. The DSI reflects a mild vocal pathology with a median DSI score in males and females of –0.8 and –0.4, respectively. Moreover, in patients with a primary complaint of VF, aerodynamic, acoustic, and DSI scores were significantly different from a normative group. Thus, voice specialists must be aware of pathologies and influencing variables behind the complaint of VF in professional voice users.

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The authors have no conflicts of interest to declare.

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