Do Standard Instrumental Acoustic, Perceptual, and Subjective Voice Outcomes Indicate Therapy Success in Patients With Functional Dysphonia?

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Summary: Objectives. The validity and sensitivity to change of instrumental acoustic measurements in patients with functional dysphonia have been controversially discussed. This work examines combined voice therapy effects on standard acoustic measurements, and if these agree with perceptual and subjective voice outcomes.
Study design. Retrospective study.
Methods. Thirty-nine patients (26 women, 13 men) aged 20–70 years (mean: 46.3, standard deviation 12.8) with functional dysphonia were investigated before and after combined voice therapy. Instrumental parameters included mean and range of speaking fundamental frequency (f_o) and intensity (SPL (dBA)); maximum SPL and mean f_o of calling voice; minimum, maximum, range of singing voice f_o and SPL, jitter (%), and the Dysphonia Severity Index. Voice Handicap Index-9 international was used for subjective and Grading-Roughness-Breathiness-Asthenia-Strain scale for perceptual assessment. Differences were investigated by Wilcoxon signed ranks test and coherences by Spearman rank correlation coefficient.
Results. After treatment, the speaking voice f_o range (7–8.13 semitones) and SPL range (12.9–14.85 dB(A)) were significantly larger ($P < 0.05$). Both parameters were highly correlated ($P < 0.001$). Subjective symptoms were significantly reduced from a mean Voice Handicap Index-9 international of 15.6–8.6, and all perceptual Grading-Roughness-Breathiness-Asthenia-Strain scale parameters were significantly improved (G: 1.05–0.51) after therapy ($P < 0.05$). These findings were not associated with any acoustic parameter ($P > 0.05$).
Conclusions. Significantly improved subjective and perceptual findings verify positive combined voice therapy effects in patients with functional dysphonia. The larger f_o and SPL speaking voice range after treatment indicate an altered voice technique. These instrumental measures may be clinical indicators of therapy success and transfer effects.
Key Words: Functional dysphonia–Instrumental acoustic measurements–VHI-9i–GRBAS scale–Therapy outcome.

INTRODUCTION

Voice disorders affect approximately one-third of the population once during lifetime[1] and may result from changes in the structure, innervation, or function of the laryngeal mechanism.[2] Adults between 40 and 59 years are the largest treatment-seeking group, with approximately 64% women.[2,3] In specialized clinics, around 30% of all patients are diagnosed with so-called functional dysphonia, characterized by an altered vocal sound, pitch, and intensity, and increased vocal effort in the absence of explaining organic or neurologic causes.[2] Functional dysphonia has been explained by an inadequate voice technique and tonus regulation in the muscles of the phonatory system.[4,5] Therefore, functional dysphonia has also been termed muscle tension dysphonia.[6]

Contributing factors for a functional dysphonia may be a high vocal demand or suboptimal working conditions, for example, high background noise levels.[7] Also an upper respiratory tract infection may result in functional voice changes, especially in elite vocal performers and professional voice users with constantly high vocal demand.[4] Generally, the prognosis is positive because in 46%–93% of patients, vocal performance can be improved by voice therapy.[8] As summarized in Table 1, direct treatment and combined indirect and direct treatment techniques have been described as most effective intervention strategy.[4,9,10,14–17]

Voice diagnostics in functional dysphonia

As recommended by the European Laryngological Society, a comprehensive voice examination usually includes subjective, visual, perceptual, aerodynamic, and instrumental acoustic assessment techniques.[18] Because videolaryngoscopic and aerodynamic evaluations give only limited details to assess functional characteristics of voice production,[9,19] subjective, perceptual, and instrumental acoustic findings have been described as key to characterize symptoms in patients with functional voice disorders.[13,14,20–22]

Subjective voice symptoms and their impact on daily life experiences can be assessed by patient self-report questionnaires such as the Voice Handicap Index (VHI). It examines functional, emotional, and physical symptoms related to voice disorders and has been described as a valid diagnostic instrument to indicate treatment success in patients with dysphonia.[15,23–25] Perceptual voice analysis consists of a structured assessment of voice sound by the examiner after defined characteristics. One of the most widely used schemes is the Grading-Roughness-Breathiness-Asthenia-Strain scale (GRBAS), which has a high sensitivity in documenting voice improvements following therapy.[26] Even though the assessment bases on a subjective rating,

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TABLE 1.
Literature Review of Voice Outcomes After Direct or Indirect Voice Therapy in Nonorganic Voice Disorders

Reference	Interventions	Participants	Diagnostic Parameter	Outcomes
Carding et al 1999[9]	A) No intervention (15) B) Indirect treatment (15) C) Direct and indirect treatment (15)	45 patients diagnosed with non-organic dysphonia	(1) Questionnaire of vocal performance (2) Auditory voice quality ratings (3) Indirect/fiberoptic laryngoscopy (4) Laryngography (5) Fundamental frequency analysis (MSF0) 6) Acoustic analysis of the speech waveform (S/N-ratio; jitter, shimmer)	(1, 2, 4) Significant difference between the scores of all three groups ($P < 0.05$) (3, 5) No significance (6) *S/N-ratio*: Significant difference between group 1 and 3, group 2 and 3, group 1 and 2 ($P < 0.05$). *Jitter:* Significant difference between group 1 and 3 ($P < 0.05$). *Shimmer:* Significant difference between group 1 and 3, group 2 and 3 ($P < 0.05$).
Watts et al 2015[10]	(A) Indirect treatment (10) (B) Direct treatment (10)	20 patients with MTD	(1) VHI (2) Acoustic parameters (MPT, S/Z-Ratio, vowel CPP, sentence CPP)	Significant group differences in pre-to-post changes on measures of VHI, MPT, speech, and vowel CPP ($P = 0.003$; 0.013; 0.025 and 0.017). Significant difference between two groups in VHI, MPT, CPP speech, and vowel (Cohen d = 1.6; 1.2; 1.2; and 1.1)
Tomlinson et al 2015[11]	Physical therapy intervention (excessive muscle recruitment) and stress management education (9)	9 patients with MTD	(1) VHI (2) NRS (3) PSFS (4) Cervical and jaw range of motion	(1) Three patients had a clinically relevant but not significant change (2) Eight patients had no pain (3) Improvement in all patients (4) Improvement in cervical flexion and lateral flexion and jaw opening in all patients, Improvement in cervical extension and rotation post intervention in eight patients
Van Lierde et al 2007[12]	Vocal hygiene, muscle relaxation exercises, and laryngeal manual therapy (27)	27 patients with hyperfunctional voice disorders (14 of 27 laryngeal pathology: two with organic voice disorder and 12 with functional voice disorder)	(1) VHI (2) Auditory perceptual evaluation (GRBAS) (3) aerodynamic analyses (MPT) (4) acoustical analyses (jitter, shimmer, voice range measurement) (5) DSI	No significant correlation between DSI and VHI values; Significant differences after voice therapy perceptual in roughness ($P = 0.02$), strainedness ($P = 0.04$), and acoustic jitter ($P = 0.03$).
Gillespie et al 2014[13]	Voice therapy (10 muscle tension dysphonia) or phonosurgery (30)	40 patients with single voice disorders: 10 vocal fold lesions, 10 MTD, 10 atrophy, 10 UVFP	(1) auditory-perceptual evaluation of voice (pitch, loudness) (2) Analysis of dysphonia in speech and voice (3) multidimensional voice profile (4) VHI	Patient with: – lesions: significant difference in CPP speech, CPP SD vowel, and VHI ($P < 0.05$) – MTD: significant difference in CSID ($P < 0.05$) – atrophy: no comparison was significant – UVFP: significant difference in CPP SD speech and CSID

Abbreviations: CPP, Cepstral Peak Prominence; CSID, Cepstral Spectral Index of Dysphonia; MPT, maximum phonation time; MSF0, mean speaking fundamental frequency; MTD, muscle tension dysphonia; NRS, numeric rating scale, PSFS, Patient-Specific Functional Scale; S/N-ratio, signal-to-noise ratio; UVFP, unilateral vocal fold paralysis; VHI, Voice Handicap Index.

a satisfyingly good consensus between different voice examiners has been reported.[27–29]

Instrumental acoustic assessments are used to determine defined physical properties of the acoustic voice signal, the vocal output. Because measurements base on an analysis of spoken prolonged vowels and elicited speech, acoustic parameters may provide objective information about uninfluenced voice function.[30,31] However, the sensitivity to change of instrumental acoustic measurements in patients with functional dysphonia has been controversially discussed.[32–34]

Voice range profiles are a graphical performance profile indicating the voice intensity and pitch range of the speaking, calling, and singing voice.[31,35] This individual profile bases on a set of defined vocal tasks, and allows deriving information about individual voice function restrictions. Based on this, the treatment plan can be tailored to the patient's needs, and therapy effects can be evaluated objectively.[36] Patients with functional dysphonia tend to have restricted high frequency and minimal intensity areas, which have been shown to improve after voice therapy.[36] However, to date, voice range profiles are considered as not sufficient for the characterization of functional restrictions, because the natural variation between individuals is large and the normative data base includes only a limited characterization of age, training, and gender effects.[31,35,37,38]

Further, widely used instrumental acoustic parameters are perturbation measures, which describe the acoustic wave irregularity from one cycle to the next. Most commonly used are jitter and shimmer, indicating the unwanted variation in fundamental frequency (f_o) and voice intensity (voice SPL), respectively.[32,33] However, their validity and reliability has been criticized as limited for the clinical application. One main pragmatic problem in clinical measurements is that the large natural voice intensity-related confounding effects are difficult to control for.[39] Combined indices such as the Dysphonia Severity Index (DSI) incorporate several acoustic measures including jitter, and are applied for the description of dysphonia severity. Studies in patients suggest that the DSI may be useful to evaluate voice improvement, because the DSI was more negative in patients with more severe dysphonia.[40–42]

Voice outcomes after treatment

Several studies in patients with functional voice disorders (Table 1) document improved subjective and perceptual findings after voice treatment.[9,10,12,13] Direct treatment and combined indirect and direct treatment techniques have been described as more effective than other intervention types.[4,9,10,14–17] However, better subjective and perceptual results did not always agree with instrumental acoustic findings.[20] Also, for several instrumental parameters, changes after therapy have been characterized inconsistently. Inhomogeneous results were found relating to perturbation measurements (jitter, shimmer) and cepstral peak prominence.[9,10,12,13] Further, Tomlinson et al hypothesized that physical therapy and stress management should improve voice parameters; however, in their study of nine patients, no significant acoustic changes were described.[11]

The review of current literature highlights that patients seem to subjectively benefit from voice therapy. However, instrumental acoustic outcomes after voice therapy have been controversially described, and clinical studies investigating therapy effects in patients with functional voice disorders are still sparse. Further, these often involve relatively small patient groups (Table 1). Also, assessment approaches vary between studies, hindering a systematic comparison of therapy effects and an efficient application in clinical practice.[31,39,43] Therefore, the main aims of the present study were to examine the effects of combined indirect and direct voice therapy in patients with functional dysphonia on standard diagnostic instrumental acoustic measurements, and if these agree with perceptual and subjective voice outcomes.

MATERIALS AND METHODS

Examined sample and exclusion criteria

Subjective, perceptual, and instrumental acoustic assessment data before and after voice treatment of 39 adults, 26 women and 13 men, with functional dysphonia were retrospectively analyzed. Personal data, questionnaires, perceptual, and acoustic data were gathered out of an encoded information systems KISIM and XION used at the Department for Phoniatrics and Speech Pathology, University Hospital Zurich. All patients signed the general informed consent of the University Hospital Zurich and agreed to further use of their data.

All patients were diagnosed and treated from January 2011 to July 2015 in the Department of Phoniatrics and Speech Pathology, University Hospital Zurich, Switzerland. Examinations were done following the assessment protocol of the European Laryngological Society including a visual, subjective, perceptual, aerodynamic, and instrumental acoustic examination.[18] Voice treatment consisted of a combined indirect and direct individualized voice therapy, including advice on vocal hygiene, management of voice behavior, and direct therapy techniques for facilitating efficient voice production.[9,44] Exercises were chosen based on the patients' needs identified after voice diagnostics. These included vocal function exercises,[45] semi-occluded vocal tract exercises, as well as exercises to relax (para)laryngeal and cervical musculatures by manual techniques, promote respiratory control, and resonant equilibrium.[6] All patients completed the treatment, and were released from treatment after a final full voice assessment.

Exclusion criteria

Patients were excluded from the study if they met one or more of the following criteria:

- known neurologic and psychiatric disorders
- hearing problems
- organic disease of the larynx
- surgery in the head and neck region
- intubation within the last 18 months.

Analyzed parameters

Instrumental acoustic outcomes

Instrumental acoustic assessments were done with the analysis software "*DIVAS* (XION GmbH, Berlin, Germany)."[46] Hardware included a head-mounted microphone with 30-cm recording distance to the mouth and a personal computer.[46] All

TABLE 2.
Investigated Instrumental Acoustic Parameters With Abbreviations and Patient Instructions

Instrumental Parameter		Patient Instruction
Speaking voice range profile		
f_o mean	mean fundamental frequency (Hz)	Measurements during spontaneous speaking. Patients were asked: "Please tell me how you came here today"
f_o range	fundamental frequency range (ST)	
SPL mean	mean intensity (dBA)	
SPL range	intensity range (dBA)	
Counting with normal voice intensity		
f_o mean	mean fundamental frequency (Hz) during counting from 20–30 with comfortable voice intensity	"Please count from 20–30 with comfortable voice intensity"
Calling voice profile		
f_o mean	minimum fundamental frequency (Hz)	"Please shout as loud as you can: "Hello Anton, come here" three times." (Translation from German)
SPL max.	maximum intensity (dBA)	
Singing voice range profile		
SPL max.	maximum intensity (dBA)	Patients were asked: "Please sing the syllable "la" as soft as you can from the middle downwards, three times. Please sing the syllable "la" as soft as you can upwards, three times." These instructions were repeated with the term "as loud as you can".
SPL min.	minimum intensity (dBA)	
SPL range	dynamic range from maximum intensity-minimum intensity (dBA)	
f_o max.	maximum of fundamental frequency (Hz)	
f_o min.	minimum of fundamental frequency (Hz)	
f_o range	range of singing voice (ST)	
Acoustic perturbation		
Jitter	Irregularity of fundamental frequency (%) from one acoustic wave to the next	"Please say /a/ loudly for 4 seconds" Middle segment of phonation without onset and offset phase
Combined parameter		
DSI	Dysphonia Severity Index: Calculated incorporating several acoustic and aerodynamic parameters after Wuyts et al[40] f_o max. of singing voice (Hz), SPL min. of singing voice (dBA), maximum phonation time (Sec), jitter (%)	

All measurements were done using the software *DIVAS*[46] with a head-mounted microphone at 30-cm distance from the mouth.[18]
Abbreviation: ST, semitones.

recordings were done in normal room acoustics with windows closed. Analyzed parameters included defined characteristics of the speaking and singing voice range profiles, jitter (%), and the DSI (Table 2). For jitter analysis, a middle sequence of the sustained vowel /a/ was selected to exclude the increased variability of the voice-onset and -offset phase.[32,47] Table 2 summarizes the definition of the investigated parameters and how patients were instructed during assessments.

Subjective outcomes

Patients received the VHI-9i questionnaire with the invitation letters to the first and second assessments. The German version of VHI-9 questionnaire was validated by Nawka et al in 2003.[48] The questions are answered on a scale from never (0) to always (4). Dysphonia classification was based on adjusted standard values for the VHI-12 (Table 3).[49,50] Only 26 patients completed the questionnaires before and after therapy. Of the remaining 13 patients, two persons did not fill out the questionnaire at all, five patients only before, and six patients only after therapy. Because of the retrospective study design, we were not able to track down the reasons.

Perceptual outcomes

Before and after therapy, an experienced speech therapist or phoniatrician perceptually evaluated voice quality during spontaneous speech using GRBAS scale. The parameters G (overall impression of hoarseness), R (roughness), B (breathiness), A (asthenia), and S (strain) are classified on a four-point scale from normal (0), low grade (1), middle grade (2), to high grade (3).[27] Perceptual evaluation was done when the patient was answering questions during the anamnesis, and results were directly noted. The examiners of the present study are trained on a regular

TABLE 3.
Dysphonia Classification adapted after VHI-12[49,50]

Dysphonia Classification	VHI-9i Total Value
0 = no dysphonia	0–5
1 = low grade	6–10
2 = middle grade	11–16
3 = high grade	17–36

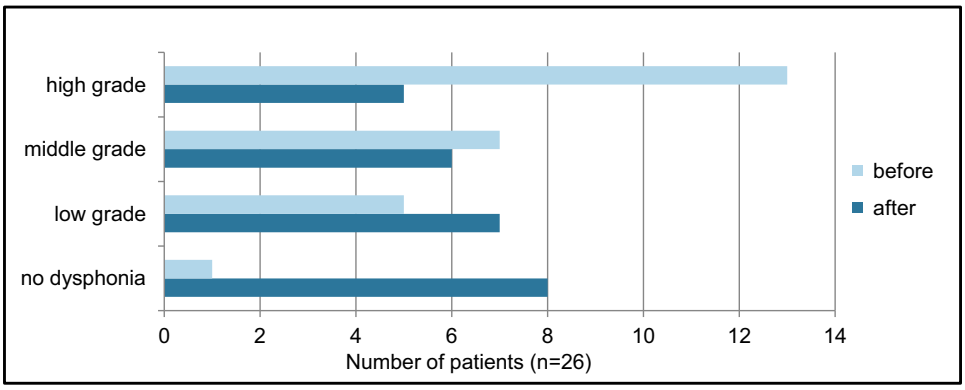

FIGURE 1. Dysphonia classification according to VHI-9i scores before and after voice therapy.[49,50] There was a decrease of 62% in the high-grade dysphonia group after treatment. Before therapy, only one patient (3.8%) was classified in the no dysphonia group, after therapy there were eight patients (30.7%) in this group.

basis by a set of standardized voice recordings, which has shown to improve intra-rater reliability.

Statistics

Statistical analysis was done with *SPSS Statistics* (IBM Corp., Armonk, NY, USA)[51] and Excel (Microsoft Corporation, Seattle, WA, USA).[52] First, the mean and median, standard deviation (SD), minimum and maximum values of all parameters were calculated. Thereafter, as data were not normally distributed, statistical differences before and after voice therapy were calculated by Wilcoxon signed ranks test. Correlations were assessed with Spearman rank correlation coefficient. For the level of significance, a probable value of $\alpha = 0.05$ was considered as significant.

RESULTS

Age and gender distribution and number of voice therapy sessions

A total of 39 patients, 26 women and 13 men, between 20 and 70 years with an overall mean age of 46.26, were included to the study. The mean age of the women was 44.50 years (SD 12.79; median 44.50, range 20–70), and of the men was 49.77 years (SD 9.98; median 51.00, range 31–63). There was no significant difference in age distribution between gender groups ($P = 0.148$, Mann-Whitney U test).

All patients had a mean of 7.64 individual therapy sessions (range from 4 to 22 sessions). Thirty-two patients (82%) had 4–10 therapy sessions, and only seven patients (18%) had more than 10 sessions.

Voice Handicap Index 9i (VHI-9i)

As described above, only 26 questionnaire pairs (before/after) could be included to the study. After therapy, there was a highly significant reduction in overall VHI-9i score results from a mean of 15.6 (SD: 6.66) to 8.6 (SD: 5.99; $P < 0.001$). When assessing single VHI-9i items, eight of nine questions showed a significant or highly significant improvement (questions F1, F3, P4, F5, F16, P17, P21, E24, $P < 0.05$). The only exception was question 9 (E 29: "My voice makes me feel incompetent"; $P = 0.146$).

Before voice treatment, 50% of all patients ($n = 13$) had a high-grade dysphonia. After therapy, only 19.2% of all patients ($n = 5$) were in this group, equaling a reduction of 61.5% within this group. The proportion of patients with no dysphonia increased from 3.8% ($n = 1$) to 30.7% ($n = 8$) after therapy (Figure 1).

GRBAS scale

After voice therapy, there was a significant improvement in all GRBAS scale parameters. The overall grade of hoarseness (G) changed from an average of 1.05 (SD: 0.56, median 1) to 0.52 (SD: 0.50; $P < 0.001$). Perceptual roughness (R) improved from a mean of 0.79 (SD: 0.69) to 0.44 (SD: 0.50, $P = 0.005$), breathiness (B) from 0.82 (SD: 0.50) to 0.23 (SD: 0.43; $P < 0.001$), asthenia (A) from 0.56 (SD: 0.55) to 0.13 (SD: 0.34; $P < 0.001$), and strain (S) from 0.58 (SD: 0.49) to 0.36 (SD: 0.48; $P = 0.022$) (Table 4).

TABLE 4.
Summary of Mean, SD, Minimum, Maximum, and Median GRBAS Scale Scores Before and After Therapy

Perceptual Parameter	Before Therapy				After Therapy				Wilcoxon Signed Ranks Test
	Ø	SD	Min./Max.	Median	Ø	SD	Min./Max.	Median	
G	1.05	0.56	0 / 3	1	0.52	0.50	0 / 1	1	$P < 0.001$*
R	0.79	0.69	0 / 3	1	0.44	0.50	0 / 1	0	$P = 0.005$*
B	0.82	0.50	0 / 2	1	0.23	0.43	0 / 1	0	$P < 0.001$*
A	0.56	0.55	0 / 2	1	0.13	0.34	0 / 1	0	$P < 0.001$*
S	0.58	0.49	0 / 1	1	0.36	0.48	0 / 1	0	$P = 0.022$*

Fields marked with an asterisk (*) highlight significant and highly significant results.

TABLE 5.
Mean (SD), Minimum, and Maximum Values of All Investigated Instrumental Acoustic Parameters and the Combined Parameter DSI

Instrumental Acoustic Parameter		Before Therapy Ø	Before Therapy SD	Before Therapy Min./Max.	After Therapy Ø	After Therapy SD	After Therapy Min./Max.	Wilcoxon Signed Ranks Test
Speaking	f_o mean (Hz)	170	49.2	82–257	166.5	49	60/242	$P = 0.861$
	f_o range (ST)	7	2.7	1/13	8.1	2.4	3/15	$P = 0.030$*
	SPL mean (dBA)	61.6	4.5	50/70	63.2	4.1	48/69	$P = 0.105$
	SPL range (dBA)	12.9	4.7	2/25	14.8	4.6	4/25	$P = 0.030$*
Counting	f_o mean (Hz)	172.5	46.5	85/259	164.1	45.3	79/240	$P = 0.021$*
	f_o mean (Hz)	324.2	61	193/431	320.9	59	208/429	$P = 0.573$
Calling	SPL max. (dBA)	96.1	9.1	70/116	97.2	7.6	83/111	$P = 0.973$
	SPL max. (dBA)	93.4	9.9	76/112	94.1	8.4	76/111	$P = 0.719$
Singing	SPL min. (dBA)	49.4	6	38/62	49.1	6	28/67	$P = 0.870$
	Dynamic range (dBA)	42.8	12.3	7/64	44.8	10.1	27/67	$P = 0.285$
	f_o max. (Hz)	723.9	272.8	227/1372	746.7	270.5	227/1268	$P = 0.594$
	f_o min. (Hz)	121.9	36	68/181	117.4	30.8	67/185	$P = 0.226$
	f_o range (ST)	30.5	6.7	12/42	31.2	6.2	15/40	$P = 0.470$
Jitter		0.84	0.6	0.1/3.6	0.79	0.3	0.3/1.4	$P = 0.917$
DSI		4.5	3.2	1.4/15.1	4.8	2.6	0.2/11.3	$P = 0.291$

Fields marked with an asterisk (*) highlight significant results.

Instrumental acoustic parameters

After therapy, the speaking voice range measured in semitones increased in average by 16% from 7–8.13 semitones ($P = 0.029$). In addition, the speaking voice intensity range increased from a mean of 12.9 to 14.85 dBA (15%, $P = 0.03$). Mean f_o during counting with comfortable voice intensity significantly decreased from 172.49 Hz to 164.1 Hz (5%, $P = 0.021$). As summarized in Table 5, there were no significant changes for all other investigated instrumental parameters after treatment.

Correlations

There was no correlation between the VHI-9i and the GRBAS scale results, nor with any of the investigated instrumental acoustic parameters. Also, there was no statistical agreement between GRBAS scale and instrumental acoustic parameters ($P > 0.05$). However, there was a correlation between the single instrumental parameters f_o range (semitones) and the SPL (dBA) range of the speaking voice. The greater the speaking voice f_o range was, the larger was the SPL range ($P < 0.001$).

DISCUSSION

In the present study, current recommendations for voice assessments were applied in patients with functional voice disorders.[18] After combined indirect and direct voice therapy, subjective voice symptoms were reduced, and perceptual voice quality was improved. An increased speaking voice pitch and intensity range (f_o and SPL range) indicates transfer effects of voice therapy contents to the patients' vocal behavior, in this case while answering a question. Further mean f_o during counting was significantly lower after voice therapy, which might be explained with a more relaxed phonation.[53,54] However, these were the only effects that were measurable by the applied standard instrumental acoustic measurement methods.

These results indicate that the voice therapy mainly affected the speaking voice technique. Studies in teachers during a working day show that increased f_o and SPL levels are a natural response to vocal use.[55] A higher f_o and SPL are associated with a higher tonus in the vocal folds.[53] Thus, the patients may have had more relaxed phonatory muscles during some voice tasks after therapy, and used an effectively different technique during counting as compared with before treatment.

In agreement with reports by Gillespie et al and van Lierde et al, there was no correlation of perceptual and subjective findings with instrumental assessment results in our patient group (Table 1). Gillespie et al argued that correlations between vocal deviation findings and VHI results were mostly observed for one or more of the VHI subscales in previous studies, emphasizing that the VHI subscores do not represent the VHI in total.[20] Also, the lack of correlations between subjective, perceptual, and instrumental outcomes was attributed to differing constructs of each measure. Furthermore, there may be correlations for some types of voice disorders, which may not be true for other types. Based on this and the present study results, we conclude that perceptual, subjective, and instrumental acoustic assessments provide independent information from each other and should be considered separately.

Subjective and perceptual voice outcomes

As documented in several studies, the VHI is a valid tool to describe voice improvement from the patient's perspective.[10,15,23,24,48,56,57] In the present study, a significant VHI-9i improvement was found, substantiating that the individualized combined indirect and direct voice therapy approach led to a significant reduction of subjective voice handicap and was effective in the patient's view.

Similarly, there was a significant improvement in all perceptual GRBAS scale parameters. In previous works, the overall grading of dysphonia (G) has been described as the most reliable parameter to indicate voice changes. Therefore, it was hypothesized that the overall impression of general hoarseness is easier to determine than all other more specific perceptual parameters.[58–60] Expert knowledge experience and training as well as the use of perceptual assessment standards have been shown to improve intra-rater reliability for perceptual assessments.[26,29,61,62] In the Department of Phoniatrics and Speech Pathology, University Hospital Zurich, defined standards and periodic perceptual assessment training with the whole team using a range of voice disorders is done, which may have led to more consistent perceptual ratings between clinicians for all GRBAS scale parameters. Based on this, we conclude that all perceptual voice characteristics of the GRBAS scale are independently valid to document therapeutic success in patients with functional voice disorders.

Clinical application of instrumental acoustic parameters

In our study, the instrumental parameters speaking f_o mean (Hz) and SPL mean (dBA), calling f_o mean and SPL max, singing SPL min/max, f_o min/max, f_o range, jitter (%), and DSI did not show significant changes after treatment. Therefore, their validity to indicate voice changes in patients with functional dysphonia is still limited. As shown in patients with structural vocal fold changes or paresis, the sensitivity to change of instrumental acoustic measurements may be higher in those patient groups as compared with patients with functional dysphonia, regardless of the severity of subjective handicap.[63] This has been shown in patients with organic voice disorders applying jitter, and the DSI.[41,64] Changes in patients with functional voice disorders may be smaller after therapy, or more specifically restricted to measurable changes in voice technique such as the f_o and SPL range.

The clinial application of instrumental acoustic measurements is still limited by a number of pragmatic influencing factors such as the wide natural individual differences of all instrumental acoustic parameters in healthy and voice-disordered adults.[65] Further, in the present study, it was not distinguished between women and men for pre- and post-treatment comparisons, even though gender-specific differences have been reported. Also, factors like personality, vocal confidence, skill, and experience influence the patient's performance during assessments.[66] In summary, the role of instrumental acoustic assessments in patients with functional voice disorders has to be further evaluated applying well-defined measurement standards and examining both women and men.[12,60]

CONCLUSIONS

Subjective assessments such as by VHI, a perceptual voice analysis by GRBAS scale, and instrumental measurements of the speaking voice f_o and SPL range as well as the mean f_o while counting with normal intensity are clinically useful tools to document therapy effects in patients with functional dysphonia. A larger f_o and SPL speaking voice range after treatment indicate an altered voice technique. Thus, these instrumental measures may be indicators of therapy success and transfer effects. All other instrumental acoustic parameters did not show significant changes after treatment. Therefore, their validity to indicate voice changes in patients with functional dysphonia is still limited.

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