# Clinical Effects of Voice Therapy on Vocal Outcomes in Unilateral Vocal Fold Paralysis: Proof-of-Concept Study for Two SOVT-Based Treatment Protocols

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**Summary: Background**. Studies on treatment efficacy in unilateral vocal fold paralysis (UVFP) often lack a predetermined treatment protocol, and little is known about the effects of specific vocal techniques on vocal outcomes and quality of life in UVFP patients. The purpose of this preliminary proof-of-concept study is to investigate the effects and feasibility of two intensive treatment protocols based on water-resistance therapy (WRT) and vocal function exercises (VFE).

**Methods**. Ten participants with acute or chronic UVFP/paresis were recruited in the study and randomly assigned to the WRT or VFE group. Three of these participants presented with aphonia and could not complete the program as prescribed. The remaining participants completed an intensive therapy program with the assigned vocal technique. Before, during, and after the program, a multidimensional voice assessment was performed. Maximum phonation time, acoustic, perceptual, and patient-reported outcome measures (PROMs) were obtained.

**Results**. WRT and VFE had positive clinical effects on instrumental and auditory-perceptual voice quality, glottal closure, and PROMs, but interindividual variability was high. Studies with larger sample sizes are necessary to confirm or refute these findings.

**Conclusion**. The WRT- and VFE-based therapy programs are both feasible and seem to elicit positive clinical changes in UVFP patients. Suggestions on how to improve the programs are provided, as well as considerations for implementation in clinical practice. Follow-up research is needed to examine the efficacy of both programs on group level.

**Key Words:** Vocal fold paralysis–Water-resistance therapy–Vocal function exercises–Voice therapy.

## INTRODUCTION

Unilateral vocal fold paralysis (UVFP) is caused by a neurologic injury to the recurrent laryngeal nerve (RLN), which results in immobility of one of the vocal folds. The RLN can be injured by a variety of causes, including iatrogenic (eg, thyroid, carotic, thoracic, or cervical spine surgery) or noniatrogenic trauma, infections, malignancy, neurologic disease, or idiopathic if no specific cause is identified.[1,2] The true incidence of UVFP is unknown, but has been estimated at 8 to 14.4% of pathologies in the dysphonic population.[2-4] Due to the one-sided vocal fold immobility, UVFP frequently causes glottal incompetence, which results in dysphonia. The voice in UVFP is typically characterized by a hoarse, breathy, and weak voice, associated with vocal fatigue, restricted pitch and loudness variations, and a short phonation time.[5,6] The degree of dysphonia may depend on the position of the paralyzed vocal fold (ie, median, paramedian, intermediate, or lateral).[7] Patients may show compensatory hyperfunctional behaviors to obtain phonation, such as anteroposterior or mediolateral compression of the ventricular vocal folds, which can result in a rough and strained voice. Globus sensations and neck discomfort are other symptoms that can occur with this condition.[2,5] Additionally, dysphonia due to UVFP has an extensive impact on patients' functional communication, quality of life (QoL), participation, and professional activities, which may in turn lead to frustration, anxiety, social isolation, depression, and an altered self-identity.[8-11] UVFP and/or neurologic voice disorders have been found to have the greatest psychosocial impact on patients compared with other voice disorders,[3,12,13] and UVFP seems to cause the highest degree of dysphonia severity.[3]

Due to these severe voice problems, UVFP requires behavioral and/or surgical treatment.[2,14,15] Behavioral voice therapy should start as early as possible, preferably within 4 weeks after UVFP onset, as vocal fold motility recovery may be poorer with delayed therapy (ie, more than 8 weeks after onset).[16] Additionally, early and appropriate behavioral voice therapy may avoid the need for (permanent) surgery.[2,5,7] Generally, the aim of voice therapy is to improve glottal closure, abdominal breath support, and intrinsic laryngeal muscle strength and agility, while avoiding

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compensatory hyperfunctional behaviors.[2,17,18] The ultimate goal is to restore functional voicing and improve the patient's voice-related QoL.[14,15]

A variety of therapy approaches are used in clinical practice and scientific literature, including pushing exercises, hard glottal attacks, half-swallow boom, abdominal breathing, head and neck relaxation, semioccluded vocal tract exercises (SOVTEs), resonant voice, the accent method, digital manipulation, manual circumlaryngeal therapy, yawn-sigh, and vocal function exercises (VFE).[14-16,18-22] In clinical practice, a variability in the types of voice therapy can be noted, although speech-language pathologists (SLPs) seem to generally use SOVTEs, resonant voice, VFE, laryngeal manipulation, and vocal hygiene.[20,22] However, effectiveness studies of specific vocal techniques in UVFP research are scarce, as they are usually imbedded in broader therapy programs.[16,21,23-25] A systematic review by Walton et al[15] showed that studies on effectiveness of voice therapy often lack a therapy protocol and a specific description of the therapy approach and dosage. Additionally, certain studies described the use of an individualized therapy approach with varying content and dosage, which hinders meaningful comparisons between treatment outcomes. Therefore, further research on specific therapy techniques is needed in order to increase the knowledge base on optimal voice therapy management of UVFP.[15]

One potentially beneficial vocal technique is VFE, which are physiologic voice exercises aimed at balancing the subsystems of voice production.[18,26] A systematic review by Angadi et al[27] reported that VFE is an effective and efficacious tool for the rehabilitation of voice disorders, although no studies with only UVFP patients were included. Additionally, the use of VFE as part of a broader therapy program has been described in clinical cases and efficacy studies with UVFP patients, in which improved vocal outcomes were generally noted.[7,18,21,23] However, no outcomes after the implementation of only VFE as a vocal technique have been reported.

Another technique that merits further investigation is water-resistance therapy (WRT), an SOVTE in which the patient phonates through a glass or flexible resonance tube that is submerged in water. WRT was considered an effective and popular SOVTE for UVFP treatment among Belgian SLPs,[20] and a qualitative study in Australia showed that SLPs utilize WRT in UVFP patients as well.[22] However, scientific studies investigating the efficacy of WRT in this population are scarce. Most existing studies on the effect of WRT were conducted for other voice disorders and reported improvements in aerodynamic, auditory-perceptual, and patient-reported outcome measures (PROMs).[28-31] Only one study described improved acoustic and aerodynamic outcomes of a flow phonation therapy program (including WRT) in two UVFP patients and one patient with unilateral vocal fold paresis, but no conclusions about the relative effectiveness of WRT can be made as it was embedded in a broader therapy program.[32]

In terms of therapy dosage for UVFP, most scientific studies used weekly or twice-weekly sessions of 30 minutes spread over several weeks or months, often with an individually determined therapy duration.[15] However, based on the principles of neuroplasticity and motor learning, and promising results of "massed practice" in recent studies, a short-term intensive voice therapy (IVT) program may have benefits over a traditional approach, such as improved learning and consolidation of vocal behaviors, time efficiency, cost-effectiveness, higher attendance rates and patient compliance, the possibility to target multiple voice production components simultaneously, and opportunities in terms of specificity and individuality.[33-35] Recent studies with dysphonic patients have demonstrated that IVT is at least as effective as traditional spaced practice across various vocal and PROMs.[33,35-37] Nevertheless, IVT may potentially overdose the laryngeal system, so this should be considered and monitored throughout treatment.[36,38,39] There is currently no clear understanding of the ideal therapy dosage in the UVFP population,[15] although Behlau et al[38] reported success with UVFP patients after IVT.

Therefore, the purpose of the current study is to provide a proof of concept for the feasibility and efficacy of an intensive treatment protocol consisting of either WRT or VFE in UVFP patients. It was hypothesized that both treatment protocols would elicit comparable positive effects on voice quality and PROMs due to the similarities in their underlying mechanisms. WRT might have an advantage over VFE because of its secondary source of vibration (water bubbling), which creates a fluctuating intraoral pressure that can be perceived as a "massage-like" effect on the vocal folds and the vocal tract, potentially reducing discomfort and muscle tension.[28,30,40] For this reason, WRT is hypothesized to induce the lowest risk of compensatory hyperfunctional behaviors. The advantages of VFE over WRT might include the specificity of the training schedule that could encourage adherence to home practice, and the lower requirements in terms of materials, which could additionally lower the threshold to practice at home or remotely. Overall, the results from this study may guide clinical and scientific decisions regarding UVFP care.

## METHOD

The study was approved by the Ethics Commission of Ghent University Hospital (B6702021000447).

### Participants

Participants were recruited at Ghent University Hospital. In order to be included in the study, participants had to be 18 years or older, have a diagnosis of UVFP or unilateral vocal fold paresis observed by a laryngologist, and have vocal complaints. Both individuals in an acute phase of UVFP (onset $< 1$ year) and a chronic phase (onset $> 1$ year) were included. All participants provided written informed consent prior to participation.

**TABLE 1.**
**Patient Characteristics per Group**

| ID | Age | Gender | Etiology | Side of paralysis/ Paresis | Onset (time before recruitment) | Medialization surgery prior to study |
|---|---|---|---|---|---|---|
| WRT group | | | | | | |
| 1 | 64 | Cisgender male | Idiopathic | Left | 13 y | No |
| 3 | 34 | Cisgender male | Iatrogenic (thyroidectomy) | Left | 2 mo | No |
| 5 | 65 | Cisgender male | Iatrogenic (thyroidectomy) | Right (paresis) | 5 y | No |
| 7 | 88 | Cisgender female | Idiopathic | Left | 3 mo | No |
| VFE group | | | | | | |
| 2 | 54 | Cisgender male | Idiopathic | Right | 2 y | Injection laryngoplasty (2x) |
| 4 | 60 | Cisgender female | Radiotherapy | Left | 14 y | No |
| 6 | 61 | Cisgender male | Unclear, potentially iatrogenic (heart surgery), or post ischemia | Left (paresis) | 3 mo | No |
| Aphonia group | | | | | | |
| 8 | 78 | Cisgender male | Radiotherapy | Left | 2 mo aphonic (prior to that: increasing dysphonia for several months) | No |
| 9 | 62 | Cisgender male | Iatrogenic (thoracal surgery) | Left | 3 mo | No |
| 10 | 61 | Cisgender male | Iatrogenic (intubation) | Right left (paresis) | 2 mo | No |

*Abbreviations:* ID, identification; VFE, vocal function exercises; WRT, water-resistance therapy.

After recruitment, participants were randomly assigned to either the WRT or VFE group. A third group, consisting of patients with aphonia or severe dysphonia who could not follow the therapy protocol as prescribed, is also described to provide a comprehensive overview. The severity of dysphonia in these participants was evidenced by the inability to calculate multiparametric voice quality indices or determine the frequency/intensity range due to the severely disturbed acoustic voice signal. A description of participant characteristics can be found in Table 1. All participants with chronic UVFP/paresis had received voice therapy in the past, and one of them (ID 2) had undergone medialization surgery. Additionally, none of the participants with acute UVFP/paresis had received any prior treatment.

## Procedure

After recruitment, all participants received two pretherapy voice assessments within a 2-week interval. During one of these voice assessments, flexible laryngovideostroboscopy (LVS) was also conducted. After these baseline assessments, the participants were randomly assigned to the WRT or VFE group using an online randomization tool, and received 2 weeks of intensive therapy with the assigned method. Every week of the intensive therapy consisted of two sessions of 1 hour at the voice clinic, and three online sessions of 15 minutes via videocall. In total, participants received 5-and-a-half hours of voice therapy over the course of 2 weeks. A first post-therapy assessment (post1) was conducted after IVT. After this assessment, participants received 6 weeks of follow-up voice therapy (FUVT), which consisted of one 30-minute guided videocall session a week. After these 6 weeks, a second post-therapy assessment (post2) was conducted. Two months after post2, a third post-therapy assessment (post3) was conducted to investigate the evolution of outcomes after conclusion of guided voice therapy. Table 2 shows a description of the protocol.

## Multidimensional voice assessment

### *Flexible LVS and visuo-perceptual assessment*

A LVS examination was performed at four different assessments (pre1 or 2, post1, post 2, and post3) by a specialized laryngologist (P.T.) blinded to group allocation. In order to visualize the vocal fold motility, participants were asked to sustain the vowel /i:/ twice, to perform a repeated "sniff" maneuver, to alternate a sniff with /i:/ repeatedly, and to perform two ascending glissandos, followed by two descending glissandos on /i:/.

After collection of all data, the LVS recordings were randomized and rated based on a consensus between a SLP (K.V.L.) and Ear, Nose, and Throat (ENT) specialist (S.C.) with expertise in diagnostics and treatment of voice disorders. Both raters were blinded to group or time allocation of the samples. The Voice-Vibratory Assessment with Laryngeal Imaging (VALI) rating form was used for evaluation of glottal closure, amplitude (ie, magnitude of lateral movement of the vocal folds), mucosal wave,

**TABLE 2.**
**Overview of the Study Protocol**

| Protocol | Description |
|---|---|
| Pre1 | First baseline voice assessment before voice therapy |
| Pre2 | Second baseline voice assessment before voice therapy (2 wk after the first) |
| Intensive VT | Two weeks of intensive voice therapy with WRT or VFE<br>– 2x 1 h live session/week<br>– 3x 15 min online session/week |
| Post1 | First post-therapy voice assessment immediately after intensive VT |
| Follow-up VT | Six weeks of follow-up voice therapy with WRT or VFE<br>– 1x 1 h online session/week |
| Post2 | Second post-therapy voice assessment immediately after follow-up VT |
| Post3 | Third post-therapy voice assessment 8 wk after conclusion of follow-up VT |

*Abbreviations:* VFE, vocal function exercises; VT, voice therapy; WRT, water-resistance therapy.

nonvibrating portions of the vocal folds, supraglottic activity (anteroposterior and mediolateral), vertical level of the vocal folds, free-edge contour, phase closure, phase symmetry, and phase regularity.[41] Additionally, the side of the paralysis was rated (left-right), and the position was rated using a four-point ordinal scale (median, paramedian, intermediate, and lateral) based on Schneider-Stickler.[42] Adduction and abduction of the left and right vocal fold were rated on a three-point ordinal scale, with 0 indicating no active movement, 1 indicating decreased movement, and 2 normal movement. Last, the pharyngeal residue in the pyriform sinus was rated using the Yale Pharyngeal Residue Severity Rating Scale.[43]

### *Instrumental voice assessment*

The instrumental voice assessments were performed in an acoustically isolated room at the voice clinic of Ghent University Hospital by one of three SLPs blinded to group allocation. The duration of this assessment was approximately 30 minutes. The complete instrumental voice assessment consisted of the following procedures.

*Maximum performance task*. In order to obtain the maximum phonation time (MPT, in seconds), participants were asked to sustain the vowel /a:/ as long as possible at their habitual pitch and loudness after maximal inspiration. Participants were seated while performing this task and were encouraged verbally by the SLP during phonation. The best of three attempts, which were timed using an online stopwatch, was retained for further analysis and calculation of the Dysphonia Severity Index (DSI).

*Acoustic analysis*. Participants were instructed to sustain the vowel /a:/ for several seconds after an automatic sequence (ie, counting from one to three) at their habitual pitch and loudness in a Shure SM-48 microphone at a distance of 15 cm from the mouth. The average fundamental frequency ($f_o$, in Hz) and jitter (%) were obtained using the Multi-Dimensional Voice Program of the Computerized Speech Lab (CSL, model 4500, KayPENTAX, Montvale, NY), of which the latter was used for calculation of the DSI.

*Frequency and intensity range*. This was determined by the Voice Range Profile of the CSL, using a Shure SM-48 microphone at 15 cm from the mouth. The procedure outlined by Heylen et al[44] was used for this task. Participants were instructed to sustain the vowel /a:/ for several seconds using their habitual pitch and loudness, followed by their lowest fundamental frequency ($f_o$-low), lowest intensity (I-low), highest fundamental frequency ($f_o$-high), and highest intensity (I-high), respectively. All participants received verbal encouragement and the desired productions were modeled by the SLP during this task. The aforementioned parameters were used to calculate the participants' frequency and intensity range. Additionally, $f_o$-high and I-low were retained for DSI calculation.

*Dysphonia Severity Index*. The DSI is a quantitative correlate of voice quality and vocal capacity, based on a weighted combination of the parameters MPT (in seconds), $f_o$-high (in Hz), I-low (in dB), and jitter (in %) according to the formula "DSI = 0.13 MPT + 0.0053 $f_o$-high − 0.26 I-low − 1.18 jitter(%) + 12.4."[45] The obtained score usually varies from − 5 to + 5, although lower and higher scores are possible in extreme cases. The cutoff score between a normophonic and disordered voice quality was determined at + 1.6,[46] in which a higher score corresponds to a better voice quality, while a lower score indicates an increasingly severe dysphonia. The minimal clinically relevant change in DSI was set at 2.49.[47]

*Acoustic Voice Quality Index*. The Acoustic Voice Quality Index (AVQI) is an acoustic and quantitative correlate of overall dysphonia severity based on a sustained vowel and continuous speech. Scores range from 0 to 10, and the clinical cutoff between normophonia and dysphonia lies at 2.95 for Dutch, with

higher scores indicating a higher dysphonia severity. To calculate the AVQI, a weighted combination of the output of six acoustic time- (ie, shimmer local, shimmer local dB, and harmonics-to-noise ratio [HNR]), frequency- (ie general slope of the spectrum, tilt of the regression line through the spectrum), and frequency-domain (smoothed cepstral peak prominence [CPPs]) measures is modeled in the linear regression formula "2.571 [3.295 − 0.111 (CPPs) − 0.073 (HNR) − 0.213 (shimmer local) + 2.789 (shimmer local dB) − 0.032 (slope) + 0.077 (tilt)]."[48] Participants were instructed to sustain the vowel /a:/ for 5 seconds, followed by reading the Dutch oronasal reading passage "Papa en Marloes"[49] aloud (see Appendix A). The speech samples were recorded using an AKG Lyra USB condenser microphone, positioned at a distance of 15 cm from the mouth, and the software program Praat, version 6.2.07.[50] All samples were recorded using a sampling frequency of 44.1 kHz and were saved as a mono channel WAV file with a bit depth of 16 bits. The middle 3 seconds of the /a:/ and the first two sentences of the reading passage were used to calculate each participant's AVQI score. A minimum signal-to-noise ratio (SNR) of 30 dB is required to obtain acceptable perturbation measurements.[51] Samples with an SNR less than 30 dB were therefore removed from further analysis of the AVQI. A change of 0.54 in AVQI score was determined as the minimal clinically relevant change, based on Barsties and Maryn.[52]

### *Auditory-perceptual voice assessment*

The auditory-perceptual voice assessment was performed by two SLPs (T.P. and C.L.) using the GRBASI scale.[53,54] All speech samples contained a sustained /a:/ and continuous speech (ie, reading of the complete passage "Papa en Marloes"), and were anonymized and presented in a randomized order. The SLPs were both blinded to group and time allocation of the samples. First, the SLPs rated all samples individually, and during a second listening session, a consensus evaluation was performed. To ensure intrarater reliability, 20% of the speech samples were randomly repeated throughout the assessment.

### *Patient-reported outcome measures*

*Voice Handicap Index*. The Voice Handicap Index (VHI) is a self-assessment tool for measuring the psychosocial impact of voice disorders, developed by Jacobson et al.[55] It consists of 30 statements, equally distributed over three domains: functional, physical, and emotional. On a five-point rating scale (0 = never, 1 = almost never, 2 = sometimes, 3 = almost always, 4 = always), the patient indicates their response, achieving a minimum score of 0 and a maximum of 120. The higher the score, the more severe the perceived impact of the voice disorder on a patient's activities of daily life (ADL). For the Dutch version of the VHI, a score below 20 indicates that the voice does not impose limitations on the patient's ADL, while a score of 20-40 suggests the presence of some limitations. A score of 40-60 indicates substantial limitations of ADL, and a score higher than 60 suggests that the voice disorder is considered a handicap.[56] The minimal clinically relevant changes for the total VHI score and the physical, functional, and emotional subscales were set at 14 and 8, 6, and 7 points, respectively.[57]

*Additional questionnaires*. During the first assessment, the participants completed a questionnaire based on De Bodt et al[58] about their vocal complaints, lifestyle habits, and vocal risk factors. After IVT and FUVT, participants were also asked to provide feedback about the therapy program (see Appendix B).

## Voice therapy

The content of voice therapy was standardized as much as possible between all participants, and was provided by the first author (I.K.). The WRT protocol was based on Meerschman et al,[36] while the VFE protocol has been described by Stemple et al.[26] If participants in the VFE group were unable to match the pitch of the piano or SLP, modifications according to Radhakrishnan and Scheidt[59] were implemented. During FUVT, exercises on word, sentence, text, and semispontaneous speech level were added to the VFE program. This addition was made to facilitate transfer to daily speech, and to align the content with the WRT program in terms of hierarchical levels of phonation and speech. A specific description of the therapy content can be found in Appendix C. Because participant 7 repeatedly swallowed water through the tube during the initial WRT exercises, the cup of water was removed and the program was offered as "tube in air" exercises.

An online web-based training tool developed by the first author (I.K.) was also presented to the participants to facilitate home practice. Participants were able to read information about the exercises and could watch short clips of all vocal exercises performed by the therapist, with written instructions on how to perform each exercise correctly. They were also encouraged to practice at home at least once per day for a maximum of 15 minutes at a time. Home practice was monitored by providing a homework chart to the participants, which they returned after the therapy program.

In the group of participants who had severe dysphonia and aphonia, a trial of WRT or VFE was performed. As these trials were unsuccessful, their program consisted of breathing exercises and exercises to elicit phonation (head posture, digital manipulation, hard voice onset, and inhalation phonation) while avoiding hyperfunctional compensation.

## Analysis

Due to the small sample size within each group, the results from this preliminary study are described qualitatively and descriptively. Intrarater reliability for the auditory- and visuo-perceptual assessments was calculated using a two-

way mixed, single-measures, consistency Intraclass Correlation Coefficient (ICC(3,1)) in IBM SPSS Statistics 29 (SPSS Corporation, Chicago, IL). Guidelines described by Koo and Li[60] were used for interpretation of intrarater reliability: poor below 0.50, moderate between 0.50 and 0.75, good between 0.75 and 0.90, and excellent above 0.90. For the purposes of the current study, only parameters with good or excellent intrarater reliability were included in the "Results" section. For the visuo-perceptual evaluations, all parameters regarding side, position, motility, and saliva residue were included, as well as the following parameters from the VALI protocol: glottal closure (ICC = 1), mediolateral supraglottal compression (ICC = 0.952), phase closure (ICC = 0.842), and regularity (ICC = 0.933). The parameters amplitude right and nonvibrating portion right both yielded good-to-excellent ICCs, but were excluded because the ICCs for the left side (which was usually the paralyzed side) were moderate. For the auditory-perceptual evaluations, Roughness and Asthenia yielded excellent reliability (ICC = 1), and good intrarater reliability was found for Grade (ICC = 0.828), Breathiness (ICC = 0.878), Strain (ICC = 0.882), and Instability (ICC = 0.882).

## RESULTS

### Pretherapy characteristics and group allocation

An overview of pretherapy vocal symptoms and risk factors in all groups can be found in Table 3. Other vocal complaints included having an unpredictable voice quality (especially in participants with chronic UVFP) and decreased voice range (mentioned by 1 participant in the WRT and 1 in the VFE group).

Over the course of the study, certain issues in terms of group allocation occurred: three participants (ID 8-10) had severe dysphonia to aphonia during the IVT, and could therefore not follow the treatment protocol as described. Their therapy program consisted of different techniques to elicit phonation. After the intensive treatment period did not yield sufficient results, laryngeal electromyography (LEMG) was performed, which revealed a poor prognosis of neural recovery in all three participants. Participant 8 opted for type-I thyroplasty, whereas the other two participants underwent in-office injection laryngoplasty. Participant 9 underwent an additional type-I thyroplasty 4 months after the initial injection laryngoplasty. Similarly, participant 7 was assigned to the WRT group, but due to comprehension difficulties during the program, she did not complete the IVT program as described. However, the data of these four participants were added to the current study to provide a comprehensive description of factors that may influence choices of treatment. Participant 6 (VFE group) followed the IVT as foreseen, but could not continue with the FUVT due to scheduling issues.

### Laryngovideostroboscopic outcomes

For participants 1 and 8, only one LVS recording was available, so these participants were excluded from the description of the LVS outcomes. The evolution of glottal closure, phase closure, regularity, mediolateral supraglottic activity, and saliva residue of all other participants is described in Table 4.

In the WRT group, participant 3 showed a paramedian position of the paralyzed vocal fold (left) during all assessments, except at post2, when it was rated as median. Participant 5 showed no paralysis, but a right-sided paresis with decreased abduction. No changes in motility were noted over time. In participant 7, the most notable change between pre and post1 consisted of improved abduction in the nonparalytic side, while no motility was observed in the

**TABLE 3.**
**Pretherapy Vocal Symptoms and Risk Factors Per Group**

| | WRT (n = 4) | VFE (n = 3) | Aphonia (n = 3) | Total (n = 10) |
|---|---|---|---|---|
| Vocal symptoms and complaints | | | | |
| Hoarseness | 4 (100%) | 2 (67%) | 3 (100%) | 9 (90%) |
| Low volume | 2 (75%) | 3 (100%) | 3 (100%) | 9 (90%) |
| Vocal instability | 2 (50%) | 2 (67%) | 0 (0%) | 4 (40%) |
| Vocal fatigue | 4 (100%) | 3 (100%) | 3 (100%) | 10 (100%) |
| Irritation in the throat | 3 (75%) | 1 (33%) | 1 (33%) | 5 (50%) |
| Throat clearing | 3 (75%) | 3 (100%) | 3 (100%) | 9 (90%) |
| Swallowing problems | 0 (0%) | 1 (33%) | 1 (33%) | 2 (20%) |
| Risk factors and lifestyle habits | | | | |
| Asthma/airway infections | 0 (0%) | 1 (33%) | 2 (67%) | 3 (30%) |
| Allergies | 1 (33%) | 1 (33%) | 0 (0%) | 2 (20%) |
| Throat clearing | 3 (75%) | 3 (100%) | 3 (100%) | 9 (90%) |
| Intensive voice use in daily life | 3 (75%) | 2 (67%) | 2 (67%) | 7 (70%) |
| Professional voice use | 2 (50%) | 1 (33%) | 2 (67%) | 5 (50%) |
| Regular contact with irritants | 1 (25%) | 1 (33%) | 1 (33%) | 3 (30%) |
| GERD | 0 (0%) | 0 (0%) | 1 (33%) | 1 (10%) |

*Abbreviations:* GERD, gastroesophageal reflux disease; VFE, vocal function exercises; WRT, water-resistance therapy.

**TABLE 4.**
**Evolution of Glottal Closure for Individual Participants**

| ID | Parameter | Pre | Post1 | Post2 | Post3 |
|---|---|---|---|---|---|
| WRT group | | | | | |
| 3 | Glottal closure | Incomplete | Complete | Posterior | Posterior |
| | Phase closure | Equal | Equal | Equal | Equal |
| | Regularity | 70% | 70% | 60% | 70% |
| | ML activity | 1 | 2 | 0 | 1 |
| | Saliva residue | Mild | Mild | Mild | Trace |
| 5 | Glottal closure | Spindle | Spindle | Spindle | Spindle |
| | Phase closure | Closed | Equal | Equal | Closed |
| | Regularity | 70% | 70% | 70% | 70% |
| | ML activity | 2 | 1 | 1 | 1 |
| | Saliva residue | Trace | Mild | Trace | Trace |
| 7 | Glottal closure | Not assessable | Incomplete | NA | NA |
| | Phase closure | Not assessable | Open | | |
| | Regularity | Not assessable | 80% | | |
| | ML activity | 2 | 3 | | |
| | Saliva residue | Mild | Moderate | | |
| VFE group | | | | | |
| 2 | Glottal closure | Incomplete | Complete | Complete | Complete |
| | Phase closure | Closed | Closed | Closed | Closed |
| | Regularity | 80%* | 50%* | 40%* | Not assessable |
| | ML activity | 3 | 4 | 3 | 3 |
| | Saliva residue | Moderate | Moderate | Moderate | Moderate |
| 4 | Glottal closure | Posterior | Posterior | Complete | Complete |
| | Phase closure | Closed | Equal | Open | Closed |
| | Regularity | 80% | 60% | 80% | 70% |
| | ML activity | 4 | 3 | 3 | 3 |
| | Saliva residue | Moderate | Moderate | Moderate | Moderate |
| 6 | Glottal closure | Spindle | Anterior | NA | NA |
| | Phase closure | Closed | Closed | | |
| | Regularity | 70% | 70% | | |
| | ML activity | 1 | 1 | | |
| | Saliva residue | No residue | No residue | | |
| Aphonia group | | | | | |
| 9 | Glottal closure | Spindle | Spindle | NA | NA |
| | Phase closure | Open | Open | | |
| | Regularity | 40% | 50% | | |
| | ML activity | 3 | 3 | | |
| | Saliva residue | Moderate | Moderate | | |
| 10 | Glottal closure | Incomplete | Incomplete | NA | NA |
| | Phase closure | Open | Open | | |
| | Regularity | 100% | 90% | | |
| | ML activity | 4 | 4 | | |
| | Saliva residue | Severe | Severe | | |

*Abbreviations:* ML, mediolateral; NA, not applicable (due to dropout); VFE, vocal function exercises; WRT, water-resistance therapy.

* Noted as difficult to assess due to supraglottic compression.

paralytic side. In the VFE group, participant 2 had a paramedian position of the paralyzed vocal fold (right), which was rated as median at post2 and post3. No changes in vocal fold motility were observed. In participant 4, an intermediate position of the left vocal fold was noted without active movement. This parameter did not change over time. Participant 6 had a left vocal fold paresis with decreased adduction and abduction at the pretherapy assessment, which improved to normal adduction and decreased abduction at post1. The participants with aphonia showed interindividual variety. Participant 9 had a left vocal fold paralysis in a lateral position at the pretherapy assessment, and in an intermediate position at post1. Participant 10 had a right vocal fold paralysis and left vocal fold paresis without changes in motility between the pre- and post assessments.

## Instrumental vocal outcomes

### *Maximum performance task*

In the WRT group, the two participants with chronic UVFP/paresis (ID 1 and 5) showed stable MPT measures around 15 seconds during nearly all assessments, which never reached the clinical norm value for Belgian cisgender male adults (21.8 seconds). For participant 1, a MPT of 20.6 seconds was found at post3, and the highest MPT in participant 5 was found at post1 (18.7 seconds). Participant 3 (acute UVFP) showed a steady improvement of MPT from 17.3 seconds at pre1 to 32.7 seconds at post2, which remained stable at post3. Since this improvement was already apparent at pre2 with 23.4 seconds, the degree of contribution by the therapy program is unclear. Participant 7 had a notably short MPT (4 seconds), which remained stable through all assessments. Two participants in the VFE group showed a certain improvement of MPT. Participant 2 improved between pre1 (12.3 seconds) and post1 (26 seconds), but then showed a slight decline in MPT again to 18.7 seconds at post3, while participant 6 showed an increased MPT between the pretherapy assessments (16.3 seconds) and post1 (19.7 seconds). No changes in MPT were found in participant 4, who demonstrated an MPT around 14 seconds during all assessments. In the aphonia group, it was not possible to measure the MPT for participants 9 and 10 during the pretherapy assessments. At post1, the MPT for these participants was 1.2 and 2 seconds, respectively. Similarly, the MPT in participant 8 remained very short (< 5 seconds) throughout all assessments. However, due to the high dysphonia severity, the reliability of the MPT measures (timed based on auditory-perceptual evaluation of pitch by the assessor) in the aphonia group may be reduced and should be interpreted with caution.

### *Acoustic measures*

In most participants across all groups, $f_o$ remained stable over time. Notably, participant 1 showed a steady decrease in $f_o$ of approximately 5 semitones (from 165.552 Hz at pre1 to 122.312 Hz at post2) after voice therapy, with an increase at post3 to 141.371 Hz. For the aphonia group, it was not possible to measure $f_o$ at the preassessments for participants 9 and 10, and the post-therapy measures for these participants showed an abnormally high $f_o$ compared with normative values for Belgian adult men (78-166 Hz).[61]

The evolution in frequency and intensity range for each participant is described in Table 5. In general, the frequency range showed a lot of variation over time and no clear improvement in both the WRT and VFE group, except for participants 1 and 2 at post2. Improvements in intensity range were generally observed in both groups. In the WRT group, participants 1 and 3 improved at post2 and participant 7 at post1. Participant 5 showed a smaller improvement at post1. In the VFE group, participant 2 improved at post1 and post2, while participant 4 had a larger-intensity range at post3 compared with the pretherapy assessments. It was often not possible to measure the frequency and intensity range in the aphonia group, and the assessments that succeeded showed clinically deviating values for both ranges. While improvements in frequency and/or intensity range were observed in several participants, it is difficult to ascertain whether these changes are clinically relevant, since no information on these clinically important changes is available in the literature.

### *Multiparametric voice quality measures*

Table 6 shows the individual trajectories of DSI and AVQI across the WRT and VFE groups. Overall, the DSI showed varying results. In the WRT group, a clinically relevant improvement in DSI was found for participant 1 between post1 (− 0.7) and post2 (+ 2.1), which remained stable at post3. For participant 3, a clinically relevant improvement was noted between pre2 (− 0.4) and post1 (+ 2.1), and then again between post1 and post2 (+ 4.6), which also remained stable at post3. However, participant 5 showed a clinically relevant deterioration of DSI between pre1 (+ 0.5) and pre2 (− 4.4), mostly due to an increased jitter at pre2, which then improved clinically at post2 (− 1.4), and showed a further positive trend at post3 (− 0.7). The cause of this deterioration between the pretherapy assessments is unclear, but this participant did present with complaints of an unstable and unpredictable voice quality. Participant 7, who only received IVT, also showed a clinically relevant improvement (from − 14.1 to − 8.3), but the DSI was still indicative of severe dysphonia. For the VFE group, somewhat different patterns were found. Participant 2 showed a clinically improved DSI between pre1 (− 0.8) and post1 (+ 2.1), but not between pre2 (+ 1.6) and post1. However, the DSI further improved at post2 (+ 3.4), but showed a clinically relevant deterioration again at post3 (− 0.6). For participant 4, a clinically relevant improvement of DSI was found between the pretherapy assessments (− 0.6 and − 0.2) and post1 (+ 3.1), but a clinically relevant deterioration was then found at post3, to its baseline level (− 0.1). Participant 6 showed a clinically relevant improvement between pre1 (− 0.8) and post1 (+ 1.7), but not between pre2 (+ 0.7) and post1. In the aphonia group, it was not possible to calculate the DSI at any of the assessments.

The AVQI also showed varying trends. In the WRT group, large interindividual differences were noted. Participant 1 showed normophonic outcomes during all assessments, with a clinically relevant deterioration between pre1 (1.42) and pre2 (1.97), and an improvement between pre2 and post2 (1.28). However, at post3, a clinically relevant deterioration was noted (2.74). For participant 3, a clinically relevant improvement in AVQI was observed between the preassessments (3.87 and 3.67) and post2 (3.07), which remained stable at post3 (3.03). Participant 5 showed a variable trajectory: first, a deterioration between pre1 (2.87) and pre2 (4.3) was observed, which further deteriorated during post1 (5.72), followed by an improvement at post2 (3.35) and another deterioration

**TABLE 5.**
**Evolution of Frequency and Intensity Range**

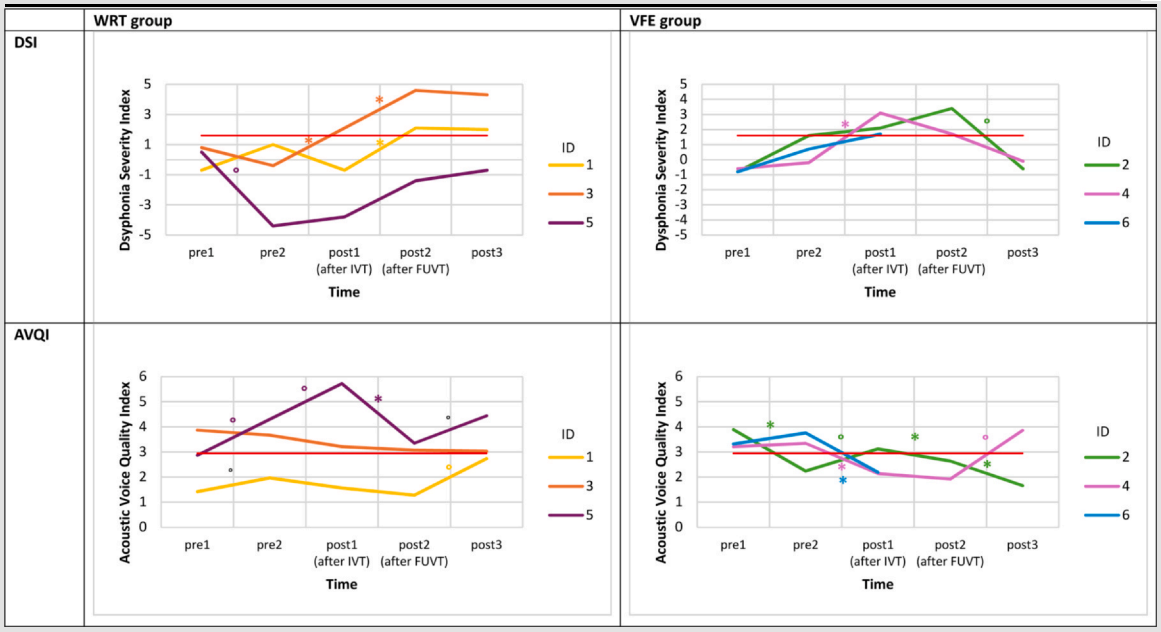
| ID | Range | Pre1 | Pre2 | Post1 | Post2 | Post3 |
|---|---|---|---|---|---|---|
| WRT group | | | | | | |
| 1 | $f_o$-low-$f_o$-high (Hz) | 82.41-493.88 | 82.41-493.88 | 87.31-554.37 | 73.42-659.26 | 82.41-523.25 |
| | $f_o$-range (ST) | 31 | 31 | 32 | 38 | 32 |
| | I-low-I-high (dB) | 62-101 | 57-101 | 67-105 | 56-106 | 54-100 |
| | I-range (dB) | 39 | 44 | 38 | 50 | 46 |
| 3 | $f_o$-low-$f_o$-high (Hz) | 92.5-311.13 | 73.42-329.63 | 87.31-311.13 | 82.41-392.00 | 77.78-415.30 |
| | $f_o$-range (ST) | 21 | 26 | 22 | 27 | 29 |
| | I-low-I-high (dB) | 54-90 | 53-96 | 56-96 | 50-97 | 52-100 |
| | I-range (dB) | 36 | 43 | 40 | 47 | 48 |
| 5 | $f_o$-low-$f_o$-high (Hz) | 73.42-466.16 | 87.31-415.30 | 77.78-493.88 | 69.30-493.88 | 69.30-466.16 |
| | $f_o$-range (ST) | 32 | 27 | 32 | 34 | 33 |
| | I-low-I-high (dB) | 54-93 | 59-99 | 61-104 | 61-103 | 61-98 |
| | I-range (dB) | 39 | 40 | 43 | 42 | 37 |
| 7 | $f_o$-low-$f_o$-high (Hz) | 155.56-311.13 | 164.81-185.00 | 138.59-261.63 | NA | NA |
| | $f_o$-range (ST) | 12 | 2 | 11 | | |
| | I-low-I-high (dB) | 70-83 | 71-79 | 66-92 | NA | NA |
| | I-range (dB) | 13 | 8 | 26 | | |
| VFE group | | | | | | |
| 2 | $f_o$-low-$f_o$-high (Hz) | 103.83-493.88 | 98.00-523.25 | 92.50-523.25 | 92.50-783.99 | 92.50-349.23 |
| | $f_o$-range (ST) | 27 | 29 | 30 | 37 | 23 |
| | I-low-I-high (dB) | 60-94 | 62-94 | 60-105 | 54-101 | 65-101 |
| | I-range (dB) | 34 | 32 | 45 | 47 | 36 |
| 4 | $f_o$-low-$f_o$-high (Hz) | 116.54-587.33 | 116.54-587.33 | 110-659.26 | 123.47-622.25 | 123.47-698.46 |
| | $f_o$-range (ST) | 28 | 31 | 31 | 28 | 30 |
| | I-low-I-high (dB) | 54-86 | 55-88 | 52-88 | 54-90 | 57-100 |
| | I-range (dB) | 32 | 33 | 36 | 36 | 43 |
| 6 | $f_o$-low-$f_o$-high (Hz) | 92.50-369.99 | 77.78-349.23 | 87.31-349.23 | NA | NA |
| | $f_o$-range (ST) | 24 | 26 | 24 | | |
| | I-low-I-high (dB) | 64-101 | 56-100 | 55-100 | NA | NA |
| | I-range (dB) | 37 | 44 | 45 | | |
| Aphonia group | | | | | | |
| 8 | $f_o$-low-$f_o$-high (Hz) | 130.81-220.00 | Not possible | Not possible | NA | NA |
| | $f_o$-range (ST) | 9 | | | | |
| | I-low-I-high (dB) | Not possible | Not possible | Not possible | NA | NA |
| | I-range (dB) | | | | | |
| 9 | $f_o$-low-$f_o$-high (Hz) | Not possible | Not possible | 146.38-246.94 | NA | NA |
| | $f_o$-range (ST) | | | 9 | | |
| | I-low-I-high (dB) | Not possible | Not possible | 79-98 | NA | NA |
| | I-range (dB) | | | 19 | | |
| 10 | $f_o$-low-$f_o$-high (Hz) | Not possible | Not possible | Not possible | NA | NA |
| | $f_o$-range (ST) | | | | | |
| | I-low-I-high (dB) | Not possible | Not possible | Not possible | NA | NA |
| | I-range (dB) | | | | | |

*Abbreviations:* dB, decibel; $f_o$-high, highest frequency; $f_o$-low, lowest frequency; $f_o$-range, frequency range; ID, identification; I-high, highest intensity; I-low, lowest intensity; I-range, intensity range; NA, not applicable (due to dropout); ST, semitones; VFE, vocal function exercises; WRT, water-resistance therapy.

at post3 (4.44). It should be noted that this participant reported having a cold both at post1 and post3. For participant 7, it was not possible to calculate the AVQI due to poor SNR. The VFE group also showed variable results. Participant 2 had a varying trajectory, starting with a notable improvement between pre1 (3.89) and pre2 (2.24), followed by a deterioration at post1 (3.12), an improvement at post2 (2.64), and a further improvement at post3 (1.66). In participant 4, a clinically relevant improvement in AVQI was found between the pretherapy assessments (3.21 and 3.34) and post1 (2.14), which further improved at post2 (1.92). However, a deterioration was observed at post3 (3.86), which also showed a clinically relevant difference with pre1. Participant 6 showed a clinically relevant improvement between the pretherapy assessments (3.32 and 3.76) and post1 (2.19).

It was not possible to calculate the DSI at any time point for the participants in the aphonia group, due to the inability to perform an acoustic analysis or determine the MPT and frequency or intensity range in these participants.

**TABLE 6.**
**Individual Trajectories of Dysphonia Severity Index and Acoustic Voice Quality Index**




*Notes:* The red horizontal bar represents the clinical cutoff line for the DSI (+ 1.6) and AVQI (2.95).
*Clinically relevant improvement.
°Clinically relevant deterioration between two time points.
*Abbreviations: AVQI, Acoustic Voice Quality Index; DSI, Dysphonia Severity Index; FUVT, follow-up voice therapy; IVT, intensive voice therapy; VFE, vocal function exercises; WRT, water-resistance therapy.*

Additionally, the AVQI was not calculated since the SNR of the collected voice samples was < 30 dB.

## Auditory-perceptual outcomes

Table 7 demonstrates the evolution of GRBASI of all participants. A general positive trend was found in two participants within the WRT group (ID 1 and 3), while the other two did not show this trend. In the VFE group, participants 2 and 4 demonstrated a trend toward an improved GRBASI evaluation at post1 and post2, respectively, but a deterioration was noted in the next assessment. The aphonia group did not show notable improvements after IVT.

## Patient-reported outcomes

### *Voice Handicap Index*

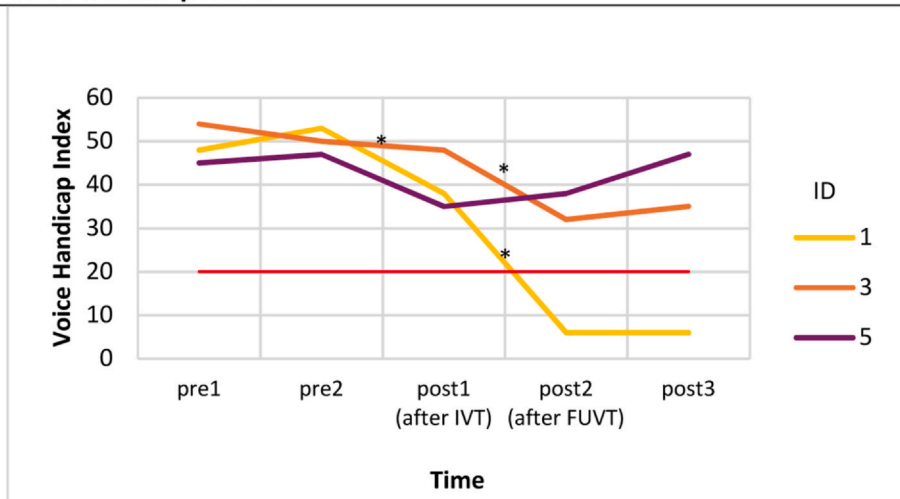
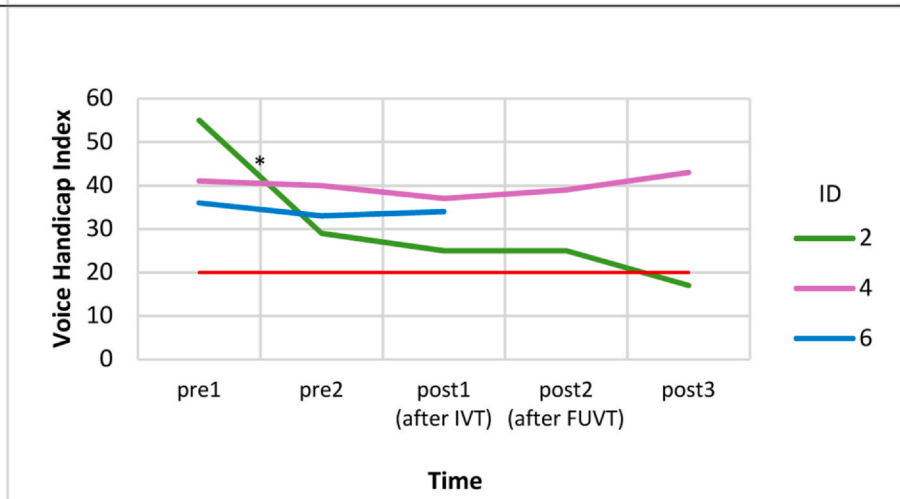
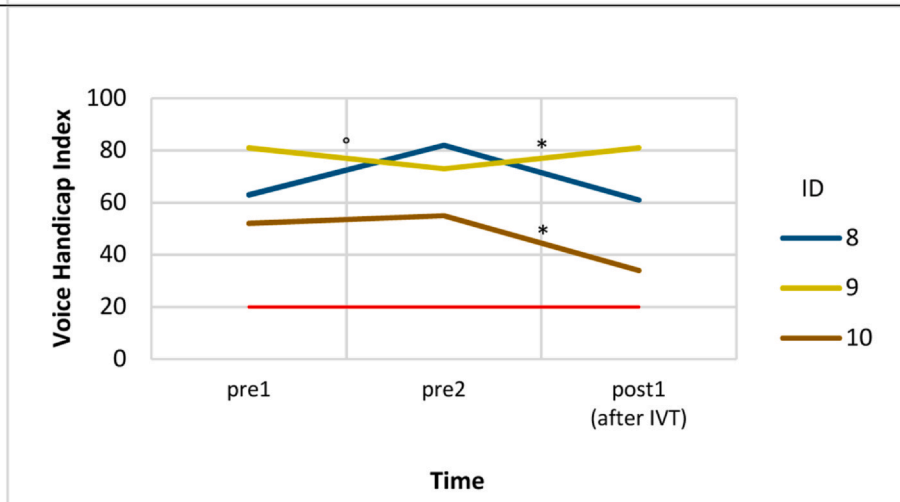
The evolution of total VHI scores in the WRT and VFE groups is illustrated in Table 8. In the WRT group,

**TABLE 7.**
**Evolution of GRBASI of All Participants**

| ID | Pre1 | Pre2 | Post1 | Post2 | Post3 |
|---|---|---|---|---|---|
| *WRT group* | | | | | |
| 1 | G1 R2 B1 A1 S1 I1 | G1 R1 B1 A0 S0 I0 | G1 R0 B1 A0 S0 I0 | G1 R1 B0 A0 S0 I0 | ***G0 R0 B1 A0 S0 I0*** |
| 3 | G1 R1 B2 A2 S0 I0 | G1 R1 B2 A1 S0 I0 | G1 R1 B1 A0 S0 I0 | G0 R1 B1 A1 S0 I0 | ***G1 R0 B1 A0 S0 I0*** |
| 5 | ***G2 R2 B1 A1 S1 I1*** | G2 R2 B1 A2 S2 I1 | G2 R3 B2 A1 S2 I1 | G2 R2 B1 A1 S2 I1 | G2 R2 B1 A2 S1 I1 |
| 7 | ***G2 R3 B2 A2 S2 I0*** | G3 R3 B2 A2 S3 I2 | G3 R3 B3 A2 S2 I2 | NA | NA |
| *VFE group* | | | | | |
| 2 | G3 R2 B3 A3 S3 I2 | G2 R2 B1 A1 S2 I0 | ***G0 R1 B0 A0 S1 I0*** | G2 R3 B2 A1 S2 I1 | G2 R2 B1 A0 S1 I1 |
| 4 | G2 R2 B1 A1 S1 I1 | G2 R1 B2 A2 S1 I2 | G2 R2 B2 A1 S1 I0 | ***G1 R1 B1 A1 S1 I0*** | G2 R2 B2 A1 S2 I0 |
| 6 | G1 R0 B1 A2 S0 I0 | G1 R0 B2 A1 S0 I0 | ***G1 R0 B1 A1 S0 I0*** | NA | NA |
| *Aphonia group* | | | | | |
| 8 | ***G3 R2 B3 A2 S3 I1*** | G3 R2 B3 A3 S3 I2 | G3 R3 B3 A2 S3 I2 | NA | NA |
| 9 | G3 R2 B3 A3 S3 I2 | G3 R2 B3 A3 S3 I2 | ***G3 R2 B3 A2 S2 I2*** | NA | NA |
| 10 | G3 R0 B3 A3 S2 I0 | ***G3 R0 B3 A3 S1 I0*** | G3 R2 B3 A3 S1 I1 | NA | NA |

*Notes:* The assessment with the best evaluation of all time points is written in bold and italics.
*Abbreviations: ID, identification; NA, not applicable (no data); VFE, vocal function exercises; WRT, water-resistance therapy.*

**TABLE 8.**
**Evolution of Total Voice Handicap Index Scores in All Groups**

| Group | Voice Handicap Index |
|---|---|
| WRT |  |
| VFE |  |
| Aphonia |  |



*Notes:* The red line represents the clinical cutoff of the total VHI (=20).
*Clinically relevant improvement.
°Clinically relevant deterioration.
*Abbreviations: VFE, vocal function exercises; VHI, Voice Handicap Index; WRT, water-resistance therapy.*

clinically relevant improvements of the VHI were found in participants 1 and 3. Participant 1 showed a notable improvement in total VHI score (− 15 points) and VHI-F (− 12) between pre2 and post1, and an improvement in total VHI (− 32), VHI-P (− 17), and VHI-E (− 10) was observed between post1 and post2. These scores remained stable at post3. For participant 3, a clinically relevant improvement in total VHI (− 16) and VHI-F (− 8) was observed, which remained stable as well at post3. Participant 5 did not show clinically relevant changes in total VHI between any of the assessments, but a clinically relevant improvement in VHI-E (− 12) was observed between pre2 and post1. For the VFE group, the only clinically relevant improvement in total VHI (− 26) and all subscales was found in participant 2 between pre1 and pre2, which remained stable over the post-therapy assessments. Within the aphonia group, participant 8 showed a clinically relevant deterioration of total VHI (+ 19) and VHI-E (+ 17) between pre1 and pre2, which improved again between pre2 and post1 (− 21 and − 10, respectively). Participant 9 only showed a deteriorated VHI-P (+ 8) between pre2 and post1, while participant 10 showed a clinically relevant improvement of total VHI (− 21), VHI-F (− 8), and VHI-E (− 11) between pre2 and post1.

### *Feedback on voice therapy*

All participants in the WRT and VFE group perceived the voice therapy program as positive. In the WRT group, participants with chronic UVFP described that they had more confidence in their voice, and that they were more conscious of their vocal technique, which allowed them to anticipate potential problems with phonation. The patient with acute UVFP described improvements in self-perceived volume (increased), phonation length (increased), and hoarseness (decreased). In the VFE group, participants with chronic UVFP indicated that the SOVT posture helped with relaxation and stability in phonation. One participant (ID 4) also mentioned that she focused more on breath support during the program, and appreciated the specificity of the exercises and the combination of live and online therapy. The participant with acute UVFP observed a noticeable improvement after IVT, but did not provide additional details. The aphonia group perceived voice therapy as neutral or positive, albeit without improvements in voice quality.

Immediately after a session, all participants in the WRT and VFE group reported a better voice quality, although two participants (ID 3 and 5) also indicated vocal fatigue. In the aphonia group, no changes were reported. After IVT, a better voice quality was reported by nearly all participants in the WRT and VFE groups. Participants in the WRT group reported better volume, increased self-confidence, and knowledge about how to achieve a more stable phonation, while participants in the VFE group reported increased vocal endurance and decreased hoarseness. Participant 4 from the VFE group felt no change in voice quality after IVT, but indicated that she had a better voice quality after the complete program. However, she still experienced difficulties with voice projection in a loud environment. The other participants reported an increased self-perceived voice quality after the complete program, with similar reports as after IVT. In the aphonia group, no changes were reported by two participants, but participant 9 did report a slightly better voice quality.

In terms of home practice, participants in the WRT group practiced for 5 to 25 minutes per day, for 3 to 6 days a week during IVT and for 1 to 4 days a week during FUVT. The reasons for not practicing were illness, a busy schedule, forgetfulness, or low motivation (noted by participant 3 during FUVT). Participant 5 reported occasional vocal fatigue when reading texts, while participant 3 indicated that he preferred reading texts over practicing with vocals or word lists. In the VFE group, participants practiced for 15 to 30 minutes per day, for 4 to 7 days per week during IVT and for 2 to 6 days per week during FUVT. The reasons for not practicing in this group were a busy schedule or illness. Participant 4 also reported difficulties with performing the first exercise (warming up) correctly.

## DISCUSSION

The current study aimed to provide a proof of concept for two SOVT-based treatment protocols for UVFP patients: WRT and VFE. It is the first study to investigate the effects of specific vocal techniques as a standardized treatment protocol in patients with UVFP. The preliminary results suggest that the two therapy programs may have positive clinical effects on instrumental and auditory-perceptual voice quality, as well as on PROMs, which prompts several suggestions for clinical practice and future research.

Previous studies with dysphonic individuals have found positive effects of a WRT program in terms of VHI, self-perceived voice quality and vocal comfort, subglottic pressure, phonation threshold pressure, and vocal tract discomfort,[28-30] but not in acoustic or auditory-perceptual outcomes. On the other hand, VFE seem to improve both acoustic voice measures and patient self-report according to a systematic review by Angadi et al.[27] In the current study, clinical improvements in several outcome measures were noted in both groups. WRT and VFE seemed to have a positive effect on the DSI of most participants, with clinical improvements noted after 2 weeks (IVT) and/or 8 weeks (IVT + FUVT). However, it is difficult to compare results with the existing literature, as no individual data are available for those previous studies to investigate clinical changes within participants. Additionally, the DSI remained stable 8 weeks after the WRT program was concluded in all three participants, in contrast to the two participants in the VFE group (ID 2 and 4) who improved but then showed a deterioration during the last assessment. A similar trend was observed for the auditory-perceptual assessment. The AVQI showed varying results, with generally improvements after IVT + FUVT, but these

improvements did not remain stable in all participants 8 weeks after conclusion of therapy. Notably, the glottal closure generally improved in the VFE group while the WRT group showed varying results, but this did not necessarily translate to improved voice quality measures. The reasons behind the decline in several vocal outcome measures during the last assessment in the two chronic UVFP participants after the VFE program are unclear and warrant further investigation. Does this program require a longer duration of guided IVT, are the results related to the nature of the voice problem, or could they be contributed to chance? A potential explanation is that the earlier introduction of connected speech in the WRT program (word level already during IVT) may have contributed to an earlier increase in vocal capabilities and transfer to everyday speech. However, the AVQI showed variable interindividual results, and due to the small sample size, it is not possible to confirm this hypothesis. In clinical practice, early inclusion of voice exercises with connected and conversational speech is highly advisable, since transfer to conversational speech is considered a useful but challenging aspect of voice therapy by patients, and is considered an important criteria for discharge from voice therapy by SLPs.[62,63] Therefore, we added exercises on word, sentence, text, and semispontaneous level in the VFE group as well during FUVT. Two weeks of IVT seemed sufficient for participants in both groups to learn the specific SOVT postures and vocal exercises, but an earlier introduction of exercises with connected and conversational speech during IVT may help facilitate transfer to daily speech and improve patient motivation and treatment adherence.[63] Besides large interindividual variety, some notable intraindividual differences between two assessments were observed. For example, participant 5 showed a sharp deterioration of different vocal outcomes between the two pretherapy assessments. The cause of this deterioration is unclear, but this participant did present with complaints of an unstable and unpredictable voice quality. The results from the assessment after IVT and from the last assessment may also be influenced by the presence of a cold in this participant, which had an impact on the self-reported voice quality and vocal comfort. Additionally, participant 2 already showed a clinically important improvement of several vocal outcomes and VHI between the pretherapy assessments, potentially due to similar complaints of vocal instability and unpredictability as participant 5.

Positive effects on PROMs were found in several participants in all groups, similar to results from previous research.[27-30] The therapy program was perceived positively and considered effective by all participants in the WRT and VFE groups, and an improved voice quality was noted by most participants, even in the absence of clinical improvements of instrumental voice quality. Other self-perceived improvements were related to auditory-perceptual (eg, increased volume and decreased hoarseness), proprioceptive (eg, increased relaxation), and/or emotional-psychological aspects (eg, increased self-confidence). These reports are similar to experiences of UVFP patients with voice therapy in clinical settings.[64] In two participants of the WRT group, the total VHI showed improvements that remained stable after conclusion of voice therapy, while one participant had a stable improvement of the emotional subscale. Notably, in the VFE group, no improvements in VHI scores were found in two participants, and the remaining participant already showed a clinical improvement between both pretherapy assessments, which could be related to the concurrent improvements in instrumental measures. Two participants in the aphonia group showed clinical improvements in VHI after IVT (one of them after a deterioration between the baseline assessments), which could potentially be attributed to the effects of patient counseling and education about UVFP and therapeutic options. This finding supports the notion that close guidance and early (presurgical) voice therapy can be of value in all UVFP patients, even in those who need surgical intervention.[2,65]

A short-term intensive treatment protocol may offer a solution to patients with chronic UVFP who experience continuous or increased vocal complaints. By providing short-term IVT with daily voice exercises, efficient voice use can be encouraged and reestablished. In our study, participants received 5.5 hours of guided therapy over the course of 2 weeks, but further investigation into the optimal therapy dosage is required. Additionally, the use of an online app has been reported to have a positive effect on patient motivation and treatment adherence.[66,67] It may also offer continued guidance to patients with chronic UVFP who wish to revisit the vocal exercises after completion of therapy, as UVFP patients with chronic voice problems may feel somewhat lost after reimbursement for voice therapy has ended.[64] In the current study, the use of the app was not monitored, so future research should investigate if this addition is a merit to the existing UVFP care.

The treatment protocol used in the current study shows promise, but several alterations can be provided to improve the program for use in clinical practice. For example, the frequency of sessions during FUVT was now set at one online session per week, but this could be replaced by either a weekly live session or by two online sessions per week at first, with a gradual decrease in frequency. During IVT, vocal fatigue after therapy sessions was noted by some participants, which should be monitored closely in clinical setting. It is difficult to determine the ideal therapy duration and dosage due to large variations in patient and UVFP characteristics, dysphonia severity, vocal demands, and response to voice therapy. However, more notable improvements could have become apparent with a longer therapy duration to encourage transfer. A comparison of outcomes between IVT and a more traditional therapy dosage could also provide new insights. In clinical practice, the duration of voice therapy in UVFP patients can vary greatly between different regions and may be influenced by the regulations on reimbursement. For example, the mean duration of voice

therapy has been estimated at 6 months or 30 sessions by Belgian SLPs, although large variations were observed,[20] while Australian SLPs usually provide 10 or fewer sessions of voice therapy.[22] In any case, the current study could provide a frame of reference to SLPs in clinical settings on therapy content and dosage in UVFP patients.

In terms of patient selection, the treatment protocol is not suitable for patients with severe dysphonia or aphonia. In the current study, LEMG was performed to aid in further clinical decision-making after an intensive trial of vocal techniques to elicit phonation did not yield sufficient results. LEMG is considered a valuable tool in the diagnosis of UVFP, and may help in predicting (poor) recovery after UVFP, which can influence further clinical management.[68,69] A study by Wang et al[70] has reported that LEMG may be more reliable if performed >2 months after UVFP onset, but voice therapy should be started as early as possible.[16,65] An intensive trial of voice therapy may already provide information about the stimulability of the voice, help avoid hyperfunctional compensatory behavior, and provide training for optimal postsurgical phonation if necessary. Additionally, the SLP may play an important role in patient education and psychological guidance before LEMG and other interventions.[2] In the current study, participants with acute UVFP did not receive postsurgical voice therapy in the study setting. Investigating the effects of WRT and VFE on outcomes in UVFP patients after medialization surgery would be an interesting follow-up study in this domain.

Patient 7 offered a different challenge besides severe dysphonia. Due to comprehension issues with the WRT technique (ie, drinking water from the flexible tube repeatedly instead of phonating through the tube), the program had to be altered to a "tube in air" SOVT technique, after which she was able to follow the instructions of the SLP. This adaptation removed the potential advantage of the secondary vibration source achieved in WRT, but still contained techniques based on SOVT. In order to provide more insights into patient selection and potential problems in clinical management of UVFP patients, data from this participant were included. No formal cognitive assessment was conducted prior to voice therapy in the current study, but the cognitive status of a patient is also an important aspect to consider during the selection of the treatment plan. This consideration may be of particular interest in the UVFP population, due to the higher prevalence of UVFP in patients who are 50-60 years or older and the potential presence of comorbidities that may affect cognitive function.[71-74]

This study was a first exploratory, proof-of-concept study to investigate the clinical effects of a WRT or VFE-based treatment protocol on vocal outcomes and QoL in UVFP patients. Because of its small sample size and heterogeneous population, it is not possible to generalize findings to all patients with UVFP. This was not the purpose of the current study, which aimed to provide preliminary insights into the feasibility of two SOVT-based therapy protocols that used specific vocal techniques. Additionally, outcomes of voice therapy might differ between acute UVFP patients (who may possibly still experience neural recovery) and chronic UVFP patients, so a comparison of vocal outcomes between these subgroups would be a valuable endeavor for future research.

Because no control group was used, it is difficult to ascertain the effect of voice therapy in comparison with spontaneous recovery/no intervention[1] and the specific treatment protocols versus administering voice therapy in general. The multiple baseline measures did provide an understanding of spontaneous evolution of the different measures, and the inclusion of chronic UVFP patients who were not expected to improve due to neurologic recovery may provide a better understanding of the impact of voice therapy in this participant group. An important limitation of the current study was the exclusion of LEMG as part of the multidimensional voice assessment before and after voice therapy, although this could have provided further insights into the influence of neural recovery on outcomes in the participants with acute UVFP. Diagnosis of UVFP was made by a specialized laryngologist based on LVS and case history, but LEMG might have additionally helped with the differentiation between UVFP and mechanical etiologies of vocal fold immobility and should be added in future studies on this topic. A therapist bias was avoided because all participants received therapy from the same SLP (I.K.), who followed the predetermined treatment protocol. However, no treatment fidelity checks were performed, which should be conducted in future research to increase the reliability and validity of treatment outcomes. The current study did describe instances where the treatment protocol could not be followed as prescribed (eg, participant 7 and the participants in the aphonia group).

Another limitation was the lack of information on minimal clinically important differences for most parameters. Literature in voice research generally uses group-level analyses to test the statistical significance of outcome measures, but this type of analysis is not always easy or ideal to interpret in terms of clinical relevance.[75] For the DSI, AVQI, and Dutch VHI, data on minimal clinically important changes were available.[47,52,57] This was not the case for the other outcome parameters, which hindered interpretation of the results in some parameters. Comparisons to normative values may offer a solution, but a normalization of voice quality or other vocal outcomes may be unattainable for some in this particular population, so a deeper understanding of clinically relevant changes may enhance the interpretation of therapy results. Therefore, we encourage efforts to determine the minimal clinically important differences of vocal outcomes and PROMs.

## CONCLUSION

This preliminary study is the first to investigate the clinical effects of two treatment protocols based on specific vocal techniques (WRT and VFE) in patients with UVFP. Both techniques seem to have positive effects on vocal outcomes

and PROMs in individuals with acute and chronic UVFP. However, notable interindividual differences were observed, and VFE may need a longer therapy duration to elicit lasting effects. Follow-up randomized controlled trials are needed to further investigate the effectiveness and efficacy of WRT and VFE in UVFP patients, but the current study provides a first proof of concept for the use of both therapy programs in future research and clinical practice.

## Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to privacy reasons but are available from the corresponding author on reasonable request.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jvoice.2024.08.034.

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