Short-term Effects of Semi-occluded Vocal Tract Therapy on the Phonation of Children with Vocal Fold Nodules: a Randomized Controlled Trial

Anke Adriaansen[a], Iris Meerschman[a], Kristiane Van Lierde[ab], Sofie Claeys[c], Estella P.-M. Ma[d], Imke Kissel[a], Tine Papeleu[a], Evelien D'haeseleer[ace]

[a]Center for Speech and Language Sciences (CESLAS), Department of Rehabilitation Sciences, Ghent University, Ghent, Belgium

[b]Department of Speech-Language Pathology and Audiology, University of Pretoria, Pretoria, South-Africa

[c]Department of Otorhinolaryngology, Ghent University Hospital, Ghent, Belgium

[d]Voice Research Laboratory, Unit of Human Communication, Learning, and Development, Faculty of Education, The University of Hong Kong, Hong Kong

[e]Royal Conservatory Brussels, Musical Department, Brussels, Belgium

Corresponding author:

Anke Adriaansen
+32471028622
Anke.adriaansen@ugent.be
Corneel Heymanslaan 10
9000 Ghent
Belgium

Co-authors:

Iris.meerschman@ugent.be
Kristiane.vanlierde@ugent.be
Sem.Claeys@UGent.be
Imke.Kissel@UGent.be
Tine.Papeleu@UGent.be
Evelien.dhaeseleer@ugent.be

The authors declare that there is no conflict of interest.

Author contributions statement: all authors meet the authorship criteria recommended by the International Committee of Medical Journal Editors (ICMJE).

Keywords: voice therapy, children, vocal fold nodules

Abstract

Purpose: The aim was to determine and compare the short-term effects of two intensive semi-occluded vocal tract programs, 'straw phonation' and 'resonant voice therapy', on the phonation of children with vocal fold nodules.

Methods: A pretest-posttest randomized controlled study design was used. Thirty children aged 6 to 12 years were randomly assigned to the straw phonation group (n = 11), resonant voice therapy group (n = 11), or control group receiving indirect treatment (n = 8) for their voice problems. All participants received 11 hours of group voice therapy over four consecutive days. A multidimensional voice assessment consisting of both objective (Dysphonia Severity Index and Acoustic Voice Quality Index) and subjective (Pediatric Voice Handicap Index and perceptual rating of overall severity) measures was performed pre- and posttherapy. Voice therapy effectiveness was evaluated using group-level analyses (linear mixed models) and individual-level analyses to investigate what proportion of participants changed to a clinically relevant degree.

Results: Group-level analyses found no significant time-by-group interactions, indicating that the evolution over time did not differ among the three groups. Within-group effects of time showed a significant and equal improvement in Dysphonia Severity Index in the straw phonation and resonant voice therapy group, and a significant improvement in perceptual rating of overall severity in the straw phonation group. For Dysphonia Severity Index, individual-level analyses showed that 36% and 45% of participants improved to a clinically relevant degree in the straw phonation and resonant voice therapy group, respectively. For Acoustic Voice Quality Index, 38% improved to a clinically relevant degree in the straw phonation group.

Conclusion: Results suggest that short-term intensive semi-occluded vocal tract programs may have a positive effect on voice quality and vocal capacities of children with vocal fold nodules. Participants seem to benefit more from a straw phonation program than a resonant voice therapy program.

Introduction

Vocal fold nodules (VFNs) are bilateral benign lesions of the membranous vocal folds, usually occurring at the at the middle of the vibrating portion . VFNs are the leading cause of pediatric dysphonia, accounting for 18 to 82% of all cases (Adriaansen et al., 2023; Dobres et al., 1990; Mandell et al., 2004). It is generally assumed that VFNs are the result of prolonged strain or phonotraumatic behaviors, which include yelling, screaming, throat-clearing, and imitating voices (Hron et al., 2019; Martins et al., 2013; Payten et al., 2022). These behaviors lead to an increased mechanical impact on the vocal fold surfaces during phonation, resulting in superficial wound formation (Titze, 1994). Remodeling of the lamina propria and epithelium during the healing process leads to the development of VFNs (Kunduk & McWhorter, 2009; Titze, 1994). Other risk factors for the development of VFNs are an extraverted personality (Roy et al., 2007), the presence of siblings (Tuzuner et al., 2017), attention deficit hyperactivity disorder (D'Alatri et al., 2015), and a medical diagnosis of asthma (Ercan et al., 2020), allergic diseases (Ercan et al., 2020), and gastroesophageal or laryngopharyngeal reflux (Saniasiaya & Kulasegarah, 2020; Singendonk et al., 2019). Personality traits and behavioral tendencies in children with VFNs were examined in the systematic review of Lee et al. (2019), which showed converging evidence for an association between an extraverted personality and VFNs in children. Moreover, it was stated that a cognitive-behavioral profile of inattention, hyperactivity/impulsivity, and negative emotional reactivity including aggressiveness may also contribute to VFNs formation in children (Lee et al., 2019). More recent research stated that children with VFNs experience diminished self-regulation, potentially contributing to persistent phonotraumatic behavior and difficult therapy adherence (Lee et al., 2022). Asthma and allergic diseases can inflame both the lower and upper airways, causing dryness, swelling, mucosal injury, and phonotraumatic behavior such as coughing and throat clearing (Chadwick, 2003; Ercan et al., 2020; Yilmaz et al., 2016). Gastroesophageal and laryngopharyngeal reflux, the retrograde flow of gastric contents into the esophagus and laryngopharynx respectively, causes caustic mucosal exposure, making the vocal fold mucosa more susceptible to injury and subsequent nodules, polyps and edema (Lechien et al., 2017; Singendonk et al., 2019).

Several treatment options are available for pediatric VFNs. Addressing comorbidities such as allergies or reflux can help reduce phonotraumatic behaviors, such as throat clearing or excessive coughing (Mudd & Noelke, 2018). Another option is to remove the VFNs. A recent systematic review with meta-analysis by Wu et al. (2023) showed that 90% of children with VFNs improved after phonosurgery. However, in 19% of the children, a recurrence of the nodules was observed at follow-up (Wu et al., 2023). The high recurrence rate of VFNs after phonosurgery in children has already been emphasized by several authors (Hron et al., 2019; Martins et al., 2013; Martins et al., 2020; Mudd & Noelke, 2018). The most important explanation is the common failure to respect postoperative vocal rest, which is essential for proper vocal fold tissue healing (Martins et al., 2020). Moreover, the immaturity of the laryngeal structures is another factor complicating the performance of phonosurgery in children (Martins et al., 2020).However, voice therapy is generally regarded as the preferable treatment option in children with VFNs (Martins et al., 2013; Mudd & Noelke, 2018). Voice therapy involves direct or indirect voice therapy techniques or a combination of both. Direct voice therapy techniques aim to modify vocal behavior through motor execution, somatosensory feedback, and auditory feedback. Indirect therapy techniques focus on the cognitive, behavioral, and psychological aspects of voice use or change the physical environment (Van Stan et al., 2015).

Three systematic reviews have been published on the effects of voice therapy in children with benign vocal fold lesions. The systematic review of Feinstein and Verdolini Abbott (2021) included 21 studies with a variety of research designs. It was concluded that behavioral voice therapy seems to be effective in improving vocal outcomes in children with benign vocal fold lesions. Direct techniques and longer therapy duration with more therapy sessions were also found to have a greater impact than indirect techniques and shorter therapy duration. One or two sessions were generally insufficient to obtain vocal improvements, and better results were noticeable in studies with at least six therapy sessions. However, included studies were found to have rather weak research designs and a number of methodological shortcomings, like incorrect statistical analyses and missing information about outcome measures (Feinstein & Verdolini Abbott, 2021).The systematic review of Al-Kadi et al. (2022) in children with dysphonia included six studies. According to the inclusion criteria, only randomized controlled trials (RCTs), cluster RCTs, quasi-RCTs, and randomized cross-over trials were eligible for inclusion. However, review of the included studies revealed that weaker research designs were also included, like the one-group pretest-posttest design. The authors concluded that both direct, indirect and combined voice therapy may produce vocal improvements in children with dysphonia, but there is not yet clarity on the clinical significance of the interventions. The Cochrane Risk of Bias tool (Higgins et al., 2011) showed a moderate risk of bias in the included studies, preventing definite conclusions from being drawn (Al-Kadi et al., 2022). Adriaansen, Meerschman, et al. (2022) also conducted a systematic review in children with VFNs, including 24 studies with a wide range of study designs. It was concluded that there is some evidence for a positive effect of voice therapy in children with VFNs since eight studies reported statistically significant improvements after voice therapy and no study reported significant deterioration of a single outcome parameter. The eclectic nature of the therapy programs and the methodological limitations of the included studies made it difficult to identify the active ingredients of a successful intervention. The QualSyst assessment tool (Kmet et al., 2004) showed that the overall quality of the included studies was only adequate (55%) with a number of studies achieving extremely low scores (Adriaansen, Meerschman, et al., 2022).

More recent experimental studies that were not included in the systematic reviews are also relevant. In an experimental pretest-posttest control-group study, Ma et al. (2021) evaluated the effectiveness of vocal hygiene education combined with resonant voice therapy in children with VFNs. Both voice quality and parent-reported voice-related quality of life showed significant improvement after six hours of voice therapy. Bian et al. (2024) also conducted a pretest-posttest control-group study that evaluated the effects of the ABCLOVE program (activation exercises, breathing, counseling, laryngeal manipulation, oral resonance, vocal exercises, and elimination of habits) in children with VFNs. They found significantly greater improvements in objective and perceptual voice-related parameters after the ABVLOVE program compared to indirect voice therapy. The experimental one-group pretest-posttest of Salderay et al. (2022) investigated the effectiveness of vocal hygiene education combined with a parent training program, including communication strategies and parental rule-setting. Nodule size and voice quality improved significantly after eight weeks of indirect voice therapy. VFNs completely resolved in 73.3% of the children. Karalı et al. (2022) used a two-group pretest-posttest design to evaluate the effects of voice therapy in children with VFNs in a group and individual format. VFNs disappeared in 62.5% of the children after group therapy, whereas 37.5% of the children had normal vocal folds after an individual voice therapy program. Taken together, direct and indirect voice therapy appear to improve voice in children with VFNs, with the caveat that the specific content, duration, and frequency of the therapy remain unclear.

A promising technique that has gained popularity in the last decade are semi-occluded vocal tract (SOVT) exercises (Titze, 2006). These exercises aim to achieve a more efficient and economic phonation. The common feature of all SOVT exercises is a reduction in the cross-sectional area of the vocal tract, in some cases combined with a lengthening of the vocal tract. Semi-occluding the vocal tract creates a non-linear feedback mechanism, based on acoustic impedance. Due to the narrowing in the distal part of the vocal tract, part of the acoustic energy will be reflected back to the source (vocal folds) in a non-linear way. The inertive reactance is high and the supraglottal pressure increases. Consequently, less subglottic pressure is required to achieve vocal fold vibration, resulting in a relatively low vibrational amplitude, less vigorous adduction and abduction of the vocal folds, decreased muscle effort and energy loss, and less vocal fold injury. In other words, there is an improved impedance matching and a heightened source-filter interaction (Andrade et al., 2014; Croake et al., 2017; Dargin & Searl, 2015; Guzman et al., 2017; Maxfield et al., 2015; Meerschman, 2018; Mills et al., 2017; Titze, 2006; Titze et al., 2022). An artificial lengthening of the vocal tract will strengthen these effects (Conroy et al., 2014; Gaskill & Quinney, 2012; Titze, 2006).

One of the most frequently and longest used SOVT exercises is the use of nasal consonants /m/, /n/, or /ŋ/. In this technique, the oral cavity is completely closed at the level of the lips, alveolar ridge or velum, with the airflow moving through the nasal cavity and the nostrils providing the semi-occlusion. Nasal consonants are the core of resonant voice therapy, which starts with a relaxed sustained phonation of nasal consonants ('humming' exercises) proceeding to speech-embedded semi-occlusions and spontaneous speech (Meerschman et al., 2017; Titze, 2006). Resonant voice therapy is rather 'intuitive' in nature, requiring instructions, feedback, and self-corrections. Several studies have reported positive effects of resonant voice therapy in adults with dysphonia (Liu et al., 2022; Meerschman et al., 2017; Saltürk et al., 2019). In children, research on the effectiveness of resonant voice therapy is rather limited. Hartnick et al. (2018) investigated the effects of a direct voice therapy program mainly focused on resonance training in children with VFNs. Voice-related quality of life was improved after 8 to 12 weeks of therapy. Furthermore, resonant voice exercises are sometimes part of a more eclectic voice therapy program, but more targeted research on this approach in children remains limited(Braden & Thibeault, 2020; Ma & Leung, 2021; Tezcaner et al., 2009).

A relatively simple SOVT exercise with an artificial lengthening of the vocal tract is straw phonation (SP) (Kang et al., 2019). This technique involves phonation of a vowel through a flow-resistant open-ended straw placed between the lips (Rosenberg, 2014; Titze, 2006). Unlike similar techniques where the straw is immersed in water, the outer end of the straw remains in open air during SP exercises (Guzman et al., 2017). The straws used for SP vary widely in length and inner diameter. It could be assumed that lengthening the straw would enhance the effects because the total length of the vocal tract is directly proportional to inertive reactance (Mills et al., 2018). However, recent research has shown that the inner diameter plays a more important role than the length of the straw (Andrade et al., 2014; Smith & Titze, 2017; Titze et al., 2022). Smaller diameters will produce a larger increase in supraglottal pressure (Andrade et al., 2016). SP is a 'non-intuitive' technique because the semi-occlusions are created using an external tool, requiring fewer instructions, feedback, and self-corrections (Rosenberg, 2014). The effects of SP in children with dysphonia have not been thoroughly studied. To our knowledge, only Ramos and Gama (2017) investigated the effects of SP in this pediatric patient group. They reported a significant decrease in roughness and breathiness after three minutes of SP, and in both dysphonia grade and breathiness after five minutes. Rigid plastic straws with a length of 8.7 cm and a diameter of 1.5 mm were used.

Voice therapy relies on motor learning principles and cognitive processes for maintenance and transfer of new vocal behavior. An important motor learning principle is distribution of practice, which refers to how a given amount of practice is distributed over time (Fu et al., 2015). Spaced practice refers to a practice schedule in which the time interval between the practice periods is relatively long, whereas massed or intensive practice refers to a practice schedule in which the amount of rest between the practice periods is short or absent (Bergan, 2010; Patel et al., 2011). Potential benefits of intensive voice therapy include enhanced learning and consolidation of vocal behaviors, time-efficiency, cost-effectiveness, higher voice therapy attendance rates and patient compliance, opportunities to simultaneously treat multiple voice production components, and opportunities for specificity and individuality (Fu et al., 2015; Thibeault et al., 2009; Wenke et al., 2023). Potential pitfalls are the practicality and complexity of scheduling intensive voice therapy sessions and the potential risk of overdosing the laryngeal system (Meerschman, Claeys, et al., 2019). There is a growing body of literature on the effectiveness of intensive voice therapy in adults with organic or functional voice problems. Each existing study showed that intensive therapy is at least equally effective as more traditional, spaced practice for several outcome parameters such as objective and subjective voice quality, voice-related quality of life, and patient satisfaction (Fu et al., 2015; Meerschman, Claeys, et al., 2019; Wenke et al., 2023; Wenke et al., 2014). In children, research on intensive voice therapy is completely lacking.

In the last two decades, more attention has been paid to the possibility of providing group voice therapy instead of individual voice therapy. Several benefits of group therapy have already been described in the literature. Group therapy would facilitate vocal practice, peer modeling, and peer feedback, and its naturalistic context would also ensure an optimal platform for generalization of therapy skills (Graham & Avent, 2004; Silva et al., 2017). From a motor learning perspective, it has been suggested that observing other people's learning process is at least equally effective as observing an expert, which supports the rationale of group therapy (Mcilwaine et al., 2010). Additionally, group therapy would provide strong psychological support through the opportunity to exchange experiences, share problems, and form personal bonds (Graham & Avent, 2004; Law et al., 2012). Lastly, practical benefits of group therapy are the cost effectiveness, improved time management and shorter waiting lists (Dickson et al., 2009; Graham & Avent, 2004; Karalı et al., 2022). In adults, there has already been some research on the effectiveness of group voice therapy. Simberg et al. (2006) investigated the effect of voice therapy in groups of six to eight teacher students with mild voice disorders. They found significant improvements in perceptual voice quality and patient-reported vocal symptoms after group therapy. Abrahamsson et al. (2018) compared the effect of individual therapy and group therapy (with a maximum of four participants) in adult patients with voice disorders. Statistically significant and similar improvements in self-perceived vocal function were found after individual and group therapy. Meerschman, Claeys, et al. (2019) compared the effects of an intensive individual and an intensive group voice therapy in adults with organic or functional voice disorders. Comparable improvements were found for multiparametric voice quality indices, auditory-perceptual evaluation, and videolaryngostroboscopic evaluation. Moreover, it has been shown that group voice therapy is effective to reduce levels of anxiety and personal risk factors such as smoking, insufficient hydration or excessive voice use in patients with dysphonia (Silva et al., 2017; Trajano et al., 2020). In children, however, research on group voice therapy is scarce. Karalı et al. (2022) investigated the effects of individual and group voice therapy in children between 9 and 14 years old with VFNs. The group therapy sessions consisted of four children in each group. It was concluded that both individual and group voice therapy seem to be beneficial in the management of VFNs, with a small advantage for individual voice therapy. In addition, Ma et al. (2021) used a group format to evaluate the effectiveness of vocal hygiene education with resonant voice therapy. They found improvements in perceptual voice quality and parent-reported voice-related quality of life after this group voice therapy program. More research is definitely needed on the effectiveness of group voice therapy in children with voice disorders.

To date, high-quality research on the effects of SOVT therapy in children with dysphonia is limited. The impact of intensive voice therapy and group voice therapy is also understudied in children. Therefore, the aim of this randomized controlled trial was to determine and compare the short-term effects of an intensive SP program with an intensive resonant voice therapy (RVT) program, organized in group sessions, on the phonation of children with VFNs. Given the promising physics of SOVT exercises, it was hypothesized that both SP and RVT would have positive short-term effects.

Methods

This study was approved by the Ethics Committee of Ghent University Hospital (registration number: B670201936069) and has been registered on ClinicalTrials.gov. The consolidated standards of reporting trials (CONSORT) non-pharmacologic treatment interventions (NPT) checklist were used to report the trial specifications (Boutron et al., 2017). Written informed consent was obtained from a parent of each participant.

Participants

Children between six and 12 years old (primary school) with VFNs were eligible to participate in this study. Participants were recruited between October 2019 and January 2023 during their consultations at the voice unit of Ghent University Hospital, through flyers in other hospital departments, through social media, or by referral from voice therapists who were informed about this project. All participants were diagnosed with VFNs by an otorhinolarygologist with extensive experience in voice diagnostics (S.C.). This age group was chosen because these children can cooperate with voice therapy and tolerate videolaryngostroboscopy. Exclusion criteria were a history of phonosurgery, nasal or ear diseases, neurological disorders, and parent-reported pubertal voice changes.

Design

A randomized controlled study design was used. Participants were assigned to one of the three intervention groups (experimental group “SP”, experimental group “RVT”, or the control group (CG) receiving indirect treatment), depending on their time of registration. Within each intervention group, the children were divided into smaller subgroups based on the timing of their intervention. The order in which the different voice treatments (subgroups) were organized was determined using a random number list. No changes in the methodology were made after trial commencement.

Voice therapy

In each intervention group, a short-term, intensive, group-format therapy program was provided. All participants received 11 hours of voice therapy spread over four consecutive days (three hours on day 1-3 and two hours on day 4). Each subgroup consisted of a minimum of two and a maximum of five children and was guided by one experienced voice therapist (I.M. or A.A.). All therapy sessions were provided at Ghent University Hospital. During the study period, participants were not allowed to attend external voice therapy.

The content and hierarchical structure of the different intervention groups were kept as similar as possible, with the exception of the direct vocal techniques. In the CG, no direct technique was included. Offered therapy consisted of basic education of the vocal mechanism, normal vocal function, and VFNs, vocal hygiene recommendations, posture advice, and costo-abdominal breathing exercises.

Participants in the experimental groups received the same counseling and breathing exercises, combined with the direct vocal technique SP or RVT. For SP, participants used a stainless-steel drinking straw with a diameter of 5 mm and a length of 23 cm. In each intervention group, vocal rest pauses were provided and activities like games, crafting, and drawing assignments were scheduled for attention and compliance breaks. Since no direct vocal technique was practiced in the CG, more play activities were scheduled in which excessive or loud voice use was being monitored and limited. Play activities and vocal rest pauses were identical in the experimental groups. Home exercises were foreseen in each study arm. Parents were not present during therapy but were informed verbally and in writing about the content of the therapy sessions so they could supervise home exercises. A detailed overview of the therapy for the three intervention groups can be found in Appendix A.

Voice assessment

A standardized and multidimensional voice assessment, based on the protocol of the European Laryngological Society (Dejonckere et al., 2003) and supplemented with the acoustic voice quality index (AVQI) (Maryn, Corthals, et al., 2010), was performed one day before the start of voice therapy and immediately after the last voice therapy session. A standardized pretest anamnesis by means of a semi-structured interview was used to examine the demographic characteristics, therapy history, vocal complaints, and risk factors. The assessments were performed by eight voice therapists of the Center for Speech and Language Sciences (T.P., I.K., J.D., C.L., C.V.S., C.A., L.B., and E.D.) with experience in voice diagnostics in two acoustically treated rooms at Ghent University Hospital. The assessors were blinded to group allocation and participants were assessed by the same assessor pre- and posttherapy. Voice assessment consisted of the following parts: (a) laryngeal anatomy and function, (b) voice quality and vocal capacities, and c) psychosocial wellbeing.

a) Laryngeal anatomy and function

Flexible videolaryngostroboscopy was performed during pretest to determine whether VFNs were present and to describe the baseline laryngeal anatomy and function in detail. In order to avoid overloading the children, videolaryngostroboscopy was performed only pretherapy. It can be perceived as an invasive examination by (young) children, therefore it was considered unethical to perform it twice over a period of five days. Flexible videolaryngostroboscopy was carried out by an experienced otorhinolaryngologist (S.C., more than 25 years of experience in diagnosing voice disorders) or one of her assistants (C.D.V. and M.D.K.). Participants were examined in seated position with the head upright. They were asked to produce a sustained vowel /i/ at habitual pitch and loudness, followed by a high-pitched /i/ and a low-to-high glissando using /i/. Videolaryngostroboscopy was sometimes terminated early due to discomfort in the children, but recording the vowel /i/ at normal pitch and loudness was the minimum requirement.

Videolaryngostroboscopic video samples were evaluated using the Voice-Vibratory Assessment with Laryngeal Imaging (VALI) rating form (Poburka et al., 2017) and a grading scale for pediatric VFNs (Nuss et al., 2012; Shah et al., 2007). The video samples were provided with audio. An otorhinolaryngologist (S.C.) and voice therapist (I.K.) randomly and blindly evaluated all video samples. Both raters had experience with administering the VALI rating form, but not with the grading scale for pediatric VFNs. A half-hour training session was provided in which each parameter was clarified with the definition, a high-quality graphic, and two video examples. The raters first evaluated the video samples independently, followed by a consensus evaluation.

b) Voice quality and vocal capacities

The Dysphonia severity index (DSI) is a multiparametric index, consisting of a weighted combination of the maximum phonation time (MPT, in s), minimal intensity (I_{low}, in dB), maximal frequency (f_{high}, in Hz), and jitter (%) (Wuyts et al., 2000). MPT was determined by asking the children to sustain the vowel /a:/ as long as possible with habitual pitch and loudness after maximum inspiration. Three measurements were performed in free field while participants were seated. Children received verbal encouragements to produce the longest possible vowel. Time was measured with a chronometer and the longest result was used for further analyses. The I_{low} and f_{high} were determined using the Voice Range Profile of the Computerized Speech Lab (CSL, model 4500, KayPENTAX, Montvale, NY) and a Shure SM-48 microphone, located at a distance of 15 cm from the mouth and angled at 45 degrees. Participants were successively asked to produce the vowel /a:/ with minimal loudness and maximal pitch and they were given multiple attempts to achieve the best result. Each production was demonstrated by the assessors, who also verbally encouraged the children. Jitter % was obtained by the Multi-Dimensional Voice Program of the CSL and the same Shure SM-48 microphone. Participants were asked to count to three (an automatic sequence), followed by a sustained vowel /a:/ with habitual pitch and loudness. A midvowel segment of three seconds registered with a sampling rate of 50 kHz was used for the analysis.

The DSI is calculated using the following formula: $0.13 \times \text{MFT} + 0.0053 \times f_{high} - 0.26 \times I_{low} - 1.18 \times \text{jitter} + 12.4$ (Wuyts et al., 2000). The index value usually ranges between -5 and +5. A lower index value indicates poorer voice quality or, more generally, poorer vocal functioning (Awan & Ensslen, 2010). The threshold score that distinguishes a normophonic from a dysphonic voice is +1.6 in adults (Raes et al., 2002). This threshold score was used since norm values for Dutch children are currently missing.

The Acoustic Voice Quality Index (AVQI) is an objective, multiparameter approach to quantify dysphonia severity on the basis of a sustained vowel /a:/ and continuous speech (Maryn, Corthals, et al., 2010). The index consists of a weighted combination of six time-domain parameters [i.e., shimmer local (SL), shimmer local decibels (SLdB), and harmonics-to-noise ratio (HNR)), frequency-domain parameters (i.e., general slope of the spectrum (slope) and tilt of the regression line through the spectrum (tilt)), and quefrency-domain parameters (i.e., smoothed cepstral peak prominence (CPPs)]. The formula of the AVQI is $2.571\,(3.295 - 0.111\,\text{CPPs} - 0.073\,\text{HNR} - 0.213\,\text{SL} + 2.789\,\text{SLdB} - 0.032\,\text{slope} + 0.077\,\text{tilt})$. The index ranges from 0 to 10 and a higher index indicates poorer voice quality. The threshold score that distinguishes a normophonic voice from a dysphonic voice in Dutch adults is 2.95

(Maryn, Corthals, et al., 2010). An Australian study suggested a threshold score of 3.46 in the pediatric population, but norm values for Dutch children are missing (Reynolds et al., 2012). In order to calculate the AVQI, the participants were asked to produce a sustained vowel /a:/ at normal pitch and loudness and to read the Dutch phonetically balanced text "Papa and Marloes" (Van de Weijer & Slis, 1991). A Samson C01U Pro microphone, located at a distance of 15 cm from the mouth, and the software program PRAAT were used (Boersma & Weenink). A midvowel segment of 3 seconds of the vowel /a:/ and the first two sentences of the text were combined in an automated script to calculate the AVQI. It is known that a minimum signal-to-noise ratio (SNR) of 30 dB is required to obtain acceptable perturbation measurements (Deliyski et al., 2005). For this reason, all participants with a pre- or posttest sample with an SNR less than 30 dB were removed from the analyses of the AVQI.

Perceptual ratings of overall severity were made along a visual analog scale with textual markers for severity placed nonlinearly beneath the line, modeled after the format of the CAPE-V rating form (American Speech-Language-Hearing Association, 2002; Kempster et al., 2009). Two experienced voice therapists (T.P. and E.D.) independently and blindly rated all the pseudonymized samples in a random order. Afterwards, they relistened to the samples together to compare their individual evaluations and to reach a consensus. This consensus evaluation was used for analysis. The samples consisted of the sustained vowel /a:/ and the full text "Papa and Marloes," which were also used to determine the AVQI. The raters were allowed to listen multiple times to the samples. Both raters had experience with administering the CAPE-V. A random selection of 15% of the samples was doubled to calculate the intra-rater reliability.

c) Psychosocial wellbeing

Pediatric Voice Handicap Index (pVHI). A parent completed the Dutch version of the pVHI, which is a parent-proxy tool to gain insight into the physical, functional and emotional impact of the voice disorder on their child (Veder et al., 2017). The pVHI consists of 23 items which are evaluated using a five-point Likert scale (0: never, 1: almost never, 2: sometimes; 3: almost always; 4: always). Total pVHI scores range from 0 to 92 with a higher score corresponding with a greater psychosocial impact. The same parent was asked to complete the questionnaire pre- and posttherapy.

Statistical analysis

The statistical analysis was performed using IBM SPSS Statistics 28 software (SPSS, Inc. Chicago, IL). The significance level was set at $\alpha = 0.05$. One-way ANOVAs were used to check for statistically significant differences in continuous parameters (e.g., age) between the three intervention groups. Fisher's exact tests were used for the comparison of categorical parameters (e.g., sex) between the three intervention groups. When a significant difference was found between the groups, pairwise comparisons with Bonferroni corrections ($\alpha < 0.016$) were conducted. The inter- and intra-rater reliability of the perceptual rating of overall severity has been examined with two-way mixed ICCs and their 95% confidence intervals, type consistency, single-rating, and interpreted following the classification of Koo and Li (2016) ((ICC > 0.9 'excellent'; 0.9 ≥ ICC > 0.75 'good'; 0.75 ≥ ICC > 0.5 'moderate'; ICC ≤ 0.5 'poor'). The effects of voice therapy were evaluated using two complementary approaches.

Firstly, a more traditional group-level analysis was conducted. Linear mixed models were used to compare groups over time on the primary outcome parameters. The restricted maximum likelihood estimation and unstructured covariance type were used and time, group, and time-by-group interaction were designated as fixed factors. A random intercept for participants was included and within-group effects of time were determined using pairwise comparisons. Unstandardized effect sizes were presented in the form of the estimated mean differences and 95% confidence intervals for the outcome variables. For the analysis of the AVQI, only participants in whom the SNR of the pretest and posttest voice samples was greater than or equal to 30 dB were selected (Deliyski et al., 2006).

Secondly, an individual-level analysis was conducted for a thorough clinical interpretation of the study results, which is not possible based on group-level average intervention effects (Sand, 2022). This individual analysis examined for each participant whether outcome parameters changed to a relevant degree or remained unchanged. Previous literature was considered to determine the magnitude of this relevant degree of change. For the DSI and AVQI, the relevant degree of change within one patient was set at 2.49 (Hakkesteegt et al., 2008) and 0.54 (Barsties & Maryn, 2013), respectively. For the pVHI and perceptual rating of overall severity, the relevant degrees of change were not yet determined. Therefore, it was opted to exclude these outcome parameters from the individual analysis. The results show for DSI and AVQI what percentage of participants improved to a relevant degree, remained unchanged or deteriorated to a relevant degree. Wilson 95% confidence intervals for proportions were calculated.

Results

For every voice sample, the SNR was measured. The mean SNR was 33.03 dB (SD: 5.4, range: 19 – 43). Participants with a pretest and/or posttest voice sample with an SNR below 30 dB were excluded for the analysis of the AVQI (remaining n = 17; SP: 8, RVT: 4, CG: 5).

The ICC to check the interrater reliability of the perceptual rating of overall severity was 0.772 (95% CI [0.574; 0.824]). The ICC to check the intrarater reliability for the consensus evaluation of the perceptual rating of overall severity was 0.873 (95% CI [0.539; 0.970]. The ICCs to check for the intrarater reliability of the first and second rater were 0.880 (95% CI [0.560; 0.972]) and 0.750 (95% CI [0.225; 0.938], respectively.

Participants

A total of 30 children participated in the study. Eleven children were assigned to each of the experimental groups, while eight were placed in the control group. There was no dropout as all participants completed the full intensive voice therapy program. Information about demographics, therapy history, vocal symptoms, and risk factors can be found in Table 1. A one-way ANOVA showed that there was no significant difference in age between the three intervention groups [$F(2, 27) = 0.280$, $p = .758$], nor in the duration of previously received voice therapy [$F(2, 10) = 2.009$, $p = .185$]. Fisher's exact tests showed that there were no significant associations between intervention group and other parameters, except for a diagnosis of allergy ($p = .033$). However, pairwise comparisons with Bonferroni corrections ($\alpha < 0.016$) showed no significant differences in allergy between the groups.

The results of flexible videolaryngostroboscopy before the start of therapy are shown in Table 2. The parents of one participant did not grant permission for videolaryngostroboscopy. The child recently had videolaryngostroboscopy at another medical center where VFNs had been diagnosed. The videolaryngostroboscopic images of another participant were of insufficient quality, making it impossible to assess them in detail. However, the presence of VFNs had been confirmed during videolaryngostroboscopy. For all participants, the parameter 'vertical level' within the VALI-protocol could not be assessed from the videolaryngostroboscopic images and is therefore not displayed. No significant differences in the VALI-parameters were found between the three groups, except for glottal closure and mediolateral supraglottic activity. Pairwise comparisons with Bonferroni corrections ($\alpha < 0.016$) showed that more participants in the CG had an incomplete glottal closure pattern than participants in the experimental groups and that participants in the CG experienced more mediolateral supraglottic activity than participants in the RVT group.

[Please insert Tables 1 and 2 approximately here]

Group analysis

The evolution pre- to posttherapy of DSI, AVQI, pVHI, and perceptual rating of overall severity in the three groups is presented in Table 3. Linear mixed models found no significant time-by-group interaction for any of the outcome parameters, indicating that the evolution over time did not significantly differ among the three groups. No significant group effects were identified for any of the outcome parameters, indicating no differences among groups independent of time. Significant time effects were found for DSI and pVHI, indicating significant changes over time in the sample as a whole, independent of group assignment. Within-group effects of time showed a significant increase in DSI in the SP (+1.8, p = .035) and the RVT (+1.8, p = .038) groups, and a significant decrease in the perceptual rating of overall severity in the SP group (-6.5, p = .025). No significant changes were observed in the CG for any outcome parameter. Graphical representations of the evolution of the DSI, AVQI, pVHI, and perceptual rating of overall severity can be found in Figures 1 – 4, respectively.

[Please insert Figures 1, 2, 3 and 4 and Table 3 approximately here]

Individual analysis

In Figures 5 and 6, the individual trajectories for the DSI and AVQI are illustrated. The columns show the trajectories in each study group and the rows show the participants who improved to a relevant degree, who remained unchanged, and who deteriorated to a relevant degree per outcome parameter.

For DSI in the SP group, 4 out of 11 participants (36%, Wilson 95% CI [0.15; 0.64]) improved to a relevant degree, 6 out of 11 participants (55%, Wilson 95% CI [0.28; 0.79]) remained unchanged, and 1 out of 11 participants (9%, Wilson 95% CI [0.02; 0.38]) deteriorated to a relevant degree. For DSI in the RVT group, 5 out of 11 participants (45%, Wilson 95% CI [0.21; 0.72]) improved to a relevant degree, 5 out of 11 participants (45%, Wilson 95% CI [0.21; 0.72]) remained unchanged, and 1 out of 11 participants (9%, Wilson 95% CI [0.02; 0.38]) deteriorated to a relevant degree. For DSI in the CG, 1 out of 8 participants (13%, Wilson 95% CI [0.02; 0.47]) improved to a relevant degree, 6 out of 8 participants (75%, Wilson 95% CI [0.41; 0.93]) remained unchanged, and 1 out of 8 participants (13%, Wilson 95% CI [0.02; 0.47]) deteriorated to a relevant degree.

For AVQI (based on the remaining samples with an SNR above 30 dB) in the SP group, 3 out of 8 participants (38%, Wilson 95% CI [0.14; 0.69] improved to a relevant degree, 3 out of 8 participants

(38%, Wilson 95% CI [0.14; 0.69] remained unchanged, and 2 out of 8 participants (25%, Wilson 95% CI [0.07; 0.59]) deteriorated to a relevant degree. For AVQI in the RVT group, 4 out of 4 participants (100%) remained unchanged. For AVQI in the CG, 2 out of 5 participants (40%, Wilson 95% CI [0.12; 0.77]) improved to a relevant degree and 3 out of 5 participants (60%, Wilson 95% CI [0.23; 0.88]) remained unchanged.

[Please insert Figures 5 and 6 approximately here]

Discussion

The aim of this study was to investigate the short-term effects of SP and RVT in children with VFNs, in terms of voice quality, vocal functioning, and voice-related quality of life. Most previous studies on voice therapy effectiveness in children had methodological shortcomings, such as an inadequate research design. This study aimed to accommodate these shortcomings in the literature by investigating the effects of pediatric voice therapy using an RCT.

The DSI, AVQI, pVHI, and perceptual rating of overall severity were included as outcome parameters. In this way, an objective multiparametric measure of vocal capacity (DSI) and voice quality (AVQI), a parent-reported measure of voice-related quality of life (pVHI), and a perceptual rating of overall severity were included. In the traditional group analysis, mean intervention effects were investigated. In the CG, no significant differences were found in any of the outcome parameters. Unlike research within pharmacology, providing a credible sham training without any influences on the vocal system is difficult (Bos-Clark & Carding, 2011; Meerschman, Van Lierde, et al., 2019). The current study opted to provide counseling, vocal hygiene recommendations, and breathing exercises in the CG, without the inclusion of any other active vocal technique. The same therapy content was offered in the experimental groups and supplemented by an SOVT program. Although the CG does not include active vocal techniques, it actually contains a form of indirect voice therapy that may cause participants to modify their vocal habits. CG results may suggest that the indirect voice therapy, along with contact and therapist relationship, may not significantly improve the voice in the short term. Evidently, this does not mean that indirect therapy is not valuable in clinical practice. It may be necessary for improvement, since the experimental groups also received counseling and vocal hygiene recommendations.

The DSI was originally developed as a multiparametric index to quantify voice quality (Wuyts et al., 2000). However, the index mainly consists of parameters that are more related to vocal capacity than voice quality, suggesting that DSI could be applied as a more global measure of vocal functioning (Awan & Ensslen, 2010). The DSI significantly and similarly improved in the SP (+1.8) and RVT group (+1.8) and remained unchanged in the CG (+0.0). Consequently, overall functioning of the voice seems to have improved to the same extent in both experimental groups. The DSI has not previously been used as an outcome parameter in effectiveness studies of pediatric voice therapy. The use of the outcome parameter DSI is also rather limited in studies in adults. Alegria et al. (2020) stated in their systematic review on the effectiveness of voice therapy in adults with VFNs that no study used a multiparametric outcome parameter, such as the DSI and the AVQI. Meerschman, Van Lierde, et al. (2019) investigated the effect of SP in adults with dysphonia. They also found a statistically significant improvement in DSI with an estimated mean difference of +1.8, which is a similar increase after six sessions of 30 minutes over a three-week duration. In a group of adults without dysphonia, Meerschman et al. (2017) found a statistically significant improvement in DSI after 12 RVT sessions over a six-week period with an estimated mean difference of +1.2, and no statistically significant difference after SP (estimated mean difference = +0.2).

The AVQI did not significantly change in any of the three groups. This multiparametric voice quality index is based on both sustained vowels and continuous speech and therefore is an “ecologically valid” outcome parameter to represent daily speech (Maryn, De Bodt, et al., 2010). The objective voice quality in daily speech thus remained unchanged at group level. It is possible that insufficient generalization to continuous and spontaneous speech occurred by the end of therapy. Despite the intensive nature of this therapy program, it is plausible that children need more time to generalize the techniques learned. In the qualitative research of Braden et al. (2018), children with dysphonia and their parents reported that generalization of the new vocal behaviors is difficult. The DSI calculation does not include parameters based on continuous speech. Therefore, a lack of generalization in daily speech might explain the different evolution between the DSI and the AVQI. Another explanation is the fact that the DSI and the AVQI were not calculated for exactly the same study group, since some of the speech samples were excluded for the calculation of the AVQI. Similar to DSI, the AVQI has not yet been widely used as an outcome parameter within other studies regarding pediatric dysphonia.

Patient-reported outcome measures are an indispensable part of voice evaluations to investigate patient’s personal perceptions and perceived health-related quality of life (Black, 2013; Slavych et al., 2021). In the field of pediatric dysphonia, parent-proxy questionnaires like the pVHI are often used (Adriaansen, Van Lierde, et al., 2022). No statistically significant differences were found in any of the three groups, indicating that the psychosocial impact of the voice disorder did not change after therapy according to the parents. It is possible that five days is unsufficient for parents to notice a change in the psychosocial impact of their child’s voice disorder. It is also possible that some parents only spent a very limited amount of time with their children during these days and were therefore more likely to rely on pre-therapy experiences when completing the questionnaire. In contrast, Ma et al. (2021) reported significantly improved pVHI scores after six weekly sessions of vocal hygiene recommendations with RVT in children with VFNs. However, these children had remarkably higher pre-therapy pVHI scores, which means a higher psychosocial impact and thus more potential to experience improvement.

Perceptual evaluation of voice quality is considered the ‘gold standard’ in voice evaluations (Oates, 2009). Perceptual rating of overall severity significantly improved in the SP group, while it remained unchanged in the RVT group and CG. Based on these results, perceptual voice quality seems to benefit more from an SP program than an RVT program. The advantages of SP include its non-intuitive nature, potentially making it more understandable to children than the highly intuitive RVT. In addition, SP provides higher inertive reactance in the vocal tract than RVT, which may also benefit transfer (Gaskill & Quinney, 2012; Maxfield et al., 2015; Titze, 2006). However, the perceptual severity of dysphonia was slightly higher in the SP group (EM = 27.5) compared to the RVT (EM = 19.6) and CG group (EM = 20.8). Thus, it is possible that the participants in the SP group simply had more opportunities to improve or that the voices of those in the RVT group and the CG were already closer to the normative range. In the study of Hartnick et al. (2018), no significant changes in CAPE-V overall severity were reported after a direct voice therapy program including resonant voice training or after an indirect voice therapy program. CAPE-V overall severity decreased on average by 6.2 points in the direct voice therapy group, while in our study the mean perceptual rating of overall severity after RVT remained rather constant with a mean difference of -0.6. However, the direct therapy also included other techniques like behavioral modelling and shaping, which may account for the small differences in outcomes. Moreover, there was also a slight difference in baseline CAPE-V overall severity. In the study of Hartnick et al. (2018), the CAPE-V overall severity at pretest varied between 29.6 and 35.3 in the direct therapy group and between 30.5 and 36.2 in the indirect therapy group. The estimated mean perceptual rating of overall severity in the RVT group of the current study was 19.6. Thus, the average CAPE-V overall severity is higher in the study of Hartnick et al. (2018) and the participants had perceptually more severe dysphonia. This might also explain the small difference in evolution in perceptual voice quality.

Since the CAPE-V is subjective in nature, it is important to check the reliability of this parameter. Inter- and intrarater reliability of the perceptual rating of overall severity were calculated for the evaluations of two raters with experience in the perceptual evaluation of dysphonic voices. The interrater reliability for the perceptual rating of overall severity was moderate to good (ICC = 0.772, 95% CI [0.574; 0.824]).

A similar interrater reliability of 0.76 was found for overall severity in the validation study of the CAPE-V, measured on the evaluations of normal and dysphonic voice samples in 21 experienced listeners (Zraick Richard et al., 2011). Helou et al. (2010) showed that the interrater reliability of CAPE-V overall severity depends on the level of experience of the raters, with experienced raters having significantly better interrater reliability results (0.73) than inexperienced raters (0.53). The intrarater reliability for the consensus evaluation of the perceptual rating of overall severity was moderate to excellent (ICC = 0.873, 95% CI [0.539; 0.970]. The intrarater reliability for the individual evaluation of overall severity was moderate to excellent in the first rater (ICC = 0.880, 95% CI [0.560; 0.972]) and poor to excellent in the second rater (ICC = 0.750, 95% CI [0.225; 0.938]). In the validation study of the CAPE-V, an average intrarater reliability for overall severity of 0.57 was found, with individual scores ranging from 0.21 to 0.85 (Zraick Richard et al., 2011). Among the experienced raters in the study of Helou et al. (2010), an average intrarater reliability of 0.911 was found. A problem inherent in the CAPE-V is the fact that raters have a personal internal standard which can vary greatly from one individual to another. Moreover, this internal standard is not stable over time, as raters with experience in dysphonia adapt to disordered voices, and exposure to a large number of samples over a short period of time can also cause a change in the internal standard (Nagle, 2016). However, the reliability results in the current study are quite high, being in line with or exceeding previous studies.

The results of a group-level analysis are not always easy to interpret in terms of clinical relevance (Sand, 2022). By conducting individual-level analyses, it was attempted to display more clinically meaningful and interpretable results. In our sample, the DSI improved from -3.0 to -1.2 in the SP group and from -2.6 to -0.8 in the RVT group, which is an increase with +1.8 points in both groups. Based on the 95% CI, we estimate the change in DSI after a similar treatment outside our sample to be somewhere between +0.1 and +3.4 in both groups. This is a very wide CI, making it difficult to generalize this result. This is not surprising given the relatively small sample size in the current study. Interestingly, the estimated mean difference in DSI (+1.8) does not reach the degree of a clinically relevant change, which was set at 2.49 (Hakkesteegt et al., 2008). However, the authors who determined this degree of change already mentioned that 2.49 is a rather large difference. Therefore, it is likely that more subtle voice changes will not lead to this change in DSI (Hakkesteegt et al., 2008). The pre-post difference in DSI was inconsistent between participants and 36% of them improved to a clinically relevant degree in the SP group. The Wilson 95% CI indicated that somewhere between 15% and 64% of future children with VFNs participating in similar SP therapy should improve to a clinically relevant degree. For RVT therapy, 45% of the participants improved to a clinically relevant degree and 21% to 72% of future children with VFNs participating in similar RVT should improve to a clinically relevant degree. In both the SP and RVT groups, one participant experienced a clinically relevant deterioration in DSI. Further analysis of these two participants shows that they were part of the youngest age group (< 7 years old). A possible explanation is that these children may not have been mature enough to benefit from voice therapy. Moreover, the parameter 'extent of lesion' of the VALI-protocol showed that the child in the RVT with a deteriorated DSI had the most extended pretest lesion of the whole study group. The deterioration might be due to the continuation of phonotraumatic behavior combined with frequent voice use during intensive group therapy with peers.

The AVQI decreased with -0.1 points in the SP group. A clinically relevant difference consists of at least 0.54 points, so a difference of -0.1 is negligible (Barsties & Maryn, 2013). Based on the 95% CI, we estimate the change in AVQI after a similar treatment outside our sample to be somewhere between -0.6 and +0.4. This CI indicates that it cannot be predicted whether the AVQI will improve (decrease) or deteriorate (increase) after similar SP therapy in children with VFNs. In our sample, 36% of the participants improved to a clinically relevant degree. The Wilson 95% CI indicated that somewhere between 14% and 69% of future children with VFNs participating in similar SP therapy should improve to a clinically relevant degree. However, 25% of the children in our sample deteriorated to a clinically relevant degree, meaning that 7% to 59% of future children with VFNs are expected to deteriorate after similar SP therapy. In the RVT group, the AVQI decreased with -0.4 points. Based on the 95% CI, we estimate the change in AVQI outside our sample to be somewhere between -1.1 and +0.3. Again, it is uncertain to predict whether there will be an improvement or deterioration in the AVQI after RVT. In our sample, no participant changed to a clinically relevant degree. However, it is important to consider the fact that that only four individuals were included for analysis of the AVQI in the RVT group.

When combining both analyses, the results showed that an intensive group voice therapy program of SP or RVT caused positive vocal effects in children with VFNs. Both techniques resulted in similar improvements in vocal capacities. More than a third of the participants (36%) improved in DSI to a clinically relevant degree in the SP group, and nearly half of the participants (45%) in the RVT group. Additionally, SP led to a significant improvement in the auditory-perceptual voice quality, whereas no difference in voice quality was measured in the RVT group. A considerable proportion of participants (38%) experienced clinically relevant progress in AVQI in the SP group, while this was not the case for any participant in the RVT group. There seems to be a preference for the SP technique over RVT regarding voice quality in this patient group. Recent research showed that SP is used less frequently in children with VFNs (61%) than RVT (83%) (Adriaansen et al., 2024). The current study supports the benefits of SP and may encourage voice therapists in the field to further integrate the technique into their clinical practice.

To our knowledge, this study is the first randomized controlled trial to investigate the effects of voice therapy in children with VFNs. Treatment outcomes could be compared to a control group receiving indirect training with baseline vocal, medical, and demographic characteristics equivalent to the experimental groups. Randomization was achieved in the order of organizing the different therapies and assessors were blinded to group allocation. The study group was homogeneous in terms of pathology, as all participants had a diagnosis of VFNs based on laryngeal imaging by an otorhinolaryngologist. Multidimensional facets of voice were evaluated, analyzing both objective, perceptual, and patient-reported outcome measures. Another strength of this study is the innovative topic. Despite 72% of voice therapists using SOVT techniques in clinical practice while treating children with VFNs, very little research is available on SOVT in children (Adriaansen et al., 2024). This study makes an initial effort to explore this under-researched area in the literature. Moreover, this is the first study to present both group-level and individual-level results in the field of pediatric dysphonia.

This study presents some limitations which should be addressed in future studies. Firstly, it is possible that the treatment duration was too short to measure major differences in some outcome parameters. For example, five days is a short period of time to notice and measure changes in voice-related quality of life. Feinstein and Verdolini Abbott (2021) also pointed out that children need time to practice and assimilate the techniques and to understand why they are in treatment as they are generally not self-referred. Secondly, no individual analyses were carried out for pVHI and perceptual rating of overall severity. Thirdly, the patient-reported outcome measure was parent-proxy in nature (pVHI), so the opinions of the children themselves were not captured. However, it has already been shown that parents' and children's perceptions on the impact of a voice problem may differ, especially for symptom experience, peer relationships, and future worries (Cohen & Wynne, 2015; Eiser, 1997; Ricci-Maccarini et al., 2013). At the start of this research project, a validated Dutch self-reported voice-related quality of life tool for children was not yet available. Fourthly, two voice therapists guided the therapy sessions: the first three intensive voice therapy programs were led by I.M. and the last seven therapy programs were led by A.A. Therefore, therapist bias could not completely be avoided. Fifthly, this study used a set straw length of 23cm. However, the length of the vocal tract in children aged 6 to 12 years can vary widely, and the length of the straw should be adjusted accordingly. Lastly, almost half of the children attended voice therapy in the past. Consequently, some participants were already familiar with the vocal techniques, which may have influenced the results. It is recommended that future research on this topic include only children without a history of voice therapy.

Several questions remain unanswered at present. Further research is required to investigate the effects of voice therapy in children with VFNs. Larger sample sizes are necessary to gain more insight into the effectiveness of SOVT therapy. Moreover, it would be interesting to compare the results of a more traditional, spaced SOVT therapy program with the results of the current study. It is also recommended to include longer-term follow-up measurements and self-reported quality of life outcome measures.

Conclusion

This study demonstrated that short-term intensive SOVT therapy can improve vocal outcomes in children with VFNs. Both SP and RVT had a positive effect on vocal capacities and SP also led to improvements in voice quality. The results suggest that participants seem to benefit more from an SP than an RVT program, encouraging voice therapists to include SP in their therapy protocol for children with VFNs. Further research is required to fully understand the impact of SOVT therapy on the phonation of children with VFNs. Future research should include longer-term follow-up measurements and investigate the effects of a more traditional spaced SOVT therapy in this patient group.

Acknowledgements

This work was supported by the Research Fund Flanders [grant number G069319N]. The authors thank Julie Daelman, Clara Leyns, Charis Van der Straeten, Cassandra Alighieri, Laura Bruneel, Casper De Vriese, and Magalie De Kezel who assisted in data collection.

Data availability statement

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

References

Abrahamsson, M., Millgård, M., Havstam, C., & Tuomi, L. (2018). Effects of Voice Therapy: A Comparison Between Individual and Group Therapy. *Journal of Voice*, *32*(4), 437-442. https://doi.org/https://doi.org/10.1016/j.jvoice.2017.06.008

Adriaansen, A., Meerschman, I., Van Lierde, K., & D'Haeseleer, E. (2022). Effects of voice therapy in children with vocal fold nodules: A systematic review. *International Journal of Language and Communication Disorders*, *57*(6), 1160-1193.

Adriaansen, A., Van Lierde, K., & D'haeseleer, E. (2024). Clinical experiences of voice therapists in the rehabilitation of pediatric vocal fold nodules. *Submitted to Journal of Voice*.

Adriaansen, A., Van Lierde, K., Meerschman, I., Claeys, S., & D'haeseleer, E. (2023). The Occurrence of Laryngeal Pathologies in a Treatment-Seeking Pediatric Population. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2023.07.001

Adriaansen, A., Van Lierde, K., Meerschman, I., Everaert, C., & D'Haeseleer, E. (2022). Validity and Reliability of the Dutch Children's Voice Handicap Index-10. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2022.04.020

Al-Kadi, M., Alfawaz, M. A., & Alotaibi, F. Z. (2022). Impact of Voice Therapy on Pediatric Patients With Dysphonia and Vocal Nodules: A Systematic Review. *Cureus*, *14*(4).

Alegria, R., Vaz Freitas, S., & Manso, M. C. (2020). Effectiveness of voice therapy in patients with vocal fold nodules: a systematic search and narrative review. *European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery*, *277*(11), 2951-2966. https://doi.org/10.1007/s00405-020-06059-8

American Speech-Language-Hearing Association. (2002). Consensus Auditory–Perceptual Evaluation of Voice (CAPE-V): ASHA Special Interest Division 3, Voice and Voice Disorders. *Rockville, MD: Author. Retrieved from https://www. asha. org/uploadedFiles/members/divs/D3CAPEVprocedures. pdf*.

Andrade, P., Wistbacka, G., Larsson, H., Södersten, M., Hammarberg, B., Simberg, S., Švec, J. G., & Granqvist, S. (2016). The Flow and Pressure Relationships in Different Tubes Commonly Used for Semi-occluded Vocal Tract Exercises. *Journal of Voice*, *30*(1), 36-41. https://doi.org/https://doi.org/10.1016/j.jvoice.2015.02.004

Andrade, P. A., Wood, G., Ratcliffe, P., Epstein, R., Pijper, A., & Svec, J. G. (2014). Electroglottographic Study of Seven Semi-Occluded Exercises: LaxVox, Straw, Lip-Trill, Tongue-Trill, Humming, Hand-Over-Mouth, and Tongue-Trill Combined With Hand-Over-Mouth. *Journal of Voice*, *28*(5), 589-595. https://doi.org/https://doi.org/10.1016/j.jvoice.2013.11.004

Awan, S. N., & Ensslen, A. J. (2010). A Comparison of Trained and Untrained Vocalists on the Dysphonia Severity Index. *Journal of Voice*, *24*(6), 661-666. https://doi.org/https://doi.org/10.1016/j.jvoice.2009.04.001

Barsties, B., & Maryn, Y. (2013). Test-Retest-Variabilität und interne Konsistenz des Acoustic Voice Quality Index. *HNO*, *61*(5), 399-403. https://doi.org/10.1007/s00106-012-2649-0

Bergan, C. (2010). Motor learning principles and voice pedagogy: theory and practice [Report]. *Journal of Singing*, *66*, 457+. https://link.gale.com/apps/doc/A252553856/HRCA?u=googlescholar&sid=googleScholar&xid=2ac5740c

Bian, Y., Wang, J., Zhang, H., Yin, X., & Zhang, Y. (2024). Voice treatment of school-aged children with vocal nodules with ABCLOVE rehabilitation. *Pediatrics & Neonatology*. https://doi.org/10.1016/j.pedneo.2023.09.015

Black, N. (2013). Patient reported outcome measures could help transform healthcare. *BMJ (Clinical research ed.)*, *346*, f167. https://doi.org/10.1136/bmj.f167

Boersma, W., & Weenink, D. *PRAAT: doing phonetics by computer (Version 6.0.14)*. In http://www.praat.org/

Bos-Clark, M., & Carding, P. N. (2011). Effectiveness of voice therapy in functional dysphonia: where are we now?[2]. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *19*(3), 160-164. https://doi.org/10.1097/moo.0b013e3283448f85

Boutron, I., Altman, D. G., Moher, D., Schulz, K. F., & Ravaud, P. (2017). CONSORT Statement for Randomized Trials of Nonpharmacologic Treatments: A 2017 Update and a CONSORT Extension for Nonpharmacologic Trial Abstracts. *Annals of Internal Medicine*, *167*(1), 40-47. https://doi.org/10.7326/M17-0046

Braden, & Thibeault, S. L. (2020). Outcomes of voice therapy in children with benign vocal fold lesions. *International journal of pediatric otorhinolaryngology*, *136*, 110121. https://doi.org/10.1016/j.ijporl.2020.110121

Braden, M., Van Leer, E., McConville, K., & Blakeslee, S. D. M. (2018). Patient, Parent, and Speech-Language Pathologists' Perceptions of Pediatric Voice Therapy Through Interviews. *American journal of speech-language pathology*, *27*(4), 1385-1404. https://doi.org/10.1044/2018_AJSLP-17-0226

Chadwick, S. J. (2003). Allergy and the contemporary laryngologist. *Otolaryngologic clinics of North America*, *36*(5), 957-988. https://doi.org/10.1016/S0030-6665(03)00049-5

Cohen, W., & Wynne, D. M. (2015). Parent and Child Responses to the Pediatric Voice-Related Quality-of-Life Questionnaire. *Journal of voice : official journal of the Voice Foundation*, *29*(3), 299-303. https://doi.org/10.1016/j.jvoice.2014.08.004

Conroy, E. R., Hennick, T. M., Awan, S. N., Hoffman, M. R., Smith, B. L., & Jiang, J. J. (2014). Effect of Variations to a Simulated System of Straw Phonation Therapy on Aerodynamic Parameters Using Excised Canine Larynges. *Journal of Voice*, *28*(1), 1-6. https://doi.org/https://doi.org/10.1016/j.jvoice.2013.08.004

Croake, D. J., Andreatta, R. D., & Stemple, J. C. (2017). Immediate Effects of the Vocal Function Exercises Semi-Occluded Mouth Posture on Glottal Airflow Parameters: A Preliminary Study.

Journal of Voice, *31*(2), 245.e249-245.e214. https://doi.org/https://doi.org/10.1016/j.jvoice.2016.08.009

D'Alatri, L., Petrelli, L., Calo, L., Picciotti, P. M., Marchese, M. R., & Bussu, F. (2015). Vocal fold nodules in school age children: attention deficit hyperactivity disorder as a potential risk factor. *Journal of voice : official journal of the Voice Foundation*, *29*(3), 287-291. https://doi.org/10.1016/j.jvoice.2014.07.019

Dargin, T. C., & Searl, J. (2015). Semi-Occluded Vocal Tract Exercises: Aerodynamic and Electroglottographic Measurements in Singers. *Journal of Voice*, *29*(2), 155-164. https://doi.org/https://doi.org/10.1016/j.jvoice.2014.05.009

Dejonckere, P., Crevier-Buchman, L., Marie, J.-P., Moerman, M., Remacle, M., & Woisard, V. (2003). Implementation of the European Laryngological Society (ELS) - Basic protocol for assessing voice treatment effect. *Revue de laryngologie - otologie - rhinologie*, *124*, 279-283.

Deliyski, D. D., Shaw, H. S., & Evans, M. K. (2005). Adverse Effects of Environmental Noise on Acoustic Voice Quality Measurements. *Journal of Voice*, *19*(1), 15-28. https://doi.org/https://doi.org/10.1016/j.jvoice.2004.07.003

Deliyski, D. D., Shaw, H. S., Evans, M. K., & Vesselinov, R. (2006). Regression Tree Approach to Studying Factors Influencing Acoustic Voice Analysis. *Folia Phoniatrica et Logopaedica*, *58*(4), 274-288. https://doi.org/10.1159/000093184

Dickson, K., Marshall, M., Boyle, J., McCartney, E., O'Hare, A., & Forbes, J. (2009). Cost analysis of direct versus indirect and individual versus group modes of manual-based speech-and-language therapy for primary school-age children with primary language impairment. *International Journal of Language & Communication Disorders*, *44*(3), 369-381. https://doi.org/https://doi.org/10.1080/13682820802137041

Dobres, R., Lee, L., Stemple, J. C., Kummer, A. W., & Kretschmer, L. W. (1990). Description of laryngeal pathologies in children evaluated by otolaryngologists. *The Journal of Speech and Hearing Disorders*, *55*(3), 526-532. https://doi.org/10.1044/jshd.5503.526

Eiser, C. (1997). Children's quality of life measures. *Archives of Disease in Childhood*, *77*, 350/354.

Ercan, N., Bostanci, I., Kaygusuz, U., & Ceylan, K. (2020). Interaction between childhood vocal fold nodules and allergic diseases. *International journal of pediatric otorhinolaryngology*, *138*, 110404. https://doi.org/10.1016/j.ijporl.2020.110404

Feinstein, H., & Verdolini Abbott, K. V. (2021). Behavioral Treatment for Benign Vocal Fold Lesions in Children: A Systematic Review. *American journal of speech-language pathology*, *30*(2), 772-788. https://doi.org/10.1044/2020_AJSLP-20-00304

Fu, S., Theodoros, D. G., & Ward, E. C. (2015). Intensive Versus Traditional Voice Therapy for Vocal Nodules: Perceptual, Physiological, Acoustic and Aerodynamic Changes. *Journal of Voice*, *29*(2), 260.e231-260.e244. https://doi.org/https://doi.org/10.1016/j.jvoice.2014.06.005

Gaskill, C. S., & Quinney, D. M. (2012). The Effect of Resonance Tubes on Glottal Contact Quotient With and Without Task Instruction: A Comparison of Trained and Untrained Voices. *Journal of Voice*, *26*(3), e79-e93. https://doi.org/https://doi.org/10.1016/j.jvoice.2011.03.003

Graham, M. S., & Avent, J. (2004). A discipline-wide approach to group treatment. *Top Lang Disord*, *24*, 105-117.

Guzman, M., Jara, R., Olavarria, C., Caceres, P., Escuti, G., Medina, F., Medina, L., Madrid, S., Muñoz, D., & Laukkanen, A.-M. (2017). Efficacy of Water Resistance Therapy in Subjects Diagnosed With Behavioral Dysphonia: A Randomized Controlled Trial. *Journal of Voice*, *31*(3), 385.e381-385.e310. https://doi.org/https://doi.org/10.1016/j.jvoice.2016.09.005

Hakkesteegt, M. M., Wieringa, M. H., Brocaar, M. P., Mulder, P. G. H., & Feenstra, L. (2008). The Interobserver and Test-Retest Variability of the Dysphonia Severity Index. *Folia Phoniatrica et Logopaedica*, *60*(2), 86-90. https://doi.org/10.1159/000114650

Hartnick, C., Ballif, C., De Guzman, V., Sataloff, R., Campisi, P., Kerschner, J., Shembel, A., Reda, D., Shi, H., Sheryka Zacny, E., & Bunting, G. (2018). Indirect vs Direct Voice Therapy for Children With Vocal Nodules: A Randomized Clinical Trial. *JAMA otolaryngology-- head & neck surgery*, *144*(2), 156-163. https://doi.org/10.1001/jamaoto.2017.2618

Helou, B., Solomon Nancy, P., Henry Leonard, R., Coppit George, L., Howard Robin, S., & Stojadinovic, A. (2010). The Role of Listener Experience on Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) Ratings of Postthyroidectomy Voice. *American journal of speech-language pathology*, *19*(3), 248-258. https://doi.org/10.1044/1058-0360(2010/09-0012)

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., Savović, J., Schulz, K. F., Weeks, L., & Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*, *343*, d5928. https://doi.org/10.1136/bmj.d5928

Hron, T. A., Kavanagh, K. R., & Murray, N. (2019). Diagnosis and Treatment of Benign Pediatric Lesions. *Otolaryngologic clinics of North America*, *52*(4), 657-668. https://doi.org/10.1016/j.otc.2019.03.010

Kang, J., Xue, C., Piotrowski, D., Gong, T., Zhang, Y., & Jiang, J. J. (2019). Lingering Effects of Straw Phonation Exercises on Aerodynamic, Electroglottographic, and Acoustic Parameters. *Journal of Voice*, *33*(5), 810.e815-810.e811. https://doi.org/https://doi.org/10.1016/j.jvoice.2018.05.002

Karalı, F. S., Azizli, E., Tadihan-Özkan, E., Eskioğlu, E. İ., Sari, A., & Resuloglu, A. (2022). Voice Therapy Efficacy in Pediatric Professional Voice Users With Vocal Fold Nodules: A Preliminary Study. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2022.09.005

Kempster, G., Gerratt, B., Verdolini Abbott, K., Barkmeier-Kraemer, J., & Hillman, R. (2009). Consensus auditory-perceptual evaluation of voice: development of a standardized clinical protocol. *American journal of speech-language pathology*, *18*(2), 124-132.

Kmet, L. M., Cook, L. S., & Lee, R. S. (2004). *Standard quality assessment criteria for evaluating primary research papers from a variety of fields*.

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of chiropractic medicine*, *15*(2), 155-163. https://doi.org/10.1016/j.jcm.2016.02.012

Kunduk, M., & McWhorter, A. J. (2009). True vocal fold nodules: the role of differential diagnosis. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *17*(6). https://journals.lww.com/co-otolaryngology/Fulltext/2009/12000/True_vocal_fold_nodules__the_role_of_differential.10.aspx

Law, T., Lee, K. Y. S., Ho, F. N. Y., Vlantis, A. C., van Hasselt, A. C., & Tong, M. C. F. (2012). The Effectiveness of Group Voice Therapy: A Group Climate Perspective. *Journal of Voice*, *26*(2), e41-e48. https://doi.org/https://doi.org/10.1016/j.jvoice.2010.12.003

Lechien, J. R., Saussez, S., Harmegnies, B., Finck, C., & Burns, J. A. (2017). Laryngopharyngeal Reflux and Voice Disorders: A Multifactorial Model of Etiology and Pathophysiology. *Journal of Voice*, *31*(6), 733-752. https://doi.org/https://doi.org/10.1016/j.jvoice.2017.03.015

Lee, J. M., Roy, N., & Dietrich, M. (2019). Personality, Psychological Factors, and Behavioral Tendencies in Children With Vocal Nodules: A Systematic Review. *Journal of voice : official journal of the Voice Foundation*, *33*(6), 945 e941-945 e918. https://doi.org/10.1016/j.jvoice.2018.07.016

Lee, J. M., Roy, N., Park, A., Muntz, H., Redmond, S. M., & Smith, M. (2022). Self-regulation in children with vocal fold nodules: A multilevel analysis. *Journal of Communication Disorders*, *97*, 106203. https://doi.org/https://doi.org/10.1016/j.jcomdis.2022.106203

Liu, H., Chen, S., Gao, L., Li, J., Liu, B., Raj, H., Xie, Q., Duan, H., Jiang, Z., Liu, Y., Chen, B., Liu, Y., & Jiang, J. (2022). Comparison Between Combination of Resonant Voice Therapy and Vocal Hygiene Education and Vocal Hygiene Education Only for Female Elementary School Teachers. *Journal of Voice*, *36*(6), 814-822. https://doi.org/https://doi.org/10.1016/j.jvoice.2020.09.028

Ma, E., & Leung, H. (2021). One-Year Follow-Up of a Vocal Hygiene Program for School-Age Children. *Folia Phoniatrica et Logopaedica 73*, 1-6.

Ma, E. P. M., Cheung, Y.-C., Siu, A. K. Y., & Lo, J. F. W. (2021). The Effectiveness of Vocal Hygiene Education With Resonant Voice Therapy for School-Aged Children With Vocal Nodules. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2021.08.015

Mandell, D., Kay, D., Dohar, J., & Yellon, R. (2004). Lack of Association Between Esophageal Biopsy, Bronchoalveolar Lavage, and Endoscopy Findings in Hoarse Children. *Archives of Otorhinolaryngology-Head & Neck Surgery*, *130*.

Martins, R. H., Branco, A., Tavares, E. L., & Gramuglia, A. C. (2013). Clinical practice: vocal nodules in dysphonic children. *European journal of pediatrics*, *172*(9), 1161-1165. https://doi.org/10.1007/s00431-013-2048-x

Martins, R. H. G., Siqueira, D. B., Dias, N. H., & Gramuglia, A. C. J. (2020). Laryngeal Microsurgery for the Treatment of Vocal Nodules and Cysts in Dysphonic Children. *Folia phoniatrica et logopaedica : official organ of the International Association of Logopedics and Phoniatrics (IALP)*, *72*(4), 325-330. https://doi.org/10.1159/000502477

Maryn, Y., Corthals, P., Van Cauwenberge, P., Roy, N., & De Bodt, M. (2010). Toward improved ecological validity in the acoustic measurement of overall voice quality: combining continuous speech and sustained vowels. *Journal of voice : official journal of the Voice Foundation*, *24*(5), 540-555. https://doi.org/10.1016/j.jvoice.2008.12.014

Maryn, Y., De Bodt, M., & Roy, N. (2010). The Acoustic Voice Quality Index: Toward improved treatment outcomes assessment in voice disorders. *Journal of Communication Disorders*, *43*(3), 161-174. https://doi.org/https://doi.org/10.1016/j.jcomdis.2009.12.004

Maxfield, L., Titze, I., Hunter, E., & Kapsner-Smith, M. (2015). Intraoral pressures produced by thirteen semi-occluded vocal tract gestures. *Logopedics Phoniatrics Vocology*, *40*(2), 86-92.

Mcilwaine, A., Madill, C., & McCabe, P. (2010). Voice therapy prepractice and the principles of motor learning. *Acquir Knowl Speech Lang Hear*, *12*(1), 29-32.

Meerschman, I. (2018). *Effect of voice training and voice therapy : content and dosage* Ghent University]. Ghent, Belgium.

Meerschman, I., Claeys, S., Bettens, K., Bruneel, L., D'haeseleer, E., & Van Lierde, K. (2019). Massed versus spaced practice in vocology: Effect of a short-term intensive voice therapy versus a long-term traditional voice therapy. *Journal of Speech, Language, and Hearing Research*, *62*(3).

Meerschman, I., Van Lierde, K., Ketels, J., Coppieters, C., Claeys, S., & D'Haeseleer, E. (2019). Effect of three semi-occluded vocal tract therapy programmes on the phonation of patients with dysphonia: lip trill, water-resistance therapy and straw phonation. *International Journal of Language & Communication Disorders*, *54*(1), 50-61. https://doi.org/https://doi.org/10.1111/1460-6984.12431

Meerschman, I. G. E., Van Lierde, K. G. E. U. X., Peeters, K., Meersman, E., Claeys, S. G. E. U., & D'Haeseleer, E. G. E. U. (2017). Short-term effect of two semi-occluded vocal tract training programs on the vocal quality of future occupational voice users : 'resonant voice training using nasal consonants' versus 'straw phonation'. *Journal of Speech, Language, and Hearing Research*, *60*(9), 2519-2536. https://doi.org/10.1044/2017_JSLHR-S-17-0017

Mills, R., Hays, C., Al-Ramahi, J., & Jiang, J. J. (2017). Validation and Evaluation of the Effects of Semi-Occluded Face Mask Straw Phonation Therapy Methods on Aerodynamic Parameters in Comparison to Traditional Methods. *Journal of Voice*, *31*(3), 323-328. https://doi.org/https://doi.org/10.1016/j.jvoice.2016.04.009

Mudd, P., & Noelke, C. (2018). Vocal fold nodules in children. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *26*(6), 426-430. https://doi.org/10.1097/MOO.0000000000000496

Nagle, F. (2016). Emerging Scientist: Challenges to CAPE-V as a Standard. *Perspectives of the ASHA Special Interest Groups*, *1*(3), 47-53. https://doi.org/10.1044/persp1.SIG3.47

Nuss, R. C., Ward, J., Recko, T., Huang, L., & Woodnorth, G. H. (2012). Validation of a Pediatric Vocal Fold Nodule Rating Scale Based on Digital Video Images. *Annals of Otology, Rhinology & Laryngology*, *121*(1), 1-6. https://doi.org/10.1177/000348941212100101

Oates, J. (2009). Auditory-perceptual evaluation of disordered voice quality: pros, cons and future directions. *Folia phoniatrica et logopaedica : official organ of the International Association of Logopedics and Phoniatrics (IALP)*, *61*(1), 49-56. https://doi.org/10.1159/000200768

Patel, R. R., Bless, D. M., & Thibeault, S. L. (2011). Boot Camp: A Novel Intensive Approach to Voice Therapy. *Journal of Voice*, *25*(5), 562-569. https://doi.org/https://doi.org/10.1016/j.jvoice.2010.01.010

Payten, C. L., Chiapello, G., Weir, K. A., & Madill, C. J. (2022). Frameworks, Terminology and Definitions Used for the Classification of Voice Disorders: A Scoping Review. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2022.02.009

Poburka, B. J., Patel, R. R., & Bless, D. M. (2017). Voice-Vibratory Assessment With Laryngeal Imaging (VALI) Form: Reliability of Rating Stroboscopy and High-speed Videoendoscopy. *Journal of voice : official journal of the Voice Foundation*, *31*(4), 513 e511-513 e514. https://doi.org/10.1016/j.jvoice.2016.12.003

Raes, J., Wuyts, F. L., De Bodt, M., & Clement, P. (2002). The Dysphonia Severity Index Used With a percentage scale. *Stem-, Spraak- en Taalpathologie*, *11*(1), 30-37.

Ramos, L. A., & Gama, A. C. C. (2017). Effect of Performance Time of the Semi-Occluded Vocal Tract Exercises in Dysphonic Children. *Journal of voice : official journal of the Voice Foundation*, *31*(3), 329-335. https://doi.org/10.1016/j.jvoice.2016.05.011

Reynolds, V., Buckland, A., Bailey, J., Lipscombe, J., Nathan, E., Vijayasekaran, S., Kelly, R., Maryn, Y., & French, N. (2012). Objective Assessment of Pediatric Voice Disorders With the Acoustic Voice Quality Index. *Journal of Voice*, *26*(5), 672.e671-672.e677. https://doi.org/https://doi.org/10.1016/j.jvoice.2012.02.002

Ricci-Maccarini, A., De Maio, V., Murry, T., & Schindler, A. (2013). Development and validation of the children's voice handicap index-10 (CVHI-10). *Journal of voice : official journal of the Voice Foundation*, *27*(2), 258 e223-258 e228. https://doi.org/10.1016/j.jvoice.2012.10.006

Rosenberg, D. (2014). Using Semi-Occluded Vocal Tract Exercises in Voice Therapy: The Clinician's Primer. *Perspectives on Voice and Voice Disorders*, *24*(2), 71-79. https://doi.org/10.1044/vvd24.2.71

Roy, N., Holt, K. I., Redmond, S., & Muntz, H. (2007). Behavioral characteristics of children with vocal fold nodules. *Journal of voice : official journal of the Voice Foundation*, *21*(2), 157-168. https://doi.org/10.1016/j.jvoice.2005.11.004

Salderay, Z. E., Yılmaz, M., Altınyay, Ş., Gölaç, H., & Gökdoğan, Ç. (2022). The Effect of An Indirect Voice Therapy Approach on the Voice of Children With Vocal Fold Nodules: A Prospective Cohort Study. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2022.01.001

Saltürk, Z., Özdemir, E., Sari, H., Keten, S., Kumral, T. L., Berkiten, G., Tutar, B., & Uyar, Y. (2019). Assessment of Resonant Voice Therapy in the Treatment of Vocal Fold Nodules. *Journal of Voice*, *33*(5), 810.e811-810.e814. https://doi.org/https://doi.org/10.1016/j.jvoice.2018.04.012

Sand, A. (2022). Inferential Statistics Is an Unfit Tool for Interpreting Data. *Applied Sciences*, *12*(15).

Saniasiaya, J., & Kulasegarah, J. (2020). Dysphonia and reflux in children: A systematic review. *International journal of pediatric otorhinolaryngology*, *139*. https://doi.org/10.1016/j.ijporl.2020.110473

Shah, R. K., Feldman, F., & Nuss, R. C. (2007). A grading scale for pediatric vocal fold nodules. *Otolaryngology–Head and Neck Surgery*, *136*(2), 193-197.

Silva, W. J. N. d., Lopes, L. W., Macedo, A. E. R. d., Costa, D. B. d., & Almeida, A. A. F. d. (2017). Reduction of Risk Factors in Patients with Behavioral Dysphonia After Vocal Group Therapy. *Journal of Voice*, *31*(1), 123.e115-123.e119. https://doi.org/https://doi.org/10.1016/j.jvoice.2016.01.007

Simberg, S., Sala, E., Tuomainen, J., Sellman, J., & Rönnemaa, A.-M. (2006). The Effectiveness of Group Therapy for Students With Mild Voice Disorders: A Controlled Clinical Trial. *Journal of Voice*, *20*(1), 97-109. https://doi.org/https://doi.org/10.1016/j.jvoice.2005.01.002

Singendonk, M., Goudswaard, E., Langendam, M., van Wijk, M., van Etten-Jamaludin, F., Benninga, M., & Tabbers, M. (2019). Prevalence of Gastroesophageal Reflux Disease Symptoms in Infants and

Children: A Systematic Review. *Journal of pediatric gastroenterology and nutrition*, *68*(6), 811-817. https://doi.org/10.1097/MPG.0000000000002280

Slavych, B. K., Zraick, R. I., & Ruleman, A. (2021). A Systematic Review of Voice-Related Patient-Reported Outcome Measures for Use with Adults. *Journal of voice : official journal of the Voice Foundation*. https://doi.org/10.1016/j.jvoice.2021.09.032

Smith, S. L., & Titze, I. R. (2017). Characterization of Flow-resistant Tubes Used for Semi-occluded Vocal Tract Voice Training and Therapy. *Journal of Voice*, *31*(1), 113.e111-113.e118. https://doi.org/https://doi.org/10.1016/j.jvoice.2016.04.001

Tezcaner, C. Z., Ozgursoy, S. K., Sati, I., & Dursun, G. (2009). Changes after voice therapy in objective and subjective voice measurements of pediatric patients with vocal nodules. *European Archives of Oto-Rhino-Laryngology*, *266*(12), 1923-1927.

Thibeault, S. L., Zelazny, S. K., & Cohen, S. (2009). Voice boot camp: intensive treatment success. *The ASHA Leader*, *14*(7), 26-27.

Titze, I. (2006). Voice Training and Therapy With a Semi-Occluded Vocal Tract: Rationale and Scientific Underpinnings. *Journal of speech, language, and hearing research : JSLHR*, *49*, 448-459. https://doi.org/10.1044/1092-4388(2006/035)

Titze, I. R. (1994). Mechanical stress in phonation. *Journal of Voice*, *8*(2), 99-105. https://doi.org/https://doi.org/10.1016/S0892-1997(05)80302-9

Titze, I. R., Maxfield, L., & Cox, K. T. (2022). Optimizing Diameter, Length, and Water Immersion in Flow Resistant Tube Vocalization. *Journal of Voice*. https://doi.org/https://doi.org/10.1016/j.jvoice.2022.09.029

Trajano, F. M. P., Almeida, L. N. A., de Alencar, S. A. L., Braga, J. E. F., & Almeida, A. A. (2020). Group Voice Therapy Reduces Anxiety in Patients With Dysphonia. *Journal of Voice*, *34*(5), 702-708. https://doi.org/https://doi.org/10.1016/j.jvoice.2019.03.003

Tuzuner, A., Demirci, S., Oguz, H., & Ozcan, K. M. (2017). Pediatric Vocal Fold Nodule Etiology: What Are Its Usual Causes in Children? *Journal of voice : official journal of the Voice Foundation*, *31*(4), 506 e519-506 e523. https://doi.org/10.1016/j.jvoice.2016.10.007

Van de Weijer, J., & Slis, I. (1991). Nasaliteitsmeting met de nasometer. *Logopedie en Foniatrie*, *63*, 97-101.

Van Stan, J. H., Roy, N., Awan, S., Stemple, J., & Hillman, R. E. (2015). A taxonomy of voice therapy. *American journal of speech-language pathology*, *24*(2), 101-125. https://doi.org/10.1044/2015_AJSLP-14-0030

Veder, L., Pullens, B., Timmerman, M., Hoeve, H., Joosten, K., & Hakkesteegt, M. (2017). Reliability and validity of the Dutch pediatric Voice Handicap Index. *International journal of pediatric otorhinolaryngology*, *96*, 15-20. https://doi.org/10.1016/j.ijporl.2017.02.023

Wenke, R., Coman, L., Walton, C., Madill, C., Theodoros, D., Bishop, C., Stabler, P., Lawrie, M., O'Neill, J., Gray, H., & Cardell, E. A. (2023). Effectiveness of Intensive Voice Therapy Versus Weekly Therapy for Muscle Tension Dysphonia: A Noninferiority Randomised Controlled Trial With Nested Focus Group. *Journal of Voice*, *37*(3), 466.e417-466.e434. https://doi.org/https://doi.org/10.1016/j.jvoice.2021.02.011

Wenke, R. J., Stabler, P., Walton, C., Coman, L., Lawrie, M., O'Neill, J., Theodoros, D., & Cardell, E. (2014). Is More Intensive Better? Client and Service Provider Outcomes for Intensive Versus Standard Therapy Schedules for Functional Voice Disorders. *Journal of Voice*, *28*(5), 652.e631-652.e643. https://doi.org/https://doi.org/10.1016/j.jvoice.2014.02.005

Wu, S. S., Ongkasuwan, J., Anne, S., & Appachi, S. (2023). Voice outcomes following surgical treatment for pediatric vocal fold nodules: A systematic review and meta-analysis. *International journal of pediatric otorhinolaryngology*, *166*, 111461. https://doi.org/https://doi.org/10.1016/j.ijporl.2023.111461

Wuyts, F. L., De Bodt, M. U., Molenberghs, G., Remacle, M., Heylen, L., Millet, B., Van Lierde, K. G. E. U. X., Raes, J., & Van de Heyning, P. H. (2000). The dysphonia severity index : an objective measure of vocal quality based on a multiparameter approach. *(2000) JOURNAL OF SPEECH LANGUAGE AND HEARING RESEARCH*. http://lib.ugent.be/catalog/pug01:171621

Yilmaz, M. D., Eyigör, H., Osma, U., Selcuk, Ö., Renda, L., Pırtık, I., & Yalcin, A. (2016). Prevalence of Allergy in Patients with Benign Lesions of Vocal Folds. *Acta Medica Mediterranea*, *32*, 195-201. https://doi.org/10.19193/0393-6384_2016_1_30

Zraick Richard, I., Kempster Gail, B., Connor Nadine, P., Thibeault, S., Klaben Bernice, K., Bursac, Z., Thrush Carol, R., & Glaze Leslie, E. (2011). Establishing Validity of the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V). *American journal of speech-language pathology*, *20*(1), 14-22. https://doi.org/10.1044/1058-0360(2010/09-0105)

Tables and figures

Table 1: Pretherapy demographic characteristics, therapy history, vocal symptoms, and risk factors in the SP group, RVT group, and CG

Abbreviations: SP, straw phonation; RVT, resonant voice therapy; CG, control group; SD, standard deviation

Table 2: Pretherapy parameters regarding laryngeal anatomy and function

Abbreviations: SP, straw phonation; RVT, resonant voice therapy; CG, control group; SD, standard deviation

Figure 1: Evolution of the mean DSI in the three groups

Figure 2: Evolution of the mean AVQI in the three groups

Figure 3: Evolution of the mean pVHI in the three groups

Figure 4: Evolution of the mean perceptual rating of overall severity in the three groups

Table 3: Evolution pre- to posttherapy in the SP group, RVT group, and CG

Abbreviations: EM, estimated mean; CI, confidence interval; EMD, estimated mean difference; DSI, dysphonia severity index; AVQI, acoustic voice quality index; pVHI, pediatric voice handicap index; SP, straw phonation; RVT, resonant voice therapy; CG, control group

Figure 5: Results for Dysphonia Severity Index (DSI) for individual participants grouped according to improvement, no change, or deterioration in outcome following each type of intervention

Abbreviations: SP, straw phonation; RVT, resonant voice therapy; CG, control group; DSI, dysphonia severity index

Figure 6: Results for Acoustic Voice Quality Index (AVQI) for individual participants grouped according to improvement, no change, or deterioration in outcome following each type of intervention

Abbreviations: SP, straw phonation; RVT, resonant voice therapy; CG, control group; AVQI: acoustic voice quality index

Appendices

Appendix A: Detailed overview of the therapy content in the three intervention groups