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META-ANALYSIS

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The maximum phonation time as marker for voice treatment efficacy: A network meta-analysis

Ben Barsties v. Latoszek[1] | **Christopher R. Watts**[2] | **Katharina Schwan**[1] | **Svetlana Hetjens**[3]

[1]Speech-Language Pathology, SRH University of Applied Health Sciences, Düsseldorf, Germany

[2]Harris College of Nursing & Health Sciences, Texas Christian University, Fort Worth, Texas, USA

[3]Department of Statistics, Medical Faculty Mannheim, University of Heidelberg, Mannheim, Germany

Correspondence
Ben Barsties v. Latoszek, Speech-Language Pathology, SRH University of Applied Health Sciences, Graf-Adolf-Straße 67, 40210 Düsseldorf, Germany.
Email: benjamin.barstiesvonlatoszek@srh.de

Abstract

Purpose: There is a diversity in treatment approaches for voice therapy in which aerodynamic treatment effects between the approaches are lacking. The evidence of voice treatments on the maximum phonation time (MPT) was quantified using the statistical approach of a network meta-analysis (NMA).

Data Sources: Three databases and manual search from inception to November 2021 were evaluated.

Study Selection: Studies were considered which were reports of randomised controlled/clinical trials (RCT) evaluating the efficacy of a specific voice therapy treatment using MPT as an outcome measure in adult participants with voice disorders. Studies were excluded if participants had been diagnosed with neurological-motor-speech disorders or who were vocally healthy. Furthermore, no medical, pharmacological, or technical instrumental treatments were used.

Data Extraction and Synthesis: Preferred Reporting Items for systematic reviews and meta-analyses extension statement guidelines were followed. Two reviewers independently screened citations, extracted data, and assessed risk of bias using PEDro scale. Random effects model was used for meta-analysis.

Results: We identified finally 12 RCT studies (treatment groups $n = 285$, and control group without an intervention $n = 62$). Eight interventions were evaluated. The only effective intervention with a significant effect was vocal function exercises (VFE) (mean pre–post difference 6.16 s, 95% confidence interval, 1.18–11.13 s).

Conclusions and Relevance: VFE effectively improved MPT from pre- to post-treatment in comparison with other voice interventions which were identified in the present NMA. Further high-quality intervention studies with large samples sizes, multidimensional measures, and homogeneous groups of dysphonia are needed to support evidence-based practice in laryngology.

KEYWORDS
dysphonia, maximum phonation time, meta-analysis, systematic review, voice treatment

1 | INTRODUCTION

A comprehensive clinical voice assessment examines the processes involved in phonation, including laryngeal imaging analysis, auditory-perceptual judgement, aerodynamic analysis, acoustic analysis, and self-assessment.[1,2] These multidimensional measures are also acquired to assess pre-to-post treatment changes. The clinical application of aerodynamic measures such as mean airflow, estimates of subglottal pressure, and temporal phonation measures (e.g., maximum phonation time, or MPT) are supported by a strong evidence base. Aerodynamic parameters provide valuable information about the interaction between respiratory and phonatory mechanisms of speech with a detailed view of the underlying physiology of phonation, the degree of effort required for voicing, and compensatory behaviours used by patients with voice disorders.[3]

MPT is considered an aerodynamic assessment which measures glottal efficiency by estimating the ability to control the pulmonary aerodynamic forces and the myoelastic forces of the larynx.[4] For MPT performance, the patient must sustain a vowel (e.g., /a/) after maximum inhalation for as long as possible, in which the total sound duration is measured in seconds. To be able to phonate a steady tone for a long time, healthy lung function along with adequate lung capacity and flow velocity of the air is a pre-requisite.[4] The alignment of subglottic pressure and glottal resistance is also crucial for sustained phonation over time. If the MPT duration is low, it is assumed that the dosage of breathing is difficult or that the glottal resistance, depending on the laryngeal pathology, is too low, which might have consequences in voice quality (e.g., a breathy voice).[5] Further influencing factors on MPT score include the number of trials,[6–8] gender,[6,9] and body mass index.[9]

MPT is a measure which is often used in voice assessments due to its non-invasiveness, fast feasibility, and low cost.[7] In addition, MPT has been used to objectify the degree of severity of dysphonia,[10] and to determine the effects of voice treatments.[11] Voice treatment is considered effective using MPT if the duration post-treatment is at least 1.41 s longer than the pre-treatment score.[12] With regard to a test–retest procedure in vocally-healthy participants, an extension of the MPT duration can also be expected at 1.01 s.[3]

Dysphonia arises from many aetiologies.[13,14] These determine the primary treatment approach, which may include behavioural voice treatment,[11,15–17] phonosurgery,[18,19] and/or pharmacological therapy.[20] Successful behavioural voice treatment depends on various factors. The underlying aetiology (e.g., neuropathologic, emotional, improper vocal habits, and structural pathology), the maintaining factors, patient motivation, the treatment approach, and the skill of the clinician are all factors that can influence treatment outcomes. There are many behavioural voice treatment approaches available to a voice clinician. To compare more than two treatments in a single analysis a statistical approach of a network meta-analysis (NMA) can be utilised. NMA is an extension of pairwise meta-analysis to compare three or more treatments for a given medical or healthcare condition, based on combining information from multiple existing comparisons among subsets of the treatments.[21] This statistical method of a meta-analysis can effectively compare the efficacy of voice treatments using the same outcome parameters and study designs.

Key points

- Various voice treatments were compared using maximum phonation time as marker for voice treatment efficacy.
- This is the second network meta-analysis on the treatment efficacy of dysphonia next to the evaluation of the voice-related handicap.
- One from eight voice treatments resulted in a significant improvement of maximum phonation time.
- Vocal function exercises have been identified in the present network meta-analysis as the only effective intervention.
- Vocal function exercises were evaluated in two network meta-analyses as effective in eliciting clinically significant treatment changes in voice handicap index and maximum phonation time.

A prior NMA for voice treatments investigated the outcome measure of voice-related handicap based on the voice handicap index (VHI).[17] That study was able to combine data from 13 randomised controlled and clinical trials (RCT) which collectively studied the effect of nine different treatment approaches on self-perceived VHI measures. Of those nine interventions, four were found to effectively improve VHI measures (e.g., at greater than chance levels based on meta-analysis statistics) from pre-to-post therapy. The analysis of pooled data via the NMA design provided high-quality evidence.

The purpose of this meta-analysis was to apply a NMA focused on RCTs evaluating the efficacy of voice treatment approaches on measures of MPT. As with our prior study, we also sought to establish an effectiveness ranking for different voice treatment approaches. By extending knowledge of the response of MPT to treatment approaches through a NMA design, clinicians may be better informed of the potential differential effectiveness of varied treatment approaches for a given voice disorder. This information may also help to interpret future clinical studies which include MPT as an outcome variable. As with our previous NMA investigating treatment effects on VHI, MPT is also a common outcome measures in clinical practice and clinical research, and justification for its use through investigation using high-quality research designs such as NMA is needed.

2 | METHODS

2.1 | Data sources and searches

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) extension statements for reporting of systematic reviews incorporating NMA of healthcare treatments was used to perform a systematic literature search in electronic databases.[22] The

MEDLINE, CENTRAL, and Speechbite electronic databases were searched from inception to November 19, 2021. Meaningful papers were identified by title and abstract. In addition, references were also reviewed in potential articles. The following search terms were used to identify the potential studies: voice disorders, dysphonia, voice therapy, voice treatment, and maximum phonation time.

2.2 | Study selection

Potential studies were included which evaluated in a RCT design a specific voice treatment approach with (a) comparisons between types of treatments or (b) control group without an intervention. Additionally, treatment efficacy was measured with the outcome parameter of MPT in adults who had voice disorders in a pre–post treatment design. MPT as a clinically significant outcome parameter for treatment efficacy has been benchmarked at 1.01–1.41 s for pre-to-post treatment comparisons.[3,12] Meaningful studies had to report the number of participants in the groups, pre- and post-treatment results of the mean and standard deviation (SD) or *p*-values. Finally, English and German languages were considered for the papers.

Papers that examining the efficacy of voice treatments in participants with a neurological motor speech disorders or in vocally healthy participants were excluded. The use of medical or pharmacological treatments were also excluded. In addition, studies were excluded if they did not provide proper explanations of the voice treatment approaches or if the voice therapy procedure did not include a primary single approach. Lastly, interventions that included technical instruments in the application of voice treatment were excluded as well.

2.3 | Data extraction and risk of bias assessment

Two researchers (BBvL and KS) independently screened titles and abstracts. Full-text articles were then reviewed in duplicate and disagreements resolved by discussion together. We extracted data about: details of study design, types of voice disorder, description of voice treatment intervention, description of comparison group, completeness of outcome data, outcome measure of maximum phonation time, and statistics. If not reported, study authors were contacted. We assessed the risk of bias of the included studies using the PEDro scale. The PEDro scale is an 10-item scale for assessing the methodological quality of RCT studies. The total score of the PEDro scale ranges from 0 to 10 points.[23] A score of 9–10 corresponds to excellent methodological quality, a score of six to eight to good quality, and a score of four to 5 to low quality. To assess the quality of studies, the PEDro scale considers the following factors: inclusion and exclusion criteria, randomised and concealed assignment of groups, association of all study participants and investigators, key outcome parameters, and statistical group comparisons.[23]

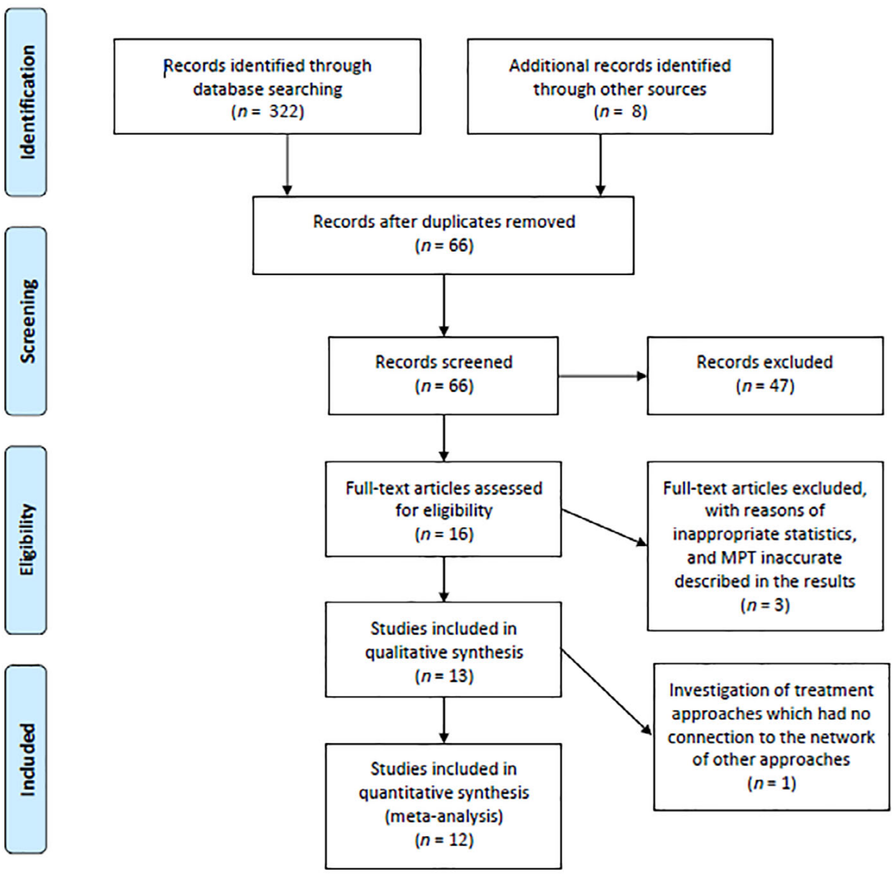

FIGURE 1 Course of study selection for the meta-analysis

TABLE 1 Characteristics of RCTs included in the NMA

Study ID	Participants	Primary single interventions (number of participants of each group; duration of treatment in weeks)	Outcome measures
Bassiouny[27]	42 voice-disordered participants with heterogeneous voice disorder	1. AM (21; 10) 2. VH (21; 2)	1. Perceptual Judgement (GRBAS) 2. Laryngeal stroboscopic findings 3. Aerodynamic (MPT, PQ, MFR, PSub) 4. Acoustic (pitch, intensity, Jit, Shim, HNR)
Pasa et al.[28]	37 teachers with a beginning to develop voice disorders related to voice symptoms and vocal misuse behaviours	1. VFE (10; 6) 2. VH (13; 6) 3. No intervention (14; 6)	1. Self-evaluation (demographic, voice knowledge, vocal misuse behaviour, vocal symptoms) 2. Aerodynamic (MPT) 3. Acoustic (frequency range)
Tay et al.[29]	22 participants with presbyphonia	1. VFE (11; 5) 2. No intervention (11; 5)	1. Perceptual Judgement (PVP) 2. Aerodynamic (MPT) 3. Acoustic (frequency range, Jit, Shim, NHR) 4. Self-evaluation (self-report questionnaire)
Kaneko et al.[30]	22 participants with presbyphonia and vocal athropy	1. VFE (16; 8) 2. No intervention (6; 8)	1. Perceptual Judgement (GRBAS) 2. Laryngeal stroboscopic findings 3. Aerodynamic (MFR, MPT) 4. Acoustic (frequency range, intensity, Jit, Shim, NHR) 5. Self-evaluation (VHI)
Watts et al.[31]	20 participants with non-organic voice disorders	1. SFP (10; 6) 2. VH (10; 6)	1. Self-evaluation (VHI) 2. Acoustic (CPP) 3. Aerodynamic (MPT, S/Z Ratio)
Tsai et al.[32]	29 medical professionals with self-perceived voice disorders	1. ABS (15; 5) 2. No intervention (14; 5)	1. Self-evaluation (self-awareness of vocal symptoms) 2. Aerodynamics (MPT, S/Z Ratio, MEP, pulmonary function test)
Kao et al.[33]	19 participants with unilateral adductor vocal fold paralysis within 6 months of initial diagnosis	1. VFE (10; 12.4) 2. VH (9; 12.4)	1. Self-evaluation (VHI) 2. Laryngeal stroboscopic findings 3. Perceptual judgement (CAPE-V) 4. Acoustic (Jit, Shim, NHR) 5. Aerodynamic (MPT, PQ, PTP)
La Mantia et al.[34]	19 subjects with primary laryngeal cancer treated with curatively intended radiotherapy	1. VFE (10; 6) 2. VH (10; 6)	1. Self-evaluation (VHI, EORTC QLQ-H&N35) 2. Laryngeal stroboscopic findings with high-speed parameters 3. Perceptual judgement (GRBAS) 4. Acoustic (Jit, Shim) 5. Aerodynamic (MPT, MFR)
Angadi et al.[35]	19 subjects with primary laryngeal cancer treated with curatively intended radiotherapy	1. VFE (6; 6) 2. VH (4; 6)	1. Self-evaluation (VHI) 2. Perceptual judgement (CAPE-V) 3. Aerodynamic (MPT, PSub) 4. Acoustic (frequency range) 5. Laryngeal stroboscopic findings with high-speed parameters
Tang et al.[36]	52 participants with unilateral vocal fold paralysis within 6 months of initial diagnosis	1. LQG (26; 2) 2. ABS (26; 2)	1. Aerodynamic (MPT) 2. Acoustic (Jit, Shim, NNE) 3. Perceptual judgement (GRBAS) 4. Self-evaluation (VHI, HADS)
Liu et al.[37]	34 teachers with self-perceived voice disorders	1. RV (16; 5) 2. VH (18; 2)	1. Aerodynamic (MPT) 2. Acoustic (Jit, Shim, HNR, SCR, NEDR, VTC) 3. Perceptual judgement (GRBAS) 4. Self-evaluation (VHI)
Christmann et al.[38]	41 teachers with heterogeneous voice disorders	1. FK (24; 3) 2. No intervention (17; 3)	1. Aerodynamic (MPT, S/Z Ratio) 2. Acoustic (intensity range, modal intensity)

Abbreviations: ABS, abdominal breathing support; AM, accent method, CAPE-V, consensus auditory-perceptual evaluation of voice; CPP, cepstral peak prominence; EORTC QLQ-H&N35, health-related quality of life questionnaire head and neck module; FK, finger kazoo; GRBAS, grade-roughness-breathiness-asthenia-strain scale; HADS, hospital anxiety and depression scale; HNR, harmonics to noise ratio; Jit, jitter; LQG, liuzijue qigong; MEP, maximal expiratory pressure; MFR, mean flow rate; MPT, maximum phonation time; NNE, normalised noise energy; NEDR, nonlinear energy difference ratio; NHR, noise to harmonics ratio; PTP, phonation threshold pressure; PQ, phonation quotient; PSub, subglottal pressure; PVP, perceptual voice profile; RV, resonant voice; SCR, spectrum convergence ratio; SFP, stretch-and-flow phonation; Shim, shimmer; S/Z ratio, ratio of the durations for which a person can sustain the sounds 's' and 'z'; VFE, vocal function exercises; VH, vocal hygiene; VHI, voice handicap index; VTC, voice type component.

TABLE 2 PEDro assessment of methodologic quality of included studies

Score	Bassiouny (1998)	Pasa et al. (2007)	Tay et al. (2012)	Kaneko et al. (2014)	Watts et al. (2015)	Tsai et al. (2016)	Kao et al. (2017)	La Mantia et al. (2018)	Angadi et al. (2019)	Tang et al. (2019)	Liu et al. (2020)	Christmann et al. (2021)
1	0	1	1	0	1	1	1	1	1	1	1	1
2	1	1	1	0	1	1	1	1	1	1	1	1
3	0	0	0	0	0	0	0	0	1	0	0	1
4	1	0	1	1	1	1	1	1	0	1	1	1
5	0	0	0	0	0	0	0	0	1	0	0	1
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	1	1	0	1	0
8	1	1	1	1	1	1	1	1	1	1	1	0
9	1	1	1	1	1	0	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
Result	5 of 10	5 of 10	6 of 10	4 of 10	6 of 10	5 of 10	7 of 10	7 of 10	8 of 10	6 of 10	7 of 10	7 of 10

2.4 | Statistical analysis

The mean differences of the pre–post treatment (MD) and SD results of the MPT values for each treatment arm were extracted from each study. When standard deviations were lacking, the *p* values of the pre–post MD were used to calculate them. For random-effects NMA, the R package netmeta from the open statistical programming environment R was used.[24,25] Results were demonstrated as MD between pre–post outcomes with 95% confidence intervals (CI). In addition, the ranking of interventions was related on the *p* score variable. This is a critical ranking score that can be viewed as a frequentist analogue to the area under the Bayesian cumulative ranking curve, without the need for resampling methods.[26] It is an easy analytic method based on frequentist point estimates and their standard errors. *p*-scores result in a ranking on a scale from 0 to 1, with 0 being the worst and 1 being the best. This *p*-score can be interpreted as a measure of the mean level of confidence that a treatment is better than a comparable treatment. Results for the comparison with the control group are shown in the forest plot. This was created with the R package meta-for. The mean difference is presented with the 95% confidence interval, as well as the *p*-score.

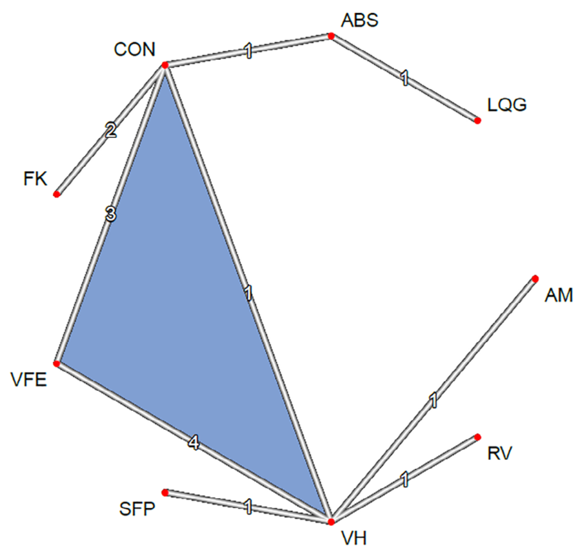

FIGURE 2 Network graph with focus on the comparison of the control group and different voice treatments (seven interventions compared with the control group by direct estimates and eight interventions compared with the control group by indirect estimates) from a multiple pairwise meta-analysis. Coloured polygons represent multi- arm studies (dark blue = three-arm study). ABS, abdominal breathing support; AM, accent method; CON, control group; FK, finger kazoo; LQG, liuzijue qigong; RV, resonant voice; SFP, stretch-and-flow phonation; VFE, vocal function exercises; VH, vocal hygiene

3 | RESULTS

3.1 | Study characteristics

The selection of papers for this meta-analysis is presented in the PRISMA chart (Figure 1). The study characteristics of the included RCT's are presented in Table 1. Finally, 12 studies were included in which 285 participants were in treatment groups and 62 participants were in control groups. The intervention groups ranged from 4 to 26 participants and the control groups from 6 to 14 participants. The statistical approach of the NMA collapses all control participants into one group and compares that data set to treatment group data from the individual studies. The control group considered participants with dysphonia without any intervention. Totally, eight voice treatment approaches were considered: abdominal breathing support (ABS), accent method (AM), finger kazoo (FK), liuzijue qigong (LQG), resonant voice (RV), stretch-and-flow phonation (SFP), vocal hygiene (VH), and vocal function exercises (VFE). The risk of bias showed for the 12 included studies that eight had a good quality and four revealed a fair quality (see Table 2).

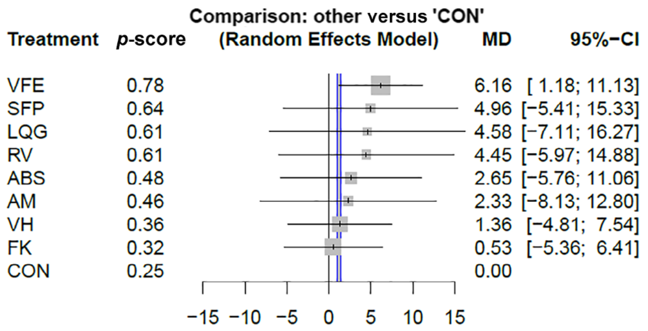

FIGURE 3 Forest plot representing the treatment effect sizes of the maximum phonation time by specific interventions in comparison with the control group sorted at the order of treatment rankings of the *p*-score. The grey area between the two blue lines represents the equivalence region for the MPT score at 1.01 –1.41 s. ABS, abdominal breathing support; AM, accent method; CI, confidence interval; CON, control group; FK, finger kazoo; MD, mean differences; LQG, liuzijue qigong; RV, resonant voice; SFP, stretch-and-flow phonation; VFE, vocal function exercises; VH, vocal hygiene

The comparisons of pairs from the eight interventions and control groups are illustrated in Figure 2. The red circles in the network graph mark voice treatments which were investigated in the included RCTs. The line connection represents the different voice treatments with each other which were in a direct examination comparison. The numbers reflect the number of included studies for these comparisons.

3.2 | Efficacy of voice treatment methods

There is a high heterogeneity in the results of NMA ($I^2 = 81.8\%$) and Figure 3 shows the forest plot. VFE manifested as the only intervention with significant outcome effects on measures of MPT as evidenced by CI which did not cross the null line in the forest plot (see Figure 3). VFE also demonstrated mean differences of the pre–post treatment above the threshold of clinical relevance (MD = 6.16 s, 95% CI = 1.18–11.13 s). According to the *p*-score ranking, VFE resulted in the strongest outcome (*p*-score = .78) that markedly exceeded all other values (see Figure 3).

4 | DISCUSSION

This present NMA is the second of its kind to evaluate the treatment efficacy of voice treatment approaches in voice-disordered participants investigated in RCT study designs. Both network meta-analyses generally reported a low risk of bias for included studies. The prior NMA investigated the VHI as primary outcome parameter, which is a common used voice parameter measuring the impact from the view of the patient.[17] In that prior study, stretch-and-flow phonation revealed significant and clinically relevant treatment outcomes. This intervention ranked as the superior voice treatment across all other treatments, but RV, comprehensive voice rehabilitation program, and VFE approaches demonstrated statistically significant improvements on VHI score, as well.[17] Three of these four relevant voice treatments were included in the present NMA with the objective aerodynamic primary outcome parameter of MPT as well. However, VFE was the only treatment approach confirmed to yield significant improvement in MPT compared to other voice treatment interventions. Thus, two NMA studies have found VFE to be effective in eliciting clinically significant pre-to-post treatment changes in measures of VHI and MPT.

VFE as a treatment approach utilises four core exercises that were designed to strengthen and balance the laryngeal musculature and to calibrate airflow with muscular effort.[39] The treatment stimuli consist of multiple repetitions of a nasal vowel /i/ (exercise #1) or modified vowel /o/ phonation—called lip buzz (exercise #2 to 4), in which maximal sustained phonation is trained in exercises #1 and #4.[40] As such, VFE can be characterised as adhering to the specify principle for motor learning when relating these exercises to measures of MPT. That is, two of the four VFE exercises require maximum sustained phonation. VFE is a physiologic vocal treatment concept that strive to improve the strength, balance, and stamina of laryngeal muscles under consideration of improving the balance among laryngeal muscle effort, respiratory effort and control, and the supraglottic placement of the tone.[39]

A previous meta-analysis of VFE[16] showed comparable results to the present NMA in MPT mean improvements. In this previous meta-analysis seven studies with different study designs were included for the effect size calculation.[16] These two meta-analyses indicated high treatment efficacy when considering the outcome parameter of MPT, where treatment success can be expected in patients with heterogeneous voice disorders.

An explanation of the weak performance of the other seven voice treatment approaches analysed in this study could be that, unlike VFE, they did not specifically target maximum sustained phonation. In the VFE approach MPT is an essential ingredient, where patients control their voice production (in exercises # 1 and #4) by eliciting a prolonged vowel for as long as possible. Particularly, in exercise #4 ('power') the patient is asked to produce up to five different pitches on sustained phonation for as long as possible. Given the typical requirement for 'homework' productions of two sets repeated twice daily over the course of treatment, one can see that the dosage of VFE and the specificity for maximum sustained phonation in exercises #1 and #4 can yield improvement in measures of MPT.[41] Treatment effects for efficient glottal closure at low lung volumes in the absence of hyperfunction have been demonstrated at 3 weeks for VFE intervention, which may help to explain the physiological strategies patients have used to improve MPT measures.[42] To summarise, reports suggest that VFE treatment has an effect on measures of MPT by increasing the power of inspiratory muscles and by increasing muscular coordination, strength, and endurance during exhalation than other voice treatment methods.

4.1 | Limitations and future directions

The caveats of the present meta-analysis relate to the generalizability of the results, but also provide direction for future research.

First, a high heterogeneity of studies in the present NMA was measured ($I^2 = 81.8\%$). It could be explained through publication bias and selection biases across studies regarding (a) types and severity of dysphonia and (b) differences in responsiveness for different voice disorders of the MPT. Publication bias was not explicitly tested statistically, but overall a low number of participants were included in the treatment groups, which could explain the high 95% CI in the forest plots. The treatment duration was mostly 6 weeks with extremes of 2 weeks[27,36,37] to 12.4 weeks.[33] However, the nearly all evaluated interventions in the present study required a lower duration for intervention than an unspecified voice treatment which had an average of 9.25 weeks.[43]

Second, for the diagnosis of voice disorders as well as the evaluation of treatment outcomes, multidimensional assessments are required.[1,2] Therefore, a standardised battery of voice measurements or adherence to already established standards is important both for the delivery of voice treatments and for high-quality comparative studies of the outcome of different voice treatments.[17] Recommended protocols may consider for voice measurements: (1) laryngeal imaging,[1,2,44] (2) auditory-perceptual judgement of voice quality,[1,2] (3) acoustics,[1,2,44] (4) aerodynamics,[1,2,44] and (5) self-evaluation.[1,2]

Third, many voice treatment approaches were not considered in the present study, although they may have been considered in prior systematic reviews or surveys on voice treatment.[11,12,15,17,40,45] Reasons for exclusion were based primarily on the lack of RCT design, where studies used other voice treatment outcomes than MPT, or dropped important statistical data for a NMA.

Fourth, the search strategy for relevant papers for this present study was conducted in two languages. Other languages such as Asian languages, Spanish, or French were omitted, which could also contain potentially relevant publications.

Fifth, further studies are needed to evaluate voice treatments for homogeneous groups of dysphonia. This meta-analysis has considered organic and non-organic voice disorders in a fairly balanced proportion. However, there is a high diversity between the numerous types of voice disorders and severity of dysphonia that may vary considerably the performance of the MPT. Evaluating the treatment effects of specific approaches for other voice disorders generally encountered in clinical practice, for example laryngitis, vocal fold nodules, vocal fold polyps, vocal fold oedema, vocal fold cyst, vocal fold paralysis, leucoplakia, carcinoma, and muscle tension dysphonia.[13,14]

Sixth, the assessment of intensity and frequency of voice treatment approaches should be further explored, as treatment dose issues are poorly understood in the voice treatment literature.

5 | CONCLUSION

This NMA reported here provides evidence that VFE was effective in improving MPT. The effect on MPT showed in other voice treatment approaches no significant or clinically relevant treatment effects. Thus, the presented NMA reduced the number of effective interventions from a larger pool of voice treatment approaches based on an aerodynamic analysis, when MPT is being utilised as a clinical outcome measure. Otherwise, these findings may be especially useful for clinicians using diverse therapies to treat dysphonia to better assess method-specific expectations for improvement in aerodynamic measurements after MPT. Finally, the present study highlights that further contributions of high-quality intervention studies are needed to support clinical practice in laryngology.

AUTHOR CONTRIBUTIONS

Concept and design: all authors. Acquisition, analysis, or interpretation of data: BBvL and KS. Drafting of the manuscript: BBvL and CRW. Critical revision of the manuscript for important intellectual content: all authors. Statistical analysis: SH.

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None.

CONFLICT OF INTEREST

None.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/coa.14019.

DATA AVAILABILITY STATEMENT

Data may be made available on request.

ETHICS STATEMENT

There is no ethic statement given the type of study (meta analysis), which does not require ethic committee.

ORCID

Ben Barsties v. Latoszek https://orcid.org/0000-0002-0086-8163

REFERENCES

1. Dejonckere PH, Bradley P, Clemente P, Cornut G, Crevier-Buchman L, Friedrich G, et al. A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). Eur Arch Otorhinolaryngol. 2001;258:77–82. https://doi.org/10.1007/s004050000299
2. Boominathan P, Samuel J, Arunachalam R, Nagarajan R, Mahalingam S. Multi parametric voice assessment: Sri Ramachandra university protocol. Indian J Otolaryngol Head Neck Surg. 2014;66:246–51. https://doi.org/10.1007/s12070-011-0460-y
3. Awan SN, Novaleski CK, Yingling JR. Test-retest reliability for aerodynamic measures of voice. J Voice. 2013;27:674–84. https://doi.org/10.1016/j.jvoice.2013.07.002
4. Solomon NP, Garlitz SJ, Milbrath RL. Respiratory and laryngeal contributions to maximum phonation duration. J Voice. 2000;14:331–40. https://doi.org/10.1016/s0892-1997(00)80079-x
5. Barsties B, De Bodt M. Assessment of voice quality: current state-of-the-art. Auris Nasus Larynx. 2015;42:183–8. https://doi.org/10.1016/j.anl.2014.11.001
6. Cunha LJ, Pereira EC, Ribeiro VV, Dassie-Leite AP. Influence of the body position and emission number in the results of the maximum

phonation times of adults without vocal complaints. J Voice. 2019;33: 831–7. https://doi.org/10.1016/j.jvoice.2018.05.010
7. Speyer R, Bogaardt HC, Passos VL, et al. Maximum phonation time: variability and reliability. J Voice. 2010;24:281–4. https://doi.org/10.1016/j.jvoice.2008.10.004
8. Johnson AM, Goldfine A. Intrasubject reliability of maximum phonation time. J Voice. 2016;30:775.e1–4. https://doi.org/10.1016/j.jvoice.2015.11.019
9. Al-Yahya SN, Mohamed Akram MHH, Vijaya Kumar K, et al. Maximum phonation time normative values among Malaysians and its relation to body mass index. J Voice. 2022;36:457–63. https://doi.org/10.1016/j.jvoice.2020.07.015
10. Sobol M, Sielska-Badurek EM. The dysphonia severity index (DSI)-normative values. Systematic review and meta-analysis. J Voice. 2022;36:143.e9–143.e13. https://doi.org/10.1016/j.jvoice.2020.04.010
11. Speyer R. Effects of voice therapy: a systematic review. J Voice. 2008;22:565–80. https://doi.org/10.1016/j.jvoice.2006.10.005
12. Rodríguez-Parra MJ, Adrián JA, Casado JC. Voice therapy used to test a basic protocol for multidimensional assessment of dysphonia. J Voice. 2009;23:304–18. https://doi.org/10.1016/j.jvoice.2007.05.001
13. De Bodt M, Van den Steen L, Mertens F, et al. Characteristics of a dysphonic population referred for voice assessment and/or voice therapy. Folia Phoniatr Logop. 2015;67:178–86. https://doi.org/10.1159/000369339
14. Martins RH, do Amaral HA, Tavares EL, et al. Voice disorders: etiology and diagnosis. J Voice. 2016;30:761.e1–9. https://doi.org/10.1016/j.jvoice.2015.09.017
15. Desjardins M, Halstead L, Cooke M, Bonilha HS. A systematic review of voice therapy: what "effectiveness" really implies. J Voice. 2017; 31:392.e13–32. https://doi.org/10.1016/j.jvoice.2016.10.002
16. Angadi V, Croake D, Stemple J. Effects of vocal function exercises: a systematic review. J Voice. 2019;33:124.e13–34. https://doi.org/10.1016/j.jvoice.2017.08.031
17. Barsties V, Latoszek B, Watts CR, Neumann K. The effectiveness of voice therapy on voice-related handicap: a network meta-analysis. Clin Otolaryngol. 2020;45:796–804. https://doi.org/10.1111/coa.13596
18. Sataloff RT, Hawkshaw MJ, Divi V, Heman-Ackah YD. Voice surgery. Otolaryngol Clin North Am. 2007;40:1151–83. https://doi.org/10.1016/j.otc.2007.05.015
19. Reiter R, Hoffmann T. Phonomicrosurgery––a retrospective analysis of 400 cases. Laryngorhinootologie. 2017;96:597–606. https://doi.org/10.1055/s-0043-110859
20. Schönweiler R. An update of medication in voice treatment and side effects on voice relating to medication. Sprache-Stimme-Gehör. 2020;44:23–8. https://doi.org/10.1055/a-0949-7081
21. Salanti G. Indirect and mixed-treatment comparison, network, or multiple-treatments meta-analysis: many names, many benefits, many concerns for the next generation evidence synthesis tool. Res Synth Methods. 2012;3:80–97. https://doi.org/10.1002/jrsm.1037
22. Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Ann Intern Med. 2015; 162:777–84. https://doi.org/10.7326/M14-2385
23. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003;83:713–21. https://doi.org/10.1093/ptj/83.8.713
24. Rücker G, Krahn U, König J, Efthimiou O, Schwarzer G. netmeta: network meta-analysis using frequentist methods. 2019 Accessed 26 November 2019, https://github.com/guido-s/netmeta http://meta-analysis-with-r.org.
25. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2019. Accessed 26 November 2019, https://www.R-project.org/
26. Rücker G, Schwarzer G. Ranking treatments in frequentist network meta-analysis works without resampling methods. BMC Med Res Methodol. 2015;15:58. https://doi.org/10.1186/s12874-015-0060-8
27. Bassiouny S. Efficacy of the accent method of voice therapy. Folia Phoniatr Logop. 1998;50:146–64. https://doi.org/10.1159/000021458
28. Pasa G, Oates J, Dacakis G. The relative effectiveness of vocal hygiene training and vocal function exercises in preventing voice disorders in primary school teachers. Logoped Phoniatr Vocol. 2007;32: 128–40. https://doi.org/10.1080/14015430701207774
29. Tay EY, Phyland DJ, Oates J. The effect of vocal function exercises on the voices of aging community choral singers. J Voice. 2012;26: 672.e19–27. https://doi.org/10.1016/j.jvoice.2011.12.014
30. Kaneko M, Hirano S, Tateya I, Kishimoto Y, Hiwatashi N, Fujiu-Kurachi M, et al. Multidimensional analysis on the effect of vocal function exercises on aged vocal fold atrophy. J Voice. 2015; 29:638–44. https://doi.org/10.1016/j.jvoice.2014.10.017
31. Watts CR, Hamilton A, Toles L, Childs L, Mau T. A randomized controlled trial of stretch-and-flow voice therapy for muscle tension dysphonia. Laryngoscope. 2015;125:1420–5. https://doi.org/10.1002/lary.25155
32. Tsai YC, Huang S, Che WC, Huang YC, Liou TH, Kuo YC. The effects of expiratory muscle strength training on voice and associated factors in medical professionals with voice disorders. J Voice. 2016;30:759.e21–7. https://doi.org/10.1016/j.jvoice.2015.09.012
33. Kao YC, Chen SH, Wang YT, Chu PY, Tan CT, Chang WZD. Efficacy of voice therapy for patients with early unilateral adductor vocal fold paralysis. J Voice. 2017;31:567–75. https://doi.org/10.1016/j.jvoice.2017.01.007
34. La Mantia I, Cupido F, Andaloro C. Vocal function exercises and vocal hygiene combined treatment approach as a method of improving voice quality in irradiated patients for laryngeal cancers. Acta Med Mediterr. 2018;34:517–23. https://doi.org/10.19193/0393-6384_2018_2_83
35. Angadi V, Dressler E, Kudrimoti M, Valentino J, Aouad R, Gal T, et al. Efficacy of voice therapy in improving vocal function in adults irradiated for laryngeal cancers: a pilot study. J Voice. 2020;34:962.e9–962.e18. https://doi.org/10.1016/j.jvoice.2019.05.008
36. Tang J, Huang W, Chen X, Lin Q, Wang T, Jiang H, et al. Liuzijue qigong: a voice training method for unilateral vocal fold paralysis patients. Ann Otol Rhinol Laryngol. 2019;128:654–61. https://doi.org/10.1177/0003489419837265
37. Liu H, Chen S, Gao L, Li J, Liu B, Raj H, et al. Comparison between combination of resonant voice therapy and vocal hygiene education and vocal hygiene education only for female elementary school teachers. J Voice. 2022;36:814–22. https://doi.org/10.1016/j.jvoice.2020.09.028
38. Christmann MK, Scapini F, Lima JPM, Gonçalves BFDT, Bastilha GR, Cielo CA. Aerodynamic vocal measurements in female teachers: finger kazoo intensive short-term vocal therapy. J Voice. 2021;35:259–70. https://doi.org/10.1016/j.jvoice.2019.08.018
39. Stemple JC, Lee L, D'Amico B, Pickup B. Efficacy of vocal function exercises as a method of improving voice production. J Voice. 1994; 8:271–8. https://doi.org/10.1016/s0892-1997(05)80299-1
40. Stemple J, Roy N, Klaben BK. Clinical voice pathology: theory and management. 5th ed. San Diego: Plural Publishing; 2014.
41. Bane M, Angadi V, Dressler E, Andreatta R, Stemple J. Vocal function exercises for normal voice: the effects of varying dosage. Int J Speech Lang Pathol. 2019;21:37–45. https://doi.org/10.1080/17549507.2017.1373858

42. Sabol JW, Lee L, Stemple JC. The value of vocal function exercises in the practice regimen of singers. J Voice. 1995;9:27–36. https://doi.org/10.1016/s0892-1997(05)80220-6
43. De Bodt M, Patteeuw T, Versele A. Temporal variables in voice therapy. J Voice. 2015;29:611–7. https://doi.org/10.1016/j.jvoice.2014.12.001
44. Patel RR, Awan SN, Barkmeier-Kraemer J, Courey M, Deliyski D, Eadie T, et al. Recommended protocols for instrumental assessment of voice: American speech-language-hearing association expert panel to develop a protocol for instrumental assessment of vocal function. Am J Speech Lang Pathol. 2018;27:887–905. https://doi.org/10.1044/2018_AJSLP-17-0009
45. Van Stan JH, Roy N, Awan S, Stemple J, Hillman RE. A taxonomy of voice therapy. Am J Speech Lang Pathol. 2015;24:101–25. https://doi.org/10.1044/2015_AJSLP-14-0030

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