International Journal of Speech-Language Pathology

ISSN: 1754-9507 (Print) 1754-9515 (Online) Journal homepage: www.tandfonline.com/journals/iasl20

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To cite this article: Shakeela Saleem, Anna Miles & Jacqueline Allen (03 Feb 2025): Effects of LSVT LOUD and EMST in individuals with Parkinson's disease: A two arm non-randomized clinical trial, International Journal of Speech-Language Pathology, DOI: 10.1080/17549507.2025.2455635

To link to this article: https://doi.org/10.1080/17549507.2025.2455635

International Journal of Speech-Language Pathology, 2025; Early Online: 1–15

Effects of LSVT LOUD and EMST in individuals with Parkinson's disease: A two arm non-randomized clinical trial

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Abstract

Purpose: This study compared the effects of Lee Silverman Voice Treatment and Expiratory Muscle Strength Training on swallow, cough, and voice function in individuals with Parkinson's disease.

Method: Fifty-eight individuals with mild-moderate Parkinson's disease (male = 45, M = 69 years, SD = 8) were enrolled in a two-treatment clinical trial and completed four consecutive weeks of either Lee Silverman Voice Therapy or Expiratory Muscle Strength Training. All participants completed standard protocol videofluoroscopic swallow study, spirometry-cough tests, acoustic-voice assessment, and self-rated questionnaires pre- and post-therapy. Data were analysed by masked clinicians using specialised software. Mixed-model repeated measures and t-tests were performed.

Result: Lee Silverman Voice Treatment resulted in greater effects in acoustic aerodynamic voice measures (loudness, pitch-range, and aerodynamic-efficiency; $p < .05$) compared to the Expiratory Muscle Strength Training group. There were significant effects on pharyngoesophageal segment maximum opening ($p = .01$) following Lee Silverman Voice Treatment. Expiratory Muscle Strength Training resulted in significantly greater change in maximum hyoid displacement (Hmax; $p = .04$) and decreased Hmax duration ($p < .01$) compared to Lee Silverman Voice Therapy group. No cough measures and self-reported questionnaires significantly differed between groups with both groups improving post-treatment.

Conclusion: Both Lee Silverman Voice Therapy and Expiratory Muscle Strength Training improved specific swallow efficiency and airway defence capacity despite differences in task and therapeutic dose. Only Lee Silverman Voice Thearpy improved vocal intensity. Both treatments are feasible options for individuals with mild-moderate Parkinson's disease.

Keywords: *Parkinson's disease; LSVT LOUD; EMST; two-treatment trial; swallowing; voice*

Introduction

Parkinson's disease (PD) is the fastest-growing neurodegenerative disease in prevalence, disability, and mortality worldwide (Feigin et al., 2017). Aerodigestive tract dysfunction and laryngeal incompetence are common in individuals with PD and are often non-responsive to medical and surgical therapy (Baijens & Speyer, 2009; Patel et al., 2020; van Hooren et al., 2014). Aspiration pneumonia is the leading cause of death in the PD population (Kalf et al., 2012), therefore novel therapy approaches that primarily focus on improving pharyngolaryngeal deglutitive functions in PD are needed to minimise the mortality risks and improve active societal participation of individuals with PD. Non-pharmacological therapeutic interventions have grown in interest in recent years (Baijens & Speyer, 2009; Park et al., 2019; Patel et al., 2020; van Hooren et al., 2014) and in particular, studies have demonstrated efficacy in reducing swallowing (Claus et al., 2021; Manor et al., 2013; Miles et al., 2017; Pitts et al., 2009; Troche et al., 2010), cough (Pitts et al., 2009; Reyes et al., 2018, 2020) and voice symptoms (Ramig et al., 2001, 2018; Stegemöller et al., 2017; Tamplin et al., 2020). Non-invasive behavioural therapies are attractive because of their relative safety and ability to

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/17549507.2025.2455635.

ISSN 1754-9507 print/ISSN 1754-9515 online
Published by Taylor & Francis
DOI: 10.1080/17549507.2025.2455635

be administered in community settings by trained therapists.

Lee Silverman Voice Treatment (LSVT LOUD®), which follows a standard protocol with intensive and high-effort speech exercises, is a validated and globally utilised voice therapy program aimed at improving communication and vocal loudness of individuals with PD. Recent small, pilot studies demonstrate that standard LSVT LOUD® therapy resulted in some vocal improvements but also some positive spread effects in improving swallowing and cough function (El Sharkawi et al., 2002; Miles et al., 2017; Park et al., 2022). Similarly, Expiratory Muscle Strength Training (EMST) is a device-driven standardised training program recommended for individuals with PD that uses a calibrated, one-way, spring-loaded valve to mechanically overload the expiratory and submental muscles. Several EMST studies have demonstrated positive effects on specific swallow kinematic measures, as well as maximum expiratory pressure and voluntary cough flow measures (Pitts et al., 2009; Reyes et al., 2020; Sapienza et al., 2011; Troche et al., 2010, 2023) but there remains limited evidence regarding swallow efficiency measures, reflexive cough function, and voice outcomes.

A shared substrates of airway protection framework has been proposed which highlights the overlap between swallow and cough anatomy and physiology (Troche et al., 2014) and therefore investigating spread effects of LSVT LOUD® and EMST on the inter-related functions of voice, swallow, and cough may provide support for use of non-invasive options as preventative, maintenance, and/or rehabilitative strategies for individuals with PD. Therapies that benefit more than one functional area provide timely, cost-effective options, offering greater benefit to the participants. This two-treatment clinical trial evaluated the effects of LSVT LOUD® and EMST on objective voice, cough and swallowing function, and self-rated measures in individuals with PD. Hypotheses were that LSVT LOUD® and EMST would both strengthen the pharyngolaryngeal muscles and would have a significant positive impact across a range of voice, swallow, and cough functional measures. Hypotheses were also that LSVT LOUD® would have superior effects on voice; whilst EMST would have superior effects on cough.

Method

This prospective open-label non-randomised two-treatment consecutive clinical trial was performed between 2019–2022. All procedures performed were in accordance with the ethical standards of the national research committee and ethical approval gained by Health and Disability Ethics Review Committee (HDEC:19/CEN/131). Trial was registered at the Australian New Zealand Clinical Trials Registry (Reg.no: ACTRN12619001146189p). Written informed consent was obtained from all the participants included in this study prior to study commencement.

Participant recruitment, sampling, and allocation sequence

Individuals with PD were invited to participate through local Parkinson's community meetings or by their local speech-language pathologists (SLPs). Eligibility criteria included: a) A diagnosis of PD by a neurologist, b) otolaryngologist stroboscopy assessment reporting no contraindications to treatment,c) no changes in PD medications throughout the study, d) ability to commit to sessions, and e) self-reported adequate hearing, cognition, and memory to follow intervention. Exclusion criteria included: a) Comorbidity affecting swallowing, b) other neurological conditions or neurosurgical treatment or laryngeal surgery, c) history of breathing disorders or untreated hypertension, d) history of smoking within last 5 years, e) ongoing speech/swallow therapy or history of LSVT or EMST within last two years.

A sample size calculation (Noordzij et al., 2010) was completed for a continuous outcome *the measurement of maximum displacement of the pharyngoesophageal segment* (PESmax) based on previously published findings of Miles et al. (2017). Calculations were made to achieve 80% power and an alpha level of $\alpha = 0.05$. It was estimated thirty-two participants per group needed to detect a significant change in quantitative fluoroscopic swallowing measures. A further five participants were added to each group to allow for loss to follow-up (an attrition rate of 15%).

All enrolled participants were allocated into two separate groups in consecutive blocks, the first block received LSVT LOUD® and next block received EMST. All participants were enrolled as they were referred by their treating clinician. Participants were masked to treatment group until treatment commenced. There was no masking of participants during the trial as all participants were receiving treatment. Instrumental assessment measures were completed by independent assessors masked to time and group. Assessors were not involved in the treatment delivery.

Test procedure, assessment protocols, and outcomes

Participants' demographic and medical information were collected at baseline and participated in two evaluation timepoints: Baseline evaluation (T0) and one-week post-therapy evaluation (T1). At each timepoint, participants completed three instrumental assessments (videofluoroscopic swallow study (VFSS), spirometric cough measures, and acoustic/aerodynamic voice measures), four self-rated questionnaires, and reported any changes in medical status and changes in therapies/physical activities. Table I describes all measures.

Table I. Quantitative data measures.

Measure (unit)	Abbreviation	Description
Swallow timing measures (Leonard & Kendall, 2019)		
Oro-pharyngeal transit time (seconds)	OPT	Duration of bolus transit from posterior nasal spine to the time of bolus exit from valleculae
Hypo-pharyngeal transit time (seconds)	HPT	Duration of bolus transit from bolus head exit from valleculae to the time of bolus tail clearance of the PES
Total pharyngeal transit time (seconds) (OPT+ HPT = TPT)	TPT	Total time is taken from the onset of the swallow (when first movement of the bolus passes through posterior nasal spine) to clearance of bolus tail through the UES
Airway closure (seconds)	Airwaycl	Total time taken from the swallow onset and completion of supraglottic closure
PES opening-Airwaycl (seconds)	PESop-Airwaycl	Duration between complete closure of airway and onset of PES opening
Airway closure duration (seconds)	Airwaydur	Total time airway is closed during the swallow (complete supraglottic airway closure to epiglottis return to upright position after bolus clearance)
Maximum hyoid displacement duration (seconds)	Hdur	Total time hyoid is maximally displaced (retain at the anterior-superior position) during the swallow
PES opening duration (seconds)	PESdur	Total time UES is open during the swallow
Swallow displacement measures (Leonard & Kendall, 2019)		
Maximum opening of the PES (cm)	PESmax	Maximum distension of the PES
Maximum hyoid displacement (cm)	Hmax	Distance between hyoid at rest and maximally displaced (highest anterior-superior position)
Hyoid-larynx displacement (cm)	HLmax	The difference in distance between hyoid and larynx at rest and maximally approximated
Swallow ratio (area/area) measures (Leonard & Kendall, 2019)		
Pharyngeal constriction ratio	PCR	Maximum constriction of the pharynx/pharyngeal area at rest
Bolus clearance ratio	BCR	Bolus residual/area of bolus in the pharynx prior to PES opening (Jardine et al., 2020)
Aerodynamic cough measures (Hegland et al., 2014)		
Compression phase duration (ms)	CPD	Peak inspiratory flow during the inspiratory phase of the cough
Peak expiratory flow rate (L/s)	PEFR	Peak airflow during the expiratory phase of the cough
Peak expiratory flow rise time (seconds)	PEFRT	Time from the beginning of the expiratory phase to the peak expiratory flow
Cough volume acceleration (L/s/s)	CVA	Peak expiratory flow rate/peak expiratory flow rise time
Acoustic and aerodynamic voice measures (Patel et al., 2018; Ramig et al., 2001)		
Vocal intensity (dB) sound pressure level	SPL	Comfortable sustained vowel phonation or speech tasks loudness level measured by sound level metre at 50 cm distance from mouth (SPLavg-average, SPLmax-maximum)
Maximum phonation rime (seconds)	MPT	The maximum amount of time a person can sustain phonation of /ah/
Mean peak air pressure (cmH_20)	MPAP	Arithmetic mean of all peak air pressure values obtained from one or more air pressure bursts in one signal
Aerodynamic power (Watts)	APOW	Peak air pressure multiplied by the target airflow by 0.09806
Aerodynamic resistance ($cmH_20/L/s$)	ARES	Mean peak air pressure divided by the target airflow
Aerodynamic efficiency (ppm)	AEFF	Acoustic power divided by the aerodynamic power
Maximum expiratory pressure (cmH_20)	MEP	MEP was taken using the EMST 150 device as per the EMST training protocol (Troche et al., 2010; based on optimum 75% resistance pressure threshold level)
Self-Rated Questionnaires		
Parkinson's Disease Questionnaire-8 (Jenkinson et al., 1997)	PDQ-8	This is a shortened version derived from PDQ-39. It contains eight questions providing an overall index of self-perceived health in PD responses are on a 5-point rating scale from "never" to "always" (scores range from 0 to 40 but are then converted to a score out of 100, with 100 representing the greatest severity; correlation to Hoehn and Yahr (1967) staging - H&Y I [17.74), H&Y II [33.14], H&Y III [37.05], H&Y IV [47.86]).
Voice Handicap Index-10 (Rosen et al., 2004).	VHI-10	This is a 10-item tool designed to quantify a participant's own self-perceived vocal function. Responses are on a scale from never to always (0 = "never" and 4 = "always"). Scores range from 0 to 40 with higher scores indicating a greater impact on vocal function in daily communication and scores greater than 11 considered abnormal (Arffa et al., 2012).
Eating Assessment Tool-10 (Belafsky et al., 2008)	EAT-10	This is a 10-item self-reported tool describing swallow-related symptoms. It contains questions with responses measured on a scale from 0 to 4 (0 indicating "no problem" and 4 indicating "severe problem"). Scores range from 0 to 40, with any score greater than three being indicative of swallow impairment and higher scores suggesting greater swallow deficit.
	CETI-M	This is a 10-item questionnaire designed to measure the change in functional communication over time. It

(*Continued*)

Table I. (*Continued*).

Measure (unit)	Abbreviation	Description
The Communication Effectiveness Index Modified (Ramig et al., 2018)		consists of 10 items, with each response on a scale from 1 to 10 (1 indicating "not at all effective" and 10 indicating "extremely effective") with summative scores ranging from 0 to 100 and higher scores being indicative of greater communicative effectiveness. It has demonstrated a significant correlation between intelligibility and voice handicap with established reliability for PD.

Note. OPT = oro-pharyngeal transit time, HPT = hypo-pharyngeal transit time, TPT = total pharyngeal transit time, Airwaycl = airway closure, PES = pharyngoesophageal segment, PESop-Airwaycl = PES opening time-airway closure, Airwaydur = airway closure duration, Hdur = maximum hyoid displacement duration, PESdur = PES opening duration, PESmax = maximum opening of the PES, Hmax = maximum hyoid displacement, HLmax = hyoid-larynx displacement, PCR = pharyngeal constriction ratio, BCR = bolus clearance ratio, CPD = compression phase duration, PEFR = peak expiratory flow rate, PEFRT = peak expiratory flow rise time, CVA = cough volume acceleration, SPL = sound pressure level, MPT = maximum phonation time, MPAP = mean peak air pressure, APOW = aerodynamic power, ARES = aerodynamic resistance, AEFF = aerodynamic efficiency, MEP = maximum expiratory pressure, PDQ-8 = Parkinson's Disease Questionnaire-8, VHI-10 = Voice Handicap Index-10, EAT-10 = Eating Assessment Tool-10, CETI-M = The Communication Effectiveness Index Modified, H&Y = Hoehn and Yahr staging.

Intervention

Each participant completed either LSVT or EMST. Table II provides the key elements of LSVT LOUD® and EMST. Participants were all in an "on" state of medication for intervention and assessment sessions. Treatment adherence was recorded by participants using a checklist and was scored as number of completed sessions.

Videofluoroscopic swallow study (VFSS)

VFSS was conducted using a standard protocol (Leonard & Kendall, 2019) that consisted of 1 ml, 3 ml, 20 ml, 100 ml of IDDSI 0 thin barium volumes (EZ-Paque Barium Sulphate suspension, 60%w/v; 41%w/w, E-Z-EM, Inc, Westbury, NY) and 5 ml paste (E-Z-paste 60%w/w). This examination was performed using a Videofluoroscope (DF-323H, Toshiba, Japan; recorded at 30 frames per second) and images were obtained on a Toshiba Ultimax Fluorography C-arm (Model BLF-600R, Toshiba, Japan) in the anterior-posterior and lateral planes and recorded onto a digital media stick. Experienced Medical Radiation Technicians and experienced SLPs conducted all procedures. To allow for later calibration of displacement measures, a 20 mm diameter radio-opaque ring was used. Participants were seated in a lateral position and the ring was taped under the chin in midline. Participants were given trials of 1 ml, 3 ml, and 20 ml of IDDSI 0 thin liquid barium and asked to "hold in your mouth and swallow in one go when instructed". Next, they were then given 100 ml of thin IDDSI 0 barium liquid for sequential swallow with a straw and instructed to "drink the whole cup without stopping at a pace comfortable to you". Lastly, participants were given 5 ml (one teaspoon) of barium paste. VFSS data were analysed frame by frame using "Swallowtail™" (version 3.0.5 [2013 – 2019] Belldev Medical, Illinois, USA) with validated quantitative measures of timing, displacement, and residue measures (Jardine et al., 2020; Leonard & Kendall, 2019). Each swallow was rated using the 8-point penetration-aspiration scale (PAS) (where 1 = no penetration/aspiration and 8 = aspiration below the vocal cords with no attempt to clear; Rosenbek et al., 1996).

Spirometric cough assessment

Voluntary and reflexive cough strength were assessed using ADInstruments™ Spirometry (Bella Vista, Australia). For voluntary cough measures, participants were instructed to wear a nose and mouth-covering face mask linked to a PulmoMate Nebuliser model 46501 (DeVilbiss Healthcare LLC, Pennsylvania, USA). They were instructed to produce "three strong coughs as if something went down the wrong pipe". The responses of the three coughs were recorded in LabChart™ software from ADInstruments™. Participants performed the first voluntary cough assessment followed by reflex cough to avoid any residual sensation of citric acid. For involuntary (reflexive) cough measures, participants were asked to sit upright and wear a facemask covering their nose and mouth. The facemask was coupled to the spirometer. A delivery port with one-way inspiratory valve for nebulisation was connected to the facemask. The nebuliser was connected to spirometer that delivered aerosolised solution. Cough was induced using 0.8 M citric acid and participants were instructed to "cough if you need to". Participants were instructed to keep breathing as the solution was delivered. Airflow was recorded in the same manner as described above until at least three coughs were produced, or for up to 30 seconds following the presentation of the citric acid solution. These protocols were chosen based on methods previously reported in the literature (Hegland et al., 2014; Miles et al., 2013). Cough parameters were extracted and analysed using the LabChart™ software. Four validated cough parameters (Hegland et al., 2014) were recorded. All three samples of voluntary cough parameters were analysed separately. The first cough in the reflexive cough sequence was analysed.

Acoustic and phonatory aerodynamic assessment

Acoustic and aerodynamic measurements were selected and carried out based on previously reported recommendations (Lechien et al., 2023; Patel et al., 2018; Ramig et al., 2001). Participants were assessed in an upright seated position. The room's background noise level was measured at the beginning of the assessment session and maintained at a level below 50 dB throughout the session. A sound level metre, (CEL-244 Class 2, Casella) calibrated with a CEL-110/2 acoustic calibrator, was placed on a tripod 50 cm from the participant's mouth and a head-mounted omnidirectional microphone (AKG C420, Harman International Austria) was positioned at 10 cm distance from participants' lips. The microphone was connected to a computer to obtain the digital recording of the acoustic metrics using Computerised Speech Lab (CSL) 4500 (KayPENTAX, New Jersey, USA). Measures obtained from each participant were generated by undertaking the following tasks, always conducted in the same sequence: a) Standard reading passage-read the "Grandfather passage", b) spontaneous Monologue: Talk about a topic of your choice for 1 min (e.g. what did you do during your last holidays or an interesting event that you have attended recently), c) maximum phonation time: Take a deep breath in and say /a:/ for as long as you can at a comfortable level in one breath (repeat the task three times), and d) pitch range: Sustain the vowel /a:/ as high in pitch as possible for at least 3–5 sec and sustain the vowel /a:/ as low in pitch as possible for at least 3–5 sec (recorded separately for high and low pitch, repeat this task three times). The mean SPL and the maximum SPL for each task were recorded on a recording sheet. Any voice quality change or any variation during the session were recorded. Digitalised voice signals were analysed using the Multidimensional Voice Program (MDVP) and Real-Time Pitch (RTP) program of CSL 4500 (KayPENTAX, New Jersey, USA).

Aerodynamic phonatory measures were taken using the Phonatory Aerodynamic System Model 6600 (KayPENTAX, New Jersey, USA). Aerodynamic efficiency was measured using the voicing efficiency protocol. Participants were asked to produce consecutive /pa pa pa/ utterances 7–10 times at a comfortable pitch and loudness. The voicing efficiency measure provides an indication of how effectively aerodynamic energy (cm H_2O) is converted to acoustic energy (dB) during phonation. The phonatory aerodynamic system software uses an inbuilt equation, previously reported in Toles et al., 2022. This and similar efficiency ratios have shown clinical utility for assessing treatment effects in voice patients (Grillo & Verdolini, 2008; Toles et al., 2022) and provide voice information with unambiguous physiological attributes.

Self-rated questionnaires

Participants completed four validated, subjective, self-administered questionnaires at each assessment time point: a) Parkinson's Disease Questionnaire-8 (PDQ-8) is a shortened version derived from PDQ-39, that assess PD-specific health related quality of life, b) Voice Handicap Index-10 (VHI-10) is a 10-item tool designed to quantify a participant's own self-perceived vocal function, c) Eating Assessment Tool-10 (EAT-10) is a 10-item self-reported tool describing swallow-related symptoms, d) The Communication Effectiveness Index Modified (CETI-M) is a 10-item questionnaire designed to measure the change in functional communication over time.

Statistical analyses

Statistical analyses were performed using SPSS (IBM Corp., IBM Statistical Package for the Social Sciences, v 27.0 Armonk, NY, IBM Corp). A cut-off p-value $< .05$ was considered statistically significant. In view of unequal group sizes, an independent sample t-test or Mann-Whitney U was performed after testing each variable for normal distribution (Shapiro-Wilk Test) to ensure groups were comparable. Each outcome measures were tested for variable distribution and skewed data was log transformed.

Within-group comparisons to evaluate pre- and post-intervention mean change in outcome variables (swallow, cough, and voice) were analysed using paired sample t-test. Comparative effects of two intervention with two groups on two data points for each outcome variable was analysed using mixed model with random intercepts for participants to account for the repeated measures structure. We performed power analyses using paired t-test to detect the treatment effects in both groups based on their sample size. For the EMST group, with 24 participants, we detected a Cohen's d_z of 0.495 with 80% and an alpha level 0.05. For the LSVT group, with 34 participants, we detected Cohen's d_z of 0.495 with 80% and an alpha level 0.05. Inter-rater reliability (two-way random method) of 20% randomly selected quantitative VFSS measures and cough measures yielded good intraclass coefficient ranging from 0.71–0.91 ($p < .05$).

Result

Sixty-two participants with PD were recruited with four participants excluded from the final analysis due to discontinuation of therapy in week one (Figure 1 flowchart). Fifty-eight remaining participants (male = 45, M = mean 69 years, SD = 8) completed four weeks of therapy (either LSVT LOUD® [$n = 34$] or EMST [$n = 24$]). There was early termination of recruitment to the EMST group (EMST) due to prolonged COVID-19 national lockdowns. Treatment fidelity was maintained 100% by ensuring consistent

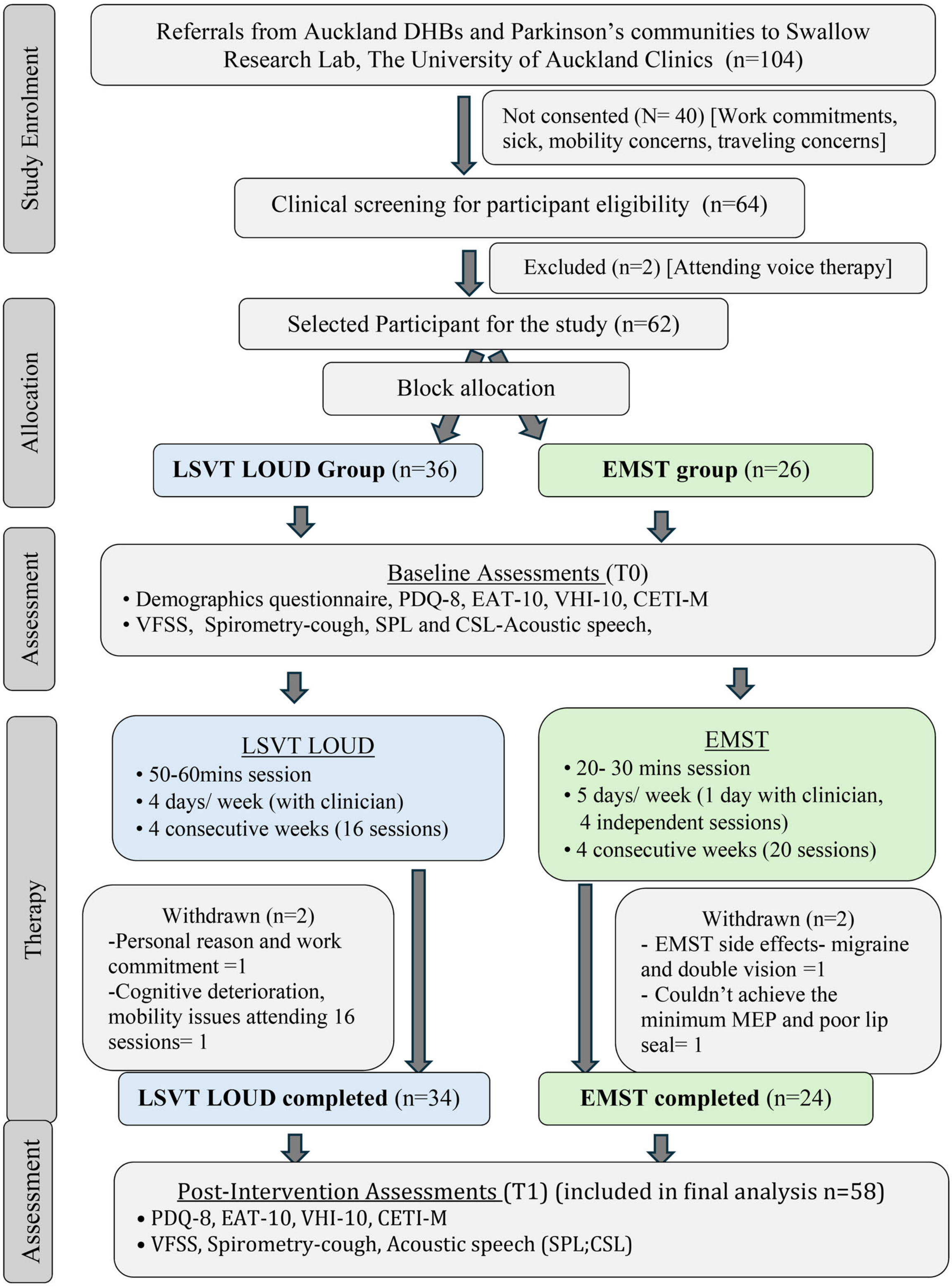

Figure 1. CONSORT diagram outlining the flow of the participants through the trial.
LSVT LOUD®-Lee Silverman voice treatment, EMST-expiratory Muscle strength training, VFSS-the videofluoroscopy study of swallowing, SPL-sound pressure level, CSL-Computerised speech Lab, PDQ-8-Parkinson Disease Questionnaire-8, EAT-10-Eating assessment tool-10, VHI-10-voice Handicap Index-10, CETI-M-Communicative Effectiveness Index-Modified.

delivery of the standard protocol of treatment and maintaining training logs. No statistically significant pre-treatment group differences ($p<.05$) were found (Table III). No changes in medical status, physical activities, or medication were reported during the study period. Summary findings of significantly improved objective and self-reported measures are provided in Table IV. Table V provides details of the

Table II. Comparison of LSVT LOUD® and EMST interventions for PD.

	Lee Silverman Voice Treatment (LSVT LOUD®)	Expiratory Muscle Strength Training (EMST)
Focus of treatment	Vocal and speech hierarchical exercises to improve loudness	Device-driven treatment to strengthen expiratory and submental muscles
Intervention dosage	One training session for each day, 4 days/week, for 4 consecutive weeks Homework exercise tasks: Every day for 4 weeks *Total sessions*: 16 (one to one session with the clinician) *Average session duration*: 50–60 minutes	One training session for each day, 5 days/week, for 4 consecutive weeks *Total sessions:* 20 (1 day/week with clinician and 4 days/week independent sessions at home) *Average session duration*: 15–20 minutes
Intervention procedures and activities	Daily exercises (first 30 minutes) Task 1: Sustained vowel /ah/ in a good quality, loud voice for as long as possible (15 repetitions) Task 2: High pitch /ah/ glide (15 repetitions) Low pitch /ah/ glide (15 repetitions) Task 3: Reading ten self-generated phrases s/he says daily in functional living with good loudness and effort (5 repetitions) Speech hierarchy exercises (second 30 minutes) Task 4: Reading and spontaneous speech drills Homework exercises: • A subset of the daily exercises and hierarchy exercises • A tailored carryover task to use the louder voice practiced in exercises in a real-world communication situation	Determining the optimal pressure threshold level (EMST device) Task 1: Set the device at 75% of the participant's Maximum Expiratory Pressure (MEP) for subsequent training Steps and guidelines: (1) Take a full breath in (2) Place the device in your mouth creating a seal with your lips (3) Blow out the air hard and quickly through the device (4) Start to blow at the beginning pressure threshold level of 30 cmH_2O (5) Turn the top cap of the device counter clockwise ¼ turn to increase the resistance and continue until the point that he/she cannot blow air through the device completely (6) At that point turn the top cap back clockwise ¼ turn to the previous setting (less resistance). This is the personal starting point for that individualCompleting the session training: The power of five Task 2: • Complete five daily sets of five breaths in each set (in total 25 blows) • 15–30 seconds resting time in between blows • 30–60 seconds resting time between sets
Shaping techniques, purpose, and approach	• Trained vocal loudness that is healthy and within normal limits through the use of modelling ("do what I do") or tactile/visual cues • Sensory calibration: To focus attention on how it feels and sounds to talk with increased vocal loudness (self-monitoring) and to internally cue (self-generate) new loudness effort in speech • Consistent bio-feedback throughout the session	• Trained the correct technique with the EMST device by modelling or visual cues and written instruction sheet • Provided consistent encouragement to identify whether they were completing the task correctly and gave feedback on the accuracy of the technique
Treatment adaptation and modification	• Targeted speech hierarchical tasks according to individual improvement level and increase the complexity across weeks (words to sentence to conversational level) • Used salient material (based on each participant's interest and hobbies) for the speech hierarchical activity and the carryover task assignment	• Weekly increase in the pressure threshold level of the EMST device as tolerated by participant (see determining optimal pressure above) • Gave specific instructions to prevent air leakage (through the nose or lips) as per the EMST protocol guidelines • Support the jaw with the hand if air escape through your lips when you blow through the device • If the air escape through your nose, use nose clip provided
Maintenance after therapy completion	Every day 10–15 minutes as per LSVT LOUD® protocol (a subset of the daily exercises and hierarchy exercises)	Practice EMST training three days/week
Intervention material	• LSVT LOUD® treatment form and homework sheets • A stopwatch, a sound level metre, voicetools app (DevExtras) was used to measure the duration, loudness level, and pitch level respectivelyhttps://www.lsvtglobal.com/LSVT LOUD)	• EMST 150 device • EMST instruction sheet • EMST training loghttps://emst150.com/
Objective and subjective clinical data collected during each treatment session and training adherence	*In-session data recording* • Measures of duration, frequency, and sound pressure level • Documentation of the percentage of cueing required to implement vocal loudness strategy • Observations of perceptual voice quality • Participant's self-reported comments about the successful use of the	*In-session data recording* • Measures of MEP, session duration, sets completion, and recording it in the EMST training log • Documentation of any specific adaptation used to perform the technique correctly and cues required • Observations of air leakage and correct use of the technique *Training adherence of 4 weeks of treatment*

(*Continued*)

Table II. (*Continued*).

	Lee Silverman Voice Treatment (LSVT LOUD®)	Expiratory Muscle Strength Training (EMST)
	improved loudness in daily communication • Participants self-reported perceived effort using the visual analogue perceived effort level scale *Training adherence of 4 weeks of treatment* • Track the progress and monitor adherence to training by collecting 16 completed treatment forms and 30 homework sheets • Each participant's motivation and commitment during the programme were rated by the clinician on a scale of 1–5	• Track the progress and monitor training adherence by having a record of completion in the training log • Each participant's motivation and commitment during the programme were rated by the clinician on a scale of 1–5 (1 = not at all motivated; 5 = extremely motivated)
Intervention delivery mode and setting	• Mostly in-person sessions: The Swallowing Research Laboratory at The University of Auckland (in a quiet room < 50 dB) • For some individuals: Mixed-method with both in-person and tele practice (via zoom) sessions that followed all the conceptual and technical specifications guided in the LSVT LOUD eLOUD	• Every first training in-person session: The Swallowing Research Laboratory, The University of Auckland • Other weekly sessions were delivered either at the clinic or via zoom sessions
Personnel delivering the intervention	Certified LSVT LOUD®, LSVT eLOUD practitioner, and Speech-language pathologist with experience in dysphagia rehabilitation	Speech-language Pathologist with experience in dysphagia rehabilitation and trained in EMST

treatment delivery, challenges, adverse effects, adherence, and adaptation strategies. Appendix 1 provides detailed statistical analyses for swallow, cough, and voice parameters.

Treatment effects on swallow function

Four participants in each group aspirated (PAS score 7–8) and 64% ($n = 37/58$) scored >3 of their EAT-10. Group differences for PAS scores did not meet statistical significance for any of the volume/consistencies trialled but PAS scores were improved for some participants following therapy (Appendix 2). *Within group comparison* showed significant effects in pre and post mean differences for maximum hyoid displacement duration (Hdur; $d = 0.54$. $p = .012$), the time taken between onset of PES opening and complete closure of the airway (PESop- Airwaycl; $d = 0.46$, $p = .025$), and maximum opening of the pharyngoesophageal sphincter (PESmax; $d = 0.49$, $p = .017$) in the LSVT LOUD® group following treatment. In the EMST group, significant effects were evident for Hdur ($d = 0.65$, $p = .004$), maximum hyoid displacement (Hmax; $d = 0.48$, $p = 0.028$), and pharyngeal area at rest (PAhold; $d = 0.48$, $p = .031$) following training. *Between-group comparison analysis* showed there were time by group interaction effects exhibited for Hdur and Hmax swallow measures. Maximum hyoid displacement duration (Hdur) was significantly reduced after EMST treatment compared to LSVT LOUD® treatment. Likewise, maximum hyoid displacement (Hmax) was significantly increased in the EMST group compared to the LSVT LOUD® group. No other swallow measures significantly differed between-group comparisons.

Treatment effects on cough measures

Impaired cough efficacy was evidenced by reduced peak expiratory flow rate (<4.0 L/s) observed for reflexive cough in 57% of participants across both treatment types at commencement of the study (n = 33/58). *Within group comparison analysis* revealed significant effects in the voluntary and reflexive cough measures of peak expiratory flow rate (PEFR; $d = 0.42$, $p = .030$), and cough volume acceleration (CVA; $d = 0.60$, $p = .002$), after LSVT LOUD® treatment. In those treated with EMST, significant effects demonstrated in voluntary compression phase duration ($d = 0.47$, $p = .031$), PEFR ($d = 0.57$, $p = .010$), and CVA ($d = 0.57$, $p = .010$) and in reflexive peak expiratory flow rise time ($d = 0.61$, $p = .011$) and CVA ($d = 0.69$, $p = .005$). *Between-group comparison analysis* revealed no difference in magnitude of improvement related to treatment type, for any of the cough measures.

Treatment effects on acoustic aerodynamic voice measures

Both groups were asked to perform the same tasks for acoustic aerodynamic voice assessments.

In the EMST therapy group, 22/24 participants increased their maximum expiratory pressures (MEP) over the course of the training while two participants were unable to increase their MEP during the four weeks of the training despite following instructions.

Within-group comparison analysis revealed significant differences between pre- and post-test scores for aerodynamic measures (mean peak air pressure [MPAP] and aerodynamic efficiency) and all acoustic

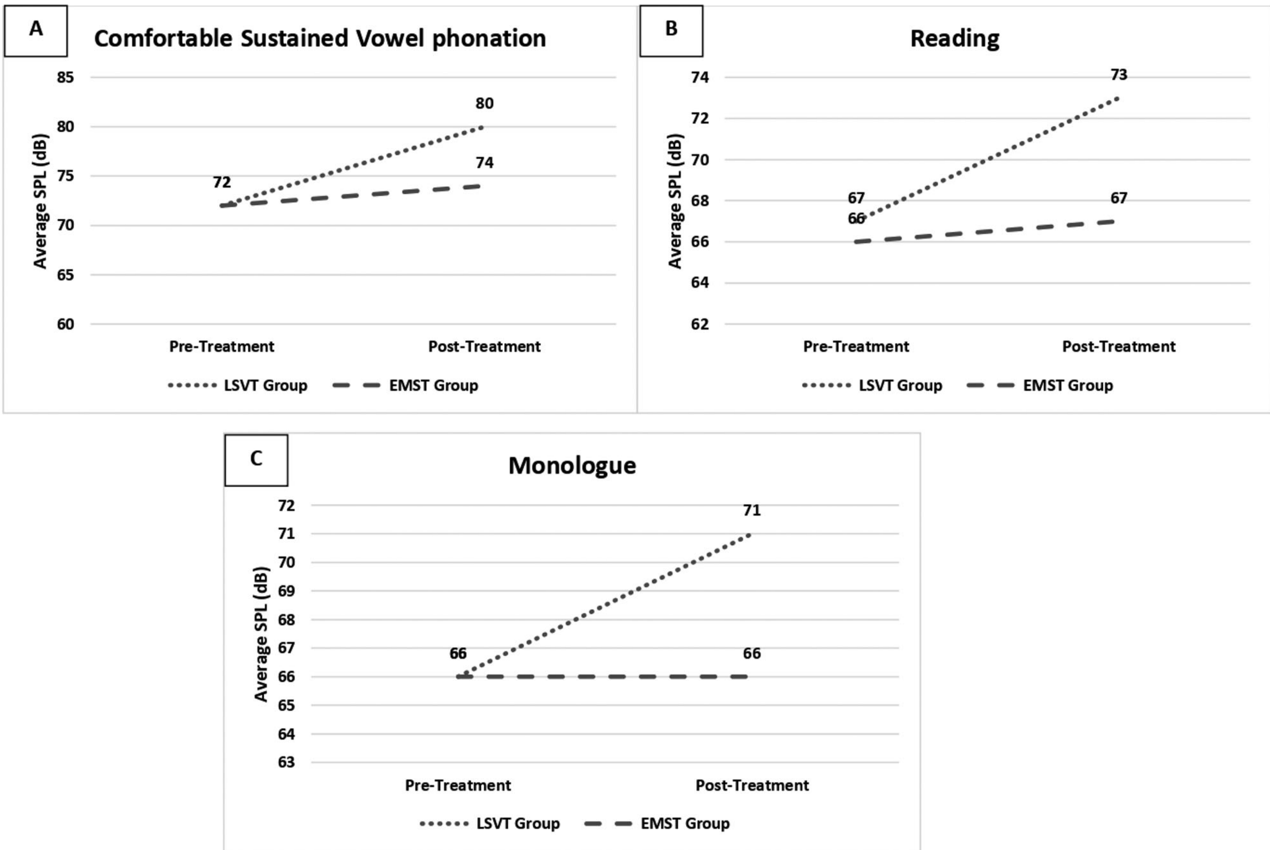

Figure 2. Change in sound pressure level following LSVT LOUD® and EMST.

except the minimum pitch variable in the LSVT LOUD group. In those treated with EMST, significant improvement was evident for MPAP ($d = 0.92$, $p = .002$), aerodynamic power ($d = 0.58$, $p = .03$) and meal SPL for the sustained vowel phonation task ($d = 0.56$, $p = .01$) but not for mean SPL for reading and monologue tasks. *Between-group comparison* analysis revealed that there were time by group interaction effects. Significant effects were seen after LSVT LOUD® for vocal intensity across speech tasks when compared to EMST treatment (Figure 2). LSVT LOUD® had significantly improved effects on aerodynamic efficiency measure when compared to EMST group. MPT and other aerodynamic measures did not significantly differ on between groups comparison.

Treatment effects on self-rated questionnaires

Within group significant changes were evident for all the self-rated questionnaires in both the intervention groups. No significant differences in treatment effects were found for between groups comparison of the total score change between baseline and post-treatment for PDQ-8, EAT-10, or VHI-10. In the CETI-M, LSVT LOUD® treatment produced increased mean score differences (mean difference = 12, *SD* = 8) following treatment compared to EMST treatment (mean difference = 5, *SD* = 7), non-significant effect ($p = 0.055$).

Discussion

This two-treatment clinical trial evaluated the swallow, cough, and voice-related effects of two PD treatments which match in duration but differ in target and dose, in 58 individuals with PD of mild-moderate severity (based on PDQ-8). There was an overall improvement across both groups for PES opening, pharyngeal area, and cough strength; however none of these measures significantly differed between groups. Between group comparisons demonstrated greater improvements in hyoid-related quantitative swallow measures following EMST and significantly greater improvement in acoustic aerodynamic voice measures after completion of LSVT LOUD®. Self-reported symptom scores (swallow, voice, and communication effectiveness) improved in both treatment groups after treatment.

Swallow safety and swallow kinematics

Improved PES opening found in this study confirms findings of our previous pilot study evaluating LSVT LOUD® in PD (Miles et al., 2017). Improvement in maximum opening of PES enables bolus flow through the oesophagus and should reduce post-swallow residue. The timing of laryngeal closure plays an important role in airway protection and preventing aspiration. Delayed laryngeal vestibule closure is observed in individuals with PD (El Sharkawi et al., 2002) and a significant effect in the onset of complete

Table III. Participant demographics and self-reported disease severity scores at baseline.

	LSVT LOUD® $n = 34$	EMST $n = 24$	Test statistics
Age (years)			
Mean ± SD	69.35 ± 8.38	68.13 ± 8.52	t (56) =0.54
(range)	(49–86)	(48–83)	$p = 0.58$
Sex			
Male/Female	26/8	19/5	–
Years of diagnosis			$U = 343$
Median (IQR)	5 (3-10)	4 (3-7)	$p = 0.302$
Parkinson's Disease Questionnaire-8 (standardised score; 0= no impact of symptom, 100 = maximum impact)	31.43 ± 16.55	27.25 ± 14.96	t (56) =0.98
Mean ± SD (range)	(0–62.5)	(3–53)	$p = 0.33$
Eating Assessment Tool-10 score (0-3 normal range, 40 = maximum)	6.76 ± 7.73	9.25 ± 6.86	t (56) =−1.26
Mean ± SD (range)	(0–26)	(0–26)	$p = 0.21$
Voice Handicap Index-10 score (0-9 normal range, 40 = maximum)	18.14 ± 9.84	17.21 ± 9.26	t (36) =0.29
Mean ± SD (range)	(4–39)	(4–39)	$p = 0.77$
Parkinson's medication taken [Sinemet or Madopar]	32/34	22/24	–
Baseline swallowing function VFSS - Penetration-Aspiration Score (PAS) ratings			–
PAS 1–2 (safe swallowers)	30	20	
PAS 3–5 (penetrators)	0	0	
PAS 6–8 (aspirators)	4	4	
Diet	All participants reported eating a regular diet.		

Note. *PDQ-8 severity - 0 = no impact of symptoms, 100 = maximum impact association, correlation to Hoehn and Yahr (1967) staging - H&Y I (17.74), H&Y II (33.14), H&Y III (37.05), H&Y IV (47.86).

closure of the laryngeal vestibule before the onset of PES opening in the current study (LSVT LOUD® group) indicates an improved airway protective mechanism after therapy.

Findings of the current study highlight the effects of EMST on hyoid-related measures and pharyngeal area. Pharyngeal constriction during swallow is highly dependent on the area of the pharynx at rest and a reduction in the area of the pharynx at rest likely correlates with improved pharyngeal muscle tone (Miles et al., 2017). The pharyngeal area at rest was significantly reduced following EMST in our cohort. EMST also produced improvement in hyoid-related measures (Hmax and Hdur) with increased hyoid displacement and hyoid apogee which may facilitate the swallow by expanding the hypopharyngeal chamber, increasing PES opening and thereby enabling bolus flow. Consequently, a faster and more coordinated swallow may have produced the significant reduction in Hdur seen during the swallows in this group. The effects of EMST on activating submental and suprahyoid muscles (Hegland et al., 2008) and facilitating anteroposterior hyoid movement may address bradykinesia of swallowing, a main clinical feature of PD-related dysphagia (Suttrup & Warnecke, 2016).

A significant reduction in EAT-10 scores following both treatments indicates that participants are aware of more functional swallows and is consistent with previous studies (Claus et al., 2021; Miles et al., 2017; Park et al., 2022). The lack of significant change in the PAS scores in this study is likely due to ceiling effects given that most participants at baseline ($n = 50/58$) recorded normal or near normal PAS scores (PAS score 1–2). However, some participants who had abnormal PAS scores at baseline improved scores following therapy (LSVT LOUD® $n = 2/4$ and EMST $n = 3/4$). To further explore the effects on PAS scores, participants with higher scores at baseline should be included in future studies.

Cough function

In both treatment groups, voluntary cough (VC) peak expiratory flow rate (PEFR) and cough volume acceleration (CVA) were significantly improved following therapy as has been previously reported following EMST (Cocks et al., 2022; Reyes et al., 2018, 2020), but not previously for LSVT LOUD® studies. Reflexive cough (RC), PEFR, and CVA improved from pre-to post-therapy after LSVT LOUD® treatment, consistent with previous work (Miles et al., 2017). In comparison, following EMST treatment, we did not find a significant effect in the PEFR, however, a significant decrease in PEFRT led to an increase in the CVA. Change in PEFRT may be a direct effect of EMST given that participants were trained to produce forceful, quick expiratory flows to generate adequate pressure to release the valve in the EMST device (Pitts et al., 2009). A recent RCT on cough rehabilitation in PD concluded that EMST did not show changes on reflexive cough measures (Troche et al., 2023). In addition, the literature suggests different motor activation patterns of muscles involved in voluntary vs reflexive (rapid and shorter muscle activation) cough production which may lead

Table IV. Summary findings of the significantly improved objective and self-reported measures within and between groups comparison of this clinical trial.

Measures	LSVT LOUD® within-group pre-post comparison	EMST within group pre-post comparison	Time by group interaction between LSVT LOUD® and EMST
Objective swallow measures	• ↓ Duration between complete closure of airway and onset of PES opening($p = 0.025$, $d = 0.46$) • ↑ Hyoid retention at the antero-superior position during swallowing (Hdur) ($p = 0.012$, $d = 0.54$) • ↑ Pharyngoesophageal sphincter (PES) maximum opening (PESmax) ($p = 0.017$, $d = 0.49$)	• ↑ Maximum hyoid displacement (Hmax)($p = 0.028$, $d = 0.48$) • ↓ Hyoid retention at the antero-superior position during swallowing (Hdur) ($p = 0.004$, $d = 0.65$) • ↓ Pharyngeal area at rest (PAhold) ($p = 0.031$, $d = 0.48$)	• ↑ Maximum hyoid displacement (Hmax) (significantly higher in EMST group) ($F = 4.26$, $p = .040$) • ↓ Hyoid retention at the antero-superior position during swallowing (Hdur) (significantly lower in EMST group)($F = 15.134$, $p < .001$)
Voluntary cough measures	↑ Peak expiratory flow rate (PEFR) ($p = 0.030$, $d = 0.42$) ↑ Cough volume acceleration (CVA) ($p = 0.002$, $d = 0.64$)	• ↓ Compression phase duration (CPD) ($p = 0.031$, $d = 0.47$) • ↑ Peak expiratory flow rate (PEFR) ($p = 0.010$, $d = 0.57$) • ↑ Cough volume acceleration (CVA) ($p = 0.010$, $d = 0.57$)	None
Involuntary cough measures	• ↑ Peak expiratory flow rate (PEFR)($p = 0.032$, $d = 0.43$) • ↑ Cough volume acceleration (CVA) ($p = 0.003$, $d = 0.61$)	• ↓ Peak expiratory flow rise time (PEFRT)($p = 0.011$, $d = 0.61$) • ↑ Cough volume acceleration (CVA) ($p = 0.005$, $d = 0.69$)	None
Acoustic and aerodynamic voice measures	• ↑ Sound pressure level (SPL)- comfortable sustained vowel phonation($p = 0.001$, $d = 1.69$) • ↑ SPL reading ($p = 0.001$, $d = 1.56$) • ↑ SPL monologue ($p = 0.001$, $d = 1.19$) • ↑ Maximum pitch ($p = 0.002$, $d = 1.02$) • ↑ Pitch range ($p = 0.009$, $d = 0.76$) • ↑ Maximum Phonation Time ($p = 0.007$, $d = 0.49$) • ↑ Mean peak air pressure ($p = 0.022$, $d = 0.69$) • ↑ Aerodynamic efficiency ($p = 0.012$, $d = 0.79$)	• ↑ SPL comfortable sustained vowel phonation ($p = 0.011$, $d = 0.56$) • ↑ Mean peak air pressure($p = 0.002$, $d = 0.92$) • ↑ Aerodynamic power ($p = 0.030$, $d = 0.58$)	Significantly higher in LSVT LOUD® group • ↑ SPL comfortable sustained vowel phonation ($F = 12.37$, $p = .001$) • ↑ SPL reading ($F = 39.29$, $p < .001$) • ↑ SPL monologue ($F = 24.64$, $p < .001$) • ↑ Maximum pitch ($F = 9.828$, $p = .003$) • ↑ Pitch range ($F = 6.131$, $p = .018$) • ↑ Aerodynamic efficiency ($F = 4.407$, $p = .045$)
Self-reported questionnaires	• ↓ PDQ-8 ($p = 0.003$, $d = 0.97$) • ↓ EAT-10 ($p = 0.001$, $d = 0.73$) • ↑ CETI-M ($p = 0.004$, $d = 0.96$)	• ↓ PDQ-8 ($p = 0.009$, $d = 0.58$) • ↓ EAT-10 ($p = 0.031$, $d = 0.46$) • ↓ VHI-10 ($p = 0.003$, $d = 0.67$) • ↑ CETI-M ($p = 0.004$, $d = 0.65$)	None

Note. ↑ = significantly increased, ↓ = significantly reduced, d = Cohen's d effect size, PDQ-8 = Parkinson's Disease Questionnaire-8, EAT-10 = Eating Assessment Tool-10, VHI-10 = Voice Handicap Index-10, CETI-M = Communication Effectiveness Index-modified version.

Table V. Treatment delivery, adherence, challenges, and adaptive strategies.

	LSVT LOUD® ($n = 34$)	EMST ($n = 24$)
Treatment delivery mode	All in-person sessions ($n = 32$) Mixed sessions* (online + in person) ($n = 2$)	All in-person sessions ($n = 16$) Mixed sessions* (online + in person) ($n = 8$)
Challenges	• Fatigue for a 45–50 minute session ($n = 5$) • Poor posture ($n = 2$) • Lack of self-monitoring skills ($n = 2$) • Incompletion of homework activities/ less motivation to do the carryover task/ inability to track data ($n = 3$) • Mobility issues/ travel restrictions to attend the in-person session ($n = 2$)	• Incorrect use of the technique (air escaping/poor lip seal, poor monitoring) ($n = 3$) • Poor coordination of training steps ($n = 2$) • Poor posture ($n = 2$) • Difficulty in independent usage of the device (understanding the weekly threshold level, reading numbers on the EMST device, rotating the device) ($n = 3$) • Inability to track the number of sets in a session ($n = 1$) • Mobility issues/ travel restrictions to attend the in-person session ($n = 8$)
Adverse effects	• No severe adverse effects. Complaints of soreness when continuing several repetitions of daily sets (but got through with it by providing frequent breaks in-between and optimal hydration, no signs of hyper phonatory effects) ($n = 4$)	• Aggravated migraine symptoms and double vision (discontinued therapy) ($n = 1$)
Treatment adaptation strategies	• Visual cues/ modelling/ shaping techniques ($n = 8$) • Incorporating family member assistance ($n = 3$) • Daily brainstorming of the home tasks and carryover tasks completion ($n = 4$) • The flexibility of treatment days within a week (for most of the participants) • Incorporated appropriate strategies for hearing aid users ($n = 2$)	• Family member training to effectively use the EMST device and incorporate family member assistance, especially in the home independent sessions ($n = 5$) • One extra week of training ($n = 1$) (P036 couldn't complete 3/5 days of the first-week training) • Training instructions sheet/ visual step-by-step guidance/ additional cues ($n = 8$)
Treatment adherence	• Completion of 16 sessions, within four consecutive weeks($n = 32$, 95%) • Completion of 14 sessions ($n = 2$)	• Completion of 20 sessions (recorded in a training log), within four consecutive weeks ($n = 21$, 88%) • Completion of 16–18 sessions ($n = 3$)

Note. LSVT LOUD® = Lee Silverman Voice Treatment, EMST = Expiratory Muscle Strength Training. *Mixed sessions were used in times of COVID-19 lockdowns and where participants were unable to attend clinic due to transport issues.

to higher airflow in voluntary compared with reflexive cough (Reyes et al., 2018). Reyes et al. showed small effects on peak cough flow in voluntary cough following EMST (Reyes et al., 2018). The effects of EMST on reflexive cough strength measure remain to be further delineated.

Comparison between groups indicates both treatments improved VC and RC strength to a similar degree in individuals with mild-moderate PD severity. These measures suggest improved cough efficiency as greater PEFR contributes to: a) Increased ability to hold an increased amount of air in the lungs and improve vital capacity and b) possible improvement with laryngeal-respiratory subsystem coordination (Hegland et al., 2014). Similarly, improved RC CVA represents one's ability to detect and create enough shearing force to expel any material that accidentally enters the airway and thus is protective for the airway (Pitts et al., 2009).

Voice and speech production

The findings from the current study consolidate previously identified benefits of LSVT LOUD® therapy on voice. MPT, vocal intensity and pitch range indicate improvement in respiratory-laryngeal sub-system coordination, laryngeal stability during phonation, and increased respiratory drive for sustained speech (Fox et al., 2012; Ramig et al., 2001, 2004, 2018, Sapir et al., 2007, 2011; Smith et al., 1995). Following EMST therapy, which is not directly focused at voice change, a significant effect was demonstrated only in the SPL for comfortable sustained vowel phonation but not for other voice measures, suggesting a more modest benefit to vocal parameters. No participants in the EMST group received any instruction on their overall voice production. EMST does not address the sensory feedback deficit in monitoring speech that is a benefit of LSVT LOUD® therapy; and as a result, participants may not have been able to naturally utilise any benefits of improvement in motor capacity in voice production (Sapir et al., 2011). There is limited evidence published addressing the effectiveness of EMST therapy on voice function in PD. An 8 week trial of EMST training (Reyes et al., 2020) in 31 PD participants reported large effects on MPT and SPL for /pa/ syllable production. In another study (Darling-White & Huber, 2017), three of the 12 PD participants showed significant improvements in SPL and utterance length for spontaneous speech tasks after 4 weeks of EMST. Our current study participants were trained for 4 weeks only. Extension of the training period may have produced an increased positive effect on vocal intensity. While there was a lack of evidence supporting the improvement of objective voice measures following EMST, a significant reduction in VHI-10 and CETI scores were reported by participants undergoing EMST therapy, suggesting improved confidence levels in specific speaking situations with less perceived effort in voice production.

Limitations and future directions

Recruitment to the EMST treatment arm was affected by the COVID-19 pandemic. Although we aimed to recruit 34 participants, we were only able to recruit 24 participants for the EMST group. Participants also had a mixture of in-person and tele-therapy sessions due to lockdowns that enforced clinic closures. While tele-therapy has been previously established in both LSVT LOUD® and EMST (Sevitz et al., 2022; Theodoros & Ramig, 2011), this hybrid approach caused by the disruption of the COVID-19 pandemic does offer limitations in treatment equality. Additional participants may have enabled us to detect greater changes in measured parameters. The acoustic outcome measures collected (e.g. MPT) are also common therapeutic tasks in the LSVT LOUD® program and therefore participants in the LSVT LOUD® may have been primed to these tasks. Follow-up study data collection is still ongoing to provide information about durability of the effects identified. It was challenging recruiting participants with more severe disease expression due to COVID travel restrictions, mobility issues, other pre-existing comorbidities, and a participant's dependency on others to bring them to assessment and treatment sessions. Recruiting individuals with less severe symptoms limits the possible degree of change in variables following the intervention and our ability to detect change (Hutcheson et al., 2018). Thus, studies addressing the effects of LSVT LOUD® and EMST in *advanced* stages of PD with individuals with more advanced swallowing difficulties are needed.

The benefit of sequential or concomitant treatment with both LSVT LOUD® and EMST has not been studied and, as the therapies appear complementary, it is possible that synergistic benefits would be experienced whilst undergoing dual therapy. Whether this type of exercise loading is tolerable to participants or justified is unclear and is a subject for future consideration.

The duration or cumulative benefit of extended use of EMST training or indeed whether there may be a possible level of beneficial "maintenance" therapy needs to be explored. It is viable for individuals with PD to continue to use the EMST device, as this is a home-based therapy, and it is also possible to offer periodic short-block maintenance therapy of LSVT LOUD®. Further study to elucidate maintenance therapy levels and benefits would be useful.

Conclusion

This two-treatment clinical trial supports the beneficial effects of both LSVT LOUD® and EMST on specific objective swallow efficiency and cough strength measures despite significant differences in task and therapeutic dose. Only LSVT LOUD® improved vocal intensity. Treatments equally improved cough parameters. Both groups reported a perceived positive change in swallowing, voice, and communicative outcomes that lead to an overall improved quality of life. The detailed effects of the treatments may be useful in designing a symptom-based treatment planning approach. Considering both treatments are non-invasive, viable interventions, they can be chosen as rehabilitative, and/or supplementary therapy to improve swallow and cough in individuals with mild to moderate PD.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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