Rehabilitation of Airway Protection in Individuals with Movement Disorders: A Telehealth Feasibility Study

Jordanna S. Sevitz, MS, CCC-SLP[1], James C. Borders, MS, CCC-SLP[1], Avery E. Dakin, MS, CCC-SLP[1], Brianna R. Kiefer, MS, CCC-SLP[2], Roy N. Alcalay, MD, MS[3,4], Sheng-Han Kuo, MD[3], Michelle S. Troche, PhD, CCC-SLP[1,3]

[1]Laboratory for the Study of Upper Airway Dysfunction, Department of Biobehavioral Sciences, Teachers College, Columbia University, New York, NY, USA

[2]Department of Speech, Language, and Hearing Sciences, Purdue University, West Lafayette, IN, USA

[3]Department of Neurology, Columbia University Irving Medical Center, New York, NY, USA

[4]Tel Aviv Sourasky Medical Center, Department of Neurology, Tel Aviv, Israel

Corresponding Author:
Michelle S. Troche, PhD, CCC-SLP
Email: mst2139@tc. columbia.edu

Abstract

Purpose: Airway protective deficits (swallowing and cough) greatly reduce health and quality of life and are a pervasive consequence of neurodegenerative movement disorders. Expiratory muscle strength training (EMST) and cough skill training (CST) are two treatment approaches to improve airway protection; however, many patients are unable to access these treatments. Telehealth may improve access to care, but it remains unknown whether these treatments are feasible and efficacious via telehealth. This study aimed to determine the practical feasibility and preliminary treatment effect of EMST and CST via telehealth.

Method: Twenty participants with movement disorders completed four weeks of EMST and two weeks of CST, including two clinician directed treatment sessions via telehealth and three days of home practice per week. Feasibility was calculated for each treatment. Practical feasibility was defined as completing treatment (EMST or CST) and obtaining the relevant outcome measures - a proxy of maximum expiratory pressure (pMEP) for EMST and peak expiratory flow rate (PEFR) for CST – within a 30-minute session/period. Session factors that may have influenced feasibility were examined. Preliminary treatment effect was defined as changes in pMEP and PEFR.

Results: Time taken to obtain pMEP and complete EMST was 17.48 minutes and to obtain PEFR and complete CST was 17.69 minutes. pMEP, single voluntary cough PEFR, and sequential voluntary cough PEFR increased from pre- to post-treatment.

Conclusions: Findings suggest that the delivery of EMST and CST is feasible via telehealth and yield improvements to pMEP and PEFR. This has important implications for expanding service delivery of airway protective interventions and reducing healthcare disparities in people with neurodegenerative movement disorders.

Introduction

Airway protective deficits are a pervasive consequence of neurogenerative movement disorders and fall on a continuum from disordered swallowing to disordered cough (Troche, Brandimore, Godoy, et al., 2014). In fact, swallowing and cough function have been shown to decline together in neurodegenerative populations (Ebihara et al., 2003, 2016; Pitts et al., 2008, 2010; Plowman, Watts, Robison, et al., 2016; Silverman et al., 2016; Tabor-Gray et al., 2020; Troche, Brandimore, Okun, et al., 2014; Troche et al., 2016) and may be attributed to motor impairments (e.g., strength, coordination), sensory impairments, or both (Clark et al., 2020; Vogel et al., 2015; Walshe, 2014). This results in multifactorial deficits across the continuum of airway protective function. Cough impairments often include increased cough motor and sensory thresholds (Tabor-Gray et al., 2020; Troche, Brandimore, Okun, et al., 2014), reduced perception of cough stimuli (Troche et al., 2016), reduced voluntary cough strength (Aiello et al., 2008; Ebihara et al., 2016; Hegland et al., 2014; Tabor-Gray et al., 2019), and peripheral weakness of the respiratory muscles (Aiello et al., 2008; Haas et al., 2004). Swallowing impairments include a wide range of deficits across oral and pharyngeal phase swallow function (Clark et al., 2020; Vogel et al., 2015; Walshe, 2014), with a high prevalence of silent aspiration, particularly in later disease stages (Bianchi et al., 2012; Kaneoka et al., 2018; Marik & Kaplan, 2003; Plowman, Watts, Robison, et al., 2016; Sohn et al., 2018; Troche, Brandimore, Okun, et al., 2014). This frequently results in decrements to quality of life such as reduced mealtime enjoyment and social isolation (Marik & Kaplan, 2003; Rogus-Pulia & Plowman, 2020; Rönnefarth et al., 2020; Takizawa et al., 2016), as well as significant health consequences including malnutrition, dehydration, and aspiration pneumonia (Bakheit, 2001; D'Amelio et al., 2006; Fall et al., 2003; Kaneoka et al., 2018; Marik & Kaplan, 2003; Ortega et al., 2017; Takizawa et al., 2016).

Moreover, aspiration pneumonia is a leading cause of death in neurodegenerative disease (Akbar et al., 2015; D'Amelio et al., 2006; Fall et al., 2003; Heemskerk & Roos, 2012; Nakashima et al., 2018). Given the significant and detrimental impact on both health and quality of life, addressing airway protective dysfunction in individuals with degenerative movement disorders is critical.

Traditional management of airway protective dysfunction in neurodegenerative populations with movement disorders has focused on compensatory strategies and functional adaptations (Bakheit, 2001; Clavé et al., 2006; Ortega et al., 2017; Rogus-Pulia & Plowman, 2020; Sura et al., 2012). Further, these interventions are often initiated later in the disease course, once airway protection is already significantly compromised (Rogus-Pulia & Plowman, 2020; Walshe, 2014). However, a growing body of literature supports the efficacy and importance of exercise-based interventions to target airway protective dysfunction in neurodegenerative disease (Argolo et al., 2013; Athukorala et al., 2014; Chiara et al., 2006; Malandraki et al., 2012, 2016; Miles et al., 2017; Pitts et al., 2009; Plowman et al., 2019; Reyes et al., 2015; Rogus-Pulia & Plowman, 2020; Sura et al., 2012; Troche et al., 2010; Tye et al., 2021) with an emphasis on the need for early intervention to maintain and/or improve function (Rogus-Pulia & Plowman, 2020). Two treatment approaches that have demonstrated preliminary efficacy to rehabilitate cough and swallowing in neurodegenerative diseases are expiratory muscle strength training (EMST) (Chiara et al., 2006; Pitts et al., 2009; Plowman et al., 2019; Reyes et al., 2015, 2018, 2020; Troche et al., 2010; van de Wetering-van Dongen et al., 2020) and cough skill training (CST) (Borders, Curtis, et al., 2021; Brandimore et al., 2017; Curtis et al., 2020). EMST has been utilized in Parkinson's disease (PD), multiple sclerosis (MS), Huntington disease (HD), and amyotrophic lateral sclerosis (ALS) (Chiara et al., 2006; Pitts et al., 2009; Plowman et al., 2019; Reyes et al., 2015; Troche et al., 2010) with positive treatment outcomes. Across these

populations, EMST treatment has resulted in improved maximum expiratory pressure (MEP) (Chiara et al., 2006; Kuo et al., 2017; Plowman et al., 2019; Plowman, Watts, Tabor, et al., 2016; Reyes et al., 2015), improved cough effectiveness (Chiara et al., 2006; Kim et al., 2009; Pitts et al., 2009; Reyes et al., 2015, 2018, 2020), and less frequent airway invasion during swallowing (Claus et al., 2021; Guillén-Solà et al., 2017; Moon et al., 2017; Pitts et al., 2009; Troche et al., 2010). CST has more recently been identified as an approach to specifically target cough effectiveness, with preliminary treatment outcomes that have demonstrated improved cough effectiveness in PD and progressive supranuclear palsy (PSP) (Borders, Curtis, et al., 2021; Curtis et al., 2020). Positive treatment effects include increased single voluntary, sequential voluntary, and reflex cough peak expiratory flow rate (PEFR) (Curtis et al., 2020), as well as increased inspiratory volume and compression phase duration (Borders, Curtis, et al., 2021), and decreased PEFR variability after training (Borders, Curtis, et al., 2021; Curtis et al., 2020).

Despite the benefits of airway protective interventions such as EMST and CST in neurodegenerative disease, utilization of speech-language pathology (SLP) services, which includes management of airway protective dysfunction, is extremely low. In a study of Medicare beneficiaries with PD, as few as 14.6% accessed SLP services (Fullard et al., 2017). Geographic distance from specialist providers (Elson et al., 2018), impaired driving (Crizzle et al., 2012; Schneider & Biglan, 2017), and caregiver burden (Beck et al., 2017; Mosley et al., 2017) have been identified as barriers to accessing treatment. Telehealth has been shown to address many of these barriers, expand provision of services, and reduce widening disparities in healthcare delivery across many neurodegenerative populations (Dorsey et al., 2010, 2020; Haulman et al., 2020; O'Hara & Jackson, 2017; Schneider & Biglan, 2017; Turner et al., 2013; Weidner & Lowman, 2020). A recent survey of 1,342 persons with PD revealed a large increase in

utilization of telehealth across allied healthcare during the coronavirus pandemic (Feeney et al., 2021). Further, almost half of the survey respondents reported that they would like to continue using telehealth after the pandemic. Despite the increased uptake in telehealth, only 7.9% of respondents accessed telehealth SLP services during this time (Feeney et al., 2021). A clear finding from this survey was that there is an urgent need for expansion of SLP telehealth services (Feeney et al., 2021). However, in order to provide efficacious services, more research is needed to understand best practices for the delivery of airway protective management via telehealth in people with neurodegenerative movement disorders.

The feasibility and utility of managing dysphagia via telehealth more generally has been defined in the literature (Borders, Sevitz, et al., 2021; Burns et al., 2017, 2019; Cassel, 2016; Collins et al., 2017; Kantarcigil et al., 2016; Kantarcigil & Malandraki, 2017; Malandraki et al., 2013, 2021; Malandraki & Kantarcigil, 2017; Morrell et al., 2017; Nordio et al., 2018; Sharma et al., 2013; Wall et al., 2020; Ward et al., 2012a, 2012b; Ward & Burns, 2014). These studies have demonstrated that clinical swallowing evaluations are feasible, reliable, and valid when performed via telehealth (Burns et al., 2019; Morrell et al., 2017; Sharma et al., 2013; Ward et al., 2012a, 2012b). Emerging evidence also suggests that swallowing interventions can be implemented across patient populations via telehealth (Cassel, 2016; Collins et al., 2017; Constantinescu et al., 2021; Nordio et al., 2018; Shinn et al., 2019; Starmer et al., 2018; Wall et al., 2020). In the head and neck cancer population, studies have demonstrated feasibility of and adherence to dysphagia exercises such as the effortful swallow, Mendelsohn maneuver, effortful pitch glides, Masako tongue hold, and jaw stretches, with improved quality of life following treatment (Constantinescu et al., 2021; Starmer et al., 2018). One small case series identified that managing compensatory swallowing strategies (e.g., chin tuck, head turn) was feasible via

telehealth for patients with neurogenic dysphagia following a cerebrovascular accident or traumatic brain injury (Cassel, 2016). Recently, it has been identified that utilizing an asynchronous telehealth model to provide swallowing exercises was equivalent to in-person service delivery in a large cohort of patients with diverse diagnoses, including those with neurologic disease (Bascuñana-Ambrós et al., 2021) and most recently, an application has been developed to track adherence of EMST when completed at home (Srp et al., 2021). However, to our knowledge, there have been no studies that have explored the feasibility of delivering EMST and CST via telehealth in patients with neurodegenerative movement disorders.

Therefore, the primary goal of this study was to determine the initial feasibility of EMST and CST via telehealth in patients with neurodegenerative movement disorders. Given the protocols and devices used for EMST and CST, we felt that the first step in assessing feasibility was to determine whether these treatments could practically be completed via telehealth in a typical treatment session. Practical feasibility explores the extent to which an intervention can be delivered under practical constraints (Bowen et al., 2009). Given that telehealth constrains the way in which clinicians can physically manipulate the devices and physically support patients, we utilized a practical feasibility lens and considered whether each treatment could be completed within 30 minutes – within the typical duration of a treatment session. Based on United States clinical practice standards, 30 minutes represents a typical treatment session duration. To further understand feasibility, we explored several session factors that may have influenced telehealth delivery to determine any future enhancements required to the telehealth model. Additionally, another important component of feasibility is limited-efficacy testing, in which outcomes are assessed in a limited and preliminary way (Bowen et al., 2009). To this end, we tested the

preliminary treatment effect of EMST and CST via telehealth by examining the change in key treatment outcomes – pMEP and PEFR.

Methods

Participants

Twenty participants enrolled in the study and were consecutively recruited via physician referrals from the [blinded for review] University Medical Center Movement Disorders Division of the Neurology Department. Inclusion criteria were: (1) at least 18 years of age, (2) a diagnosis of a neurodegenerative disease by a Movement Disorders fellowship-trained neurologist, (3) Internet connection, and (4) a device (e.g., cellphone, tablet, laptop, desktop) with audio and video capability. Exclusion criteria included: (1) history of other neurologic diagnoses unrelated to the primary diagnosis (e.g., stroke), (2) EMST-related exclusion criteria including smoking, respiratory conditions, heart disease, uncontrolled hypertension, recent surgeries, and any other head/neck conditions, (3) the inability to use videoconferencing software independently or with assistance from a caregiver, and (4) inability to follow commands for participation in behavioral therapy. There was no minimum internet bandwidth required. Exclusion criteria was broad to allow for generalization about feasibility across diverse participant factors. This study was approved by the Institutional Review Board from (blinded for review) and electronic informed consent was obtained from all participants.

Information was obtained regarding diagnosis and disease duration from the referring neurologist. All participants completed the Mini Mental State Exam (MMSE), which has shown acceptable reliability via telehealth (McEachern et al., 2008), at initial assessment to determine cognitive status. To allow for inclusion of participants with varying cognitive abilities, we did not exclude participants based on MMSE scores. We obtained these scores to provide an

accurate description of cognitive functioning in our cohort of participants. It was recommended that a caregiver/facilitator be present during telehealth sessions; however, it was not required given that both treatments have been found to be safe, do not involve eating/drinking, and this would reduce clinical translation to participants that live independently.

Study Design

Participant Preparation. In an initial phone call prior to study initiation, prospective participants were asked whether they had a device with audio and video capability that they could use for treatment (e.g., their iPhone, iPad, laptop). All prospective participants stated they had an appropriate device. Given recent findings to suggest that telehealth clinical assessment of dysphagia is feasible with varying devices and internet speeds (Borders et al., 2021), we did not standardize or track device use or internet speed in this study. Participants were provided written instructions (via email) on downloading the Zoom application (if they did not already have it) and were provided a secure, unique link for their treatment sessions. They were given written instructions (via email) to click the link to enter their session and were given the clinician's contact information if they needed assistance. Of note, given the timing of this study (during the coronavirus pandemic), all participants were referred by their neurologist to participate in this study following a virtual neurology consult. Thus, all participants had experience with telehealth for at least one neurology appointment. Participants were instructed (via email and at the start of the first session) to sit upright and position their camera to provide a direct view of their face and upper torso. Participants were asked not to move their camera angle or position throughout the session. EMST-150 (Aspire products, LLC, USA) and peak flow meter (Omron PF9940 PeakAir Peak Flow Meter, USA) devices were sent to participants' homes. These devices were used to obtain key outcomes of pMEP and PEFR and complete training exercises. Participants received

written instructions and a video tutorial explaining the devices and their uses, with additional training provided by the clinician in the first session. Ongoing support for device use was provided by the clinician, as necessary.

Clinician Preparation. All SLP clinicians received specialized training with an experienced researcher-clinician, which included a basic orientation to the telehealth platform (Zoom), session practicalities (e.g., recording the session, obtaining emergency contact information), and the treatment protocol. All study clinicians had experience using Zoom and administering the treatments. Clinicians were given the EMST-150 and peak flow meter devices to provide visual modeling to participants.

Treatment Design. Participants completed four weeks of EMST and two weeks of CST. Treatment consisted of two telehealth sessions and three days of independent home practice per week (for a total of five training days per week; Figure 1). Participants were given exercise logs to track home practice exercises. Adherence was not a primary outcome of this study, however, for participants who returned exercise logs, adherence was calculated as the number of home exercise repetitions completed over the total number of home exercise repetitions prescribed. Fifteen participants began EMST and CST together and five completed two weeks of EMST before beginning CST. An effort was made to schedule telehealth sessions during the "on" phase in medication cycle, when applicable (i.e., for participants with PD). pMEP and cough PEFR were the key treatment outcomes for EMST and CST, respectively, and were obtained prior to treatment initiation, at the start of each treatment week, and following treatment completion. pMEP and PEFR were used to set weekly EMST and CST training targets and to measure treatment effects. During telehealth sessions participants completed EMST and CST training

with specific feedback regarding task performance from the clinician and augmented by feedback from the device (i.e., audible burst of air during EMST, visual target during CST).

The sessions were either delivered by a certified SLP or by an SLP Master's student with 100% supervision from an experienced SLP clinician via Zoom, a videoconferencing platform (Zoom Video Communications Inc, 2016), were recorded in real-time, and stored to a secure server. At the conclusion of each session, the clinician documented whether a care-partner was present and the percentage of the session that the care-partner was present for. The clinician also documented any treatment- or assessment-related safety concerns. As an additional safety precaution, the treating clinician had the participants' emergency contact numbers as well as participants' local emergency response numbers available during the session.

Figure 1: Treatment Protocol and Devices

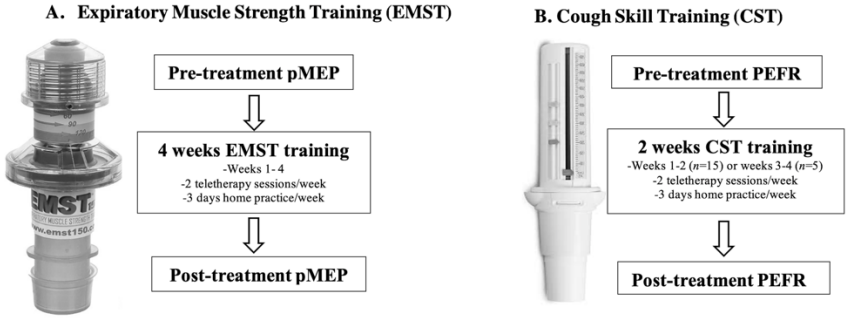

Figure 1 Caption: Participants completed EMST and CST treatment. pMEP: proxy of Maximum Expiratory Pressure; PEFR: Peak Expiratory Flow Rate.

Expiratory Muscle Strength Training (EMST)

Proxy measure of Maximum Expiratory Pressure (pMEP). Maximum expiratory pressure is a measure used to quantify the force generating capacity of the expiratory muscles. The gold standard is that MEP be obtained using a respiratory manometer (per the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines); however, it is not

financially feasible to send this equipment to patients' homes to obtain MEP with a manometer via telehealth. Therefore, a proxy measure of the strength of the expiratory muscles was obtained using the EMST-150 device (Figure 1). This measure provided a measure of baseline function, a guide to set the EMST training level, and a means to track change over time. We refer to this measure as a proxy for MEP (i.e., pMEP). The EMST-150 device ranges from 30 to 150 cm H_2O and contains a one-way spring-loaded valve which blocks airflow until a sufficient "threshold" pressure is produced to overcome the force and open the valve. To obtain pMEP, a slightly modified version of the "quarter turn" method outlined by Aspire products was used (*EMST150 Instructional Video*, 2021). To begin, participants were instructed to sit comfortably in a chair and set their EMST-150 device to the lowest resistance level by turning the device to the lowest setting. Participants were then instructed to occlude the nose with nose clips, take a big breath in, make a tight seal around the mouthpiece, and blow forcefully into the device. Verbal instructions and a visual model were provided by the clinician. If the participant could generate sufficient force to successfully open the valve inside the device, they were instructed to increase the resistance by turning the device one full turn clockwise. This procedure was repeated until the participant could no longer blow with sufficient force to open the valve. At that point, the dial was turned back (i.e., counterclockwise) one half turn. If the participant was able to open the valve, they were instructed to increase the resistance by one quarter turn; if unable to open the valve, the participant was instructed to decrease the resistance by one quarter turn. pMEP was defined as the highest threshold at which the participant was able to open the valve of the EMST-150 device. The number of turns on the EMST-150 device was converted to pMEP values to reflect the amount of resistance in cmH_2O. To determine this, the numbers on the EMST-150 device (i.e., 30, 60, 90, 120) were used as a guide and to ensure reliability, the number of turns

were counted and calculated as follows: lowest resistance = 30 cmH_2O, one turn = 45 cmH_2O, two turns = 60 cmH_2O, three turns = 75 cmH_2O, four turns = 90 cmH_2O, five turns = 120 cmH_2O, and six turns = 150 cmH_2O.

EMST Exercises. EMST exercises were completed using the same EMST-150 device and the resistance training level was set each week to approximately 75% of the participant's pMEP (Troche et al., 2010). To complete a training breath, participants were instructed to: (1) put on nose clips, (2) take a big breath in, (3) wrap their lips tightly around the mouthpiece of the device, and (4) exhale quickly and forcefully until they heard the popping or whistling sound of the valve opening. Five sets of five successful trials were completed per session (totaling 25 breaths per session).

Cough Skill Training (CST)

Cough Peak Expiratory Flow Rate. Cough peak expiratory flow rate (PEFR) was obtained using a hand-held analog peak flow meter (Silverman et al., 2014), with measurements ranging from 60 to 750 L/min (Omron PF9940 PeakAir Peak Flow Meter; Figure 1) in 10-unit increments. If a participant's PEFR was between two lines, it was visually determined to which line it was closest, and that served as the PEFR. Participants were instructed to take a big breath and "cough strong" (single) or "cough as if something went down the wrong pipe" (sequential) into the device. Verbal instructions and a visual model were provided by the clinician. Three trials of single coughs followed by three trials of sequential coughs were completed. For each trial, PEFR was read by the participants and shown to the clinician for visual confirmation. If there was any disagreement, PEFR was determined by the clinician. In cases where the participant could not read the PEFR value and a care-partner was not present, the clinician made a determination from visualization. PEFR was obtained at the beginning of each week and

training targets were set based on the maximum of the three PEFR trials for single and sequential cough, respectively. However, for analysis, all three trials were included in multilevel statistical analyses.

CST Exercises. CST exercises were completed utilizing the same peak flow meter used to measure PEFR. A target was set at 25% above the participant's maximum baseline PEFR for single and sequential coughs. A small dial on the side measured the amount of air which entered the device and provided a measure of PEFR for each trial. Practice included single coughs to primarily target strength and sequential coughs to target coordination (Ebihara et al., 2003; Fontana & Lavorini, 2006; Hegland et al., 2013). Both strong and weak coughs were also incorporated into practice given literature to suggest that variable practice enhances motor learning (Levin & Demers, 2020; Muratori et al., 2013). Participants were instructed to use the color markings on the side of the peak flow meter to mark their single and sequential cough training targets; 25% above baseline for "strong" cough practice and 25% below baseline for "weak" cough practice. Participants were instructed to: (1) take a big breath in, (2) wrap lips tightly around the mouthpiece of the device, and (3) cough into the device, aiming for your target; either a "strong" cough or a "weak" cough. Five sets of five coughs were completed (totaling 25 coughs per session). These sets were divided into two sets of single strong coughs, one set of single weak coughs, one set of sequential strong coughs, and one set of sequential weak coughs.

Outcome Measures

Practical Feasibility

The practical feasibility of EMST was defined as obtaining a proxy measure of MEP (pMEP) and completing EMST treatment within 30 minutes and the practical feasibility of CST

was defined as obtaining voluntary cough PEFR and completing CST treatment within 30 minutes. Time taken to obtain pMEP and PEFR was calculated from video recordings of the first session in which they were obtained (i.e., prior to treatment initiation). Time taken to complete each treatment (EMST and CST) was calculated from video recordings of the first treatment session in which all exercises were completed. We also calculated the time it took to complete exercises and obtain pMEP and PEFR after two weeks of treatment to see if efficiency improved. Time included task instructions and necessary cueing to complete the tasks.

Session Factors Influencing Feasibility

Based on extensive experience with in-person EMST and CST delivery and the challenges that typically occur when training patients to perform EMST correctly, we identified four key session factors that we thought may impact telehealth feasibility. These were: (1) patient factors impacting trial success, (2) technology-related issues, (3) clinician-directed facilitatory supports, and (4) care-partner-directed facilitatory supports. To identify these key session factors, the same assessment and treatment sessions that were used to determine practical feasibility and treatment effect (at baseline, mid-treatment, and post-treatment) were reviewed as a representative sample of sessions.

Preliminary Treatment Effect

EMST treatment effect was measured by pre-post treatment changes in pMEP, as measured prior to training, after two weeks of training, and after four weeks of training. CST treatment effect was measured by pre-post treatment changes in single and sequential voluntary cough PEFR, as measured pre-training and after two weeks of training.

Statistical Analysis

Statistical analyses were completed using R version 4.0.1 (R Core Team, 2018). Two-way random effects (single measure, absolute agreement) intra-class correlation coefficients (ICCs) were computed for the primary feasibility outcome to determine intra- and inter-rater reliability of the offline measurement of *time to complete training*. To determine treatment effect, pre-post treatment changes in pMEP were analyzed using paired sample t-tests – comparisons were made pre to post two weeks of training, pre to post four weeks of training, and post two weeks to post four weeks of training. Pre-post treatment changes in single and sequential voluntary cough PEFR were analyzed using linear multilevel models with participant as a random factor and time as a fixed factor. Cohen's *d* was used to determine t-test effect sizes and Cohen's d with pooled variances was used for multilevel models (Westfall et al., 2014). To facilitate future meta-analyses, we report Pearson's r correlation coefficients for the treatment effect of pMEP and multilevel correlation coefficients for the treatment effect of PEFR. Holm-Bonferroni adjustments were used for multiple comparisons within each treatment outcome (i.e., three comparisons for pMEP; two comparisons for PEFR) and adjusted p-values are reported. Statistical significance was set at $p < 0.05$.

Session factors influencing telehealth feasibility

A directed content analysis (Hsieh & Shannon, 2005) was used to identify session factors that may have influenced treatment feasibility. Following study completion, a rater unfamiliar with the participants reviewed videos of the same assessment and treatment sessions that were used to determine feasibility, documenting and categorizing all (1) patient factors impacting trial success, (2) technology-related issues, (3) clinician-directed facilitatory supports, and (4) care-partner-directed facilitatory supports. Within each of the four defined categories, a list of barriers/facilitations was compiled. The list was refined by the primary researcher who

consolidated all items into clusters that represented the underlying barriers/facilitators documented and determined a code for each barrier/facilitator cluster. The number of participants for whom each "session factor" occurred is reported. To ensure rigor and trustworthiness, inter-rater reliability was assessed (Morse, 2015). A second rater who was unfamiliar with the study reviewed 20% of the sessions, following an identical process to rater one – documenting and categorizing barriers and facilitators. Inter-rater reliability between the two raters was calculated as percent absolute agreement of session factors listed.

Results

Twenty participants (4 females, 16 males; age 48 - 83; disease duration 0.17 - 42 years) completed four weeks of EMST and two weeks of CST (Table 1). Participant diagnoses included PD (n =12), Lewy body dementia (LBD; n = 2), multiple system atrophy-cerebellar (MSA-C; n = 4); and cerebellar ataxia not otherwise specified (n = 2). MMSE scores ranged from 23-30, excluding one participant who could not complete the MMSE due to visual impairment. Eight participants had care-partners who were present during the sessions. Whether care-partners were present at each session and the percentage of the session for which they were present is documented in Table 2. Further information regarding the ways in which care-partners assisted is detailed in Table 3. For all participants (n=6) who returned exercise logs at the conclusion of treatment, adherence was above 90%. Due to missing video recordings secondary to researcher error, initial MEP duration could not be calculated for participants 12 and 17, initial PEFR duration could not be calculated for participant 17, and EMST and CST treatment duration from the first session could not be calculated for participant 17. For these two participants, practical feasibility data regarding MEP, PEFR, EMST, and/or CST duration were obtained from a subsequent session and are reported descriptively. Participant 18 did not complete all treatment

exercises. All participants were included in the preliminary treatment effect analyses. No safety concerns were documented during the assessment and treatment sessions.

Table 1. Participant Demographics

ID	Sex	Age	Primary Diagnosis	Disease duration (yrs)	MMSE Score / 30	Care-partner
1	Male	78	PD	9	30	No
2	Female	61	PD	11	16/22*	Yes
3	Male	81	PD	12	25	Yes
4	Female	74	DLB	2	23	Yes
5	Male	65	PD	8	29	No
6	Male	75	PD	4	26	Yes
7	Male	66	PD	0.17	24	Yes
8	Male	82	DLB	4	25	Yes
9	Male	60	MSA-C	1	30	No
10	Male	75	PD	10	26	No
11	Male	62	MSA-C	3	30	No
12	Male	76	PD	10	30	No
13	Female	67	PD	4	30	No
14	Male	73	PD	2	29	No
15	Male	79	PD	5	25	No
16	Female	49	Idiopathic CA	10	28	No
17	Male	56	MSA-C	4	30	No
18	Male	63	MSA	9	25	Yes
19	Male	48	CA	42	29	No
20	Male	83	PD	0.58	30	Yes

MMSE: Mini-mental state exam; PD: Parkinson's disease; DLB: Dementia with Lewy bodies; MSA-C: Multiple systems atrophy-cerebellar subtype; CA: Cerebellar ataxia; N/A: Not administered/available

*Unable to complete all components of MMSE due to visual impairment

Table 2. Caregiver Presence During Treatment Sessions

ID	Caregiver Present at the Session (Percent of Time Present)							
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
2	Yes (100)	Yes (100)	Yes (100)	Yes (95)	Yes (90)	Yes (80)	Yes (80)	Yes (80)
3	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (40)	Yes (100)	Yes (5)
4	Yes (100)	Yes (60)	Yes (75)	Yes (67)	Yes (75)	Yes (75)	Yes (65)	Yes (60)
6	Yes (25)	Yes (5)	No	No	No	No	No	No
7	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	No	Yes (100)	Yes (98)
8	Yes (100)	Yes (100)	Yes (95)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)

18	Yes (100)	Yes (100)	Yes (90)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)
20	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (100)	Yes (75)	Yes (100)

Table 3. Type of Care-Partner Involvement at Key Assessment and Treatment Sessions for Participants who had Care-Partners

ID	Session	Care-Partner Assistance	Type of Care-Partner Assistance					
			Rotating EMST device	Repeating instructions/providing verbal cues or encouragement	Holding participants' cheeks to obtain lip seal	Adjusting participant posture	Tracking data	Reading numbers on the peak flow meter
2	Pre	Yes	X				X	
	Mid	Yes	X					
	Post	Yes	X					
3	Pre	Yes	X		X	X		
	Mid	Yes	X	X		X		
	Post	Yes	X	X	X	X		X
4	Pre	Yes	X	X				
	Mid	Yes		X	X			X
	Post	Yes	X			X		X
6	Pre	No						
	Mid	No						
	Post	No						
7	Pre	No						
	Mid	Not present						
	Post	Not present						
8	Pre	Yes	X		X			
	Mid	Yes	X	X	X			
	Post	Yes	X	X	X			
18	Pre	Yes	X					X
	Mid	Yes	X					
	Post	Yes	X					
20	Pre	Yes	X	X			X	
	Mid	Yes	X					
	Post	Yes		X				X

Pre includes obtaining pMEP and PEFR, initial setting of EMST/CST devices, and first training session. Mid includes obtaining pMEP and PEFR, re-setting of devices, and training session. Post includes obtaining pMEP and PEFR.
EMST: Expiratory Muscle Strength Training; CST: Cough Skill Training; pMEP: proxy of Maximum Expiratory Pressure; PEFR: Peak Expiratory Flow Rate.

Practical Feasibility

EMST

The average time taken to obtain pMEP pre-treatment was 10.40 minutes (SD 8.45) and time taken to complete EMST exercises in the first treatment session was 7.08 minutes (SD 3.04). For those who could not be included in the quantitative feasibility analysis due to missing video recordings, MEP durations from a later session were 5.06 minutes (participant 12) and 9.66 minutes (participant 17) and EMST duration was 6.58 minutes (participant 17). Participant 18 did not complete all EMST exercises in any session.

Reliability

ICCs for the time taken to obtain MEP were 0.993 for intra-rater reliability and 0.993 for inter-rater reliability. ICCs for the time taken to complete EMST were 0.992 for intra-rater reliability and 0.996 for inter-rater reliability.

CST

At pre-treatment, the time taken to obtain PEFR was an average of 4.79 minutes (SD 2.43) and time taken to complete CST exercises in the first treatment session was 12.90 minutes (SD 5.69). For one participant who could not be included in the quantitative feasibility analysis due to a missing video recording, CST duration from a subsequent session was 7.23 minutes (participant 17). Participant 18 did not complete all CST exercises in any session.

Reliability

ICCs for the time taken to obtain PEFR were 0.819 for intra-rater reliability and 0.888 for inter-rater reliability. ICCs for the time taken to complete CST were 0.957 for intra-rater and 0.977 for inter-rater.

Preliminary Treatment Effect

EMST

Mean pMEP prior to treatment was 65.6 cm H_2O (SD = 24.5) and significantly increased to 83.6 cmH_2O (SD = 27.2) after two weeks of training ($t(19)$=6.02; $p < .001$, $d = 1.35$). The correlation between pMEP at pre-treatment and after two weeks of training was r = 0.871 ($p <$ .001). pMEP further increased to 87.4 cm H_2O (SD = 31.4) after an additional two weeks of treatment (i.e., a total of four weeks); however, the additional increase in pMEP between two and four weeks of training was not significant ($t(19)$= -1.33; $p = .198$, $d = 0.298$). The correlation between pMEP after two weeks of training and after four weeks of training was r = 0.918 (p <.001). The overall improvement from pre- to post four weeks of treatment was significant ($t(19)$ = 4.93; $p < .001$, $d = 1.13$) (Figure 2). The correlation between pMEP from pre-post four weeks of treatment was r = 0.78 (p <.001).

Figure 2: Change in proxy of Maximum Expiratory Pressure (pMEP) Pre-Post Treatment

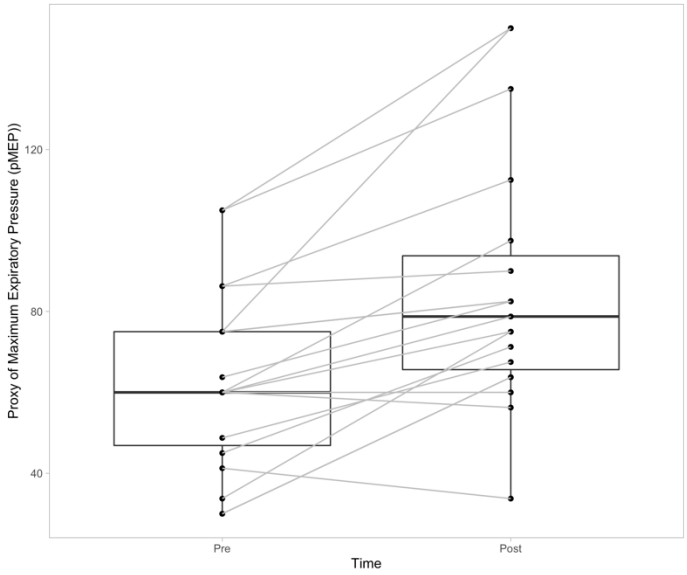

Figure 2 Caption: pMEP increased after four weeks of EMST training. Pre = pre-treatment. Post = post-four weeks of treatment.

CST

Mean PEFR for single voluntary coughs pre-treatment was 293 L/min (SD = 108) and significantly increased to 350 L/min (SD = 127) post-treatment ($t(97.13) = 5.68, p < .001, d = 1.15$). The correlation between single voluntary cough PEFR at pre and post treatment was r = -0.26 ($p = .052$). Mean PEFR for sequential voluntary coughs pre-treatment was 284 L/min (SD = 106) and significantly increased to 331 L/min (SD 132) post-treatment ($t(83.62) = 7.14, p < .001, d = 1.56$) (Figure 3). The correlation between sequential voluntary cough PEFR at pre and post treatment was r = -0.43 ($p = .003$).

Figure 3: Change in Peak Expiratory Flow Rate (PEFR) Pre-Post Treatment

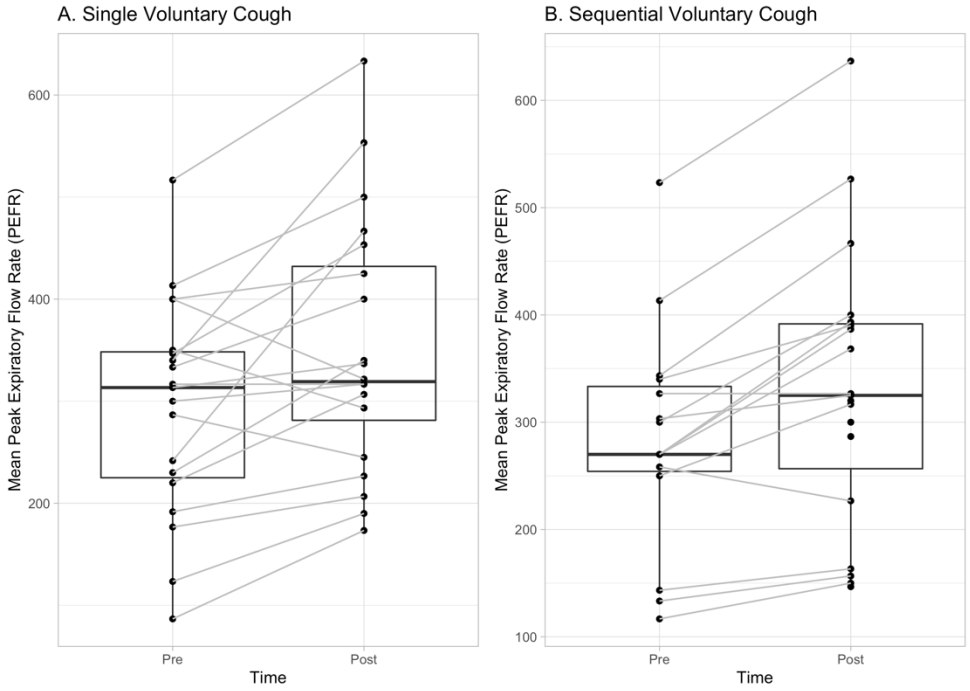

Figure 3 Caption: PEFR increased after two weeks of CST training. Pre = pre-treatment. Post = post-two weeks of treatment. This figure uses the mean PEFR for each participant to allow for clearer visual representation of within-participant data.

Session Factors Influencing Feasibility

Qualitative analysis revealed several patient factors impacting EMST/CST trial success, such as difficulty with lip seal, positioning, achieving an adequate breath, and sequencing the steps required to complete the exercise (Table 4). The primary technology-related issue

identified was momentary audio/video freezing, which impaired clinician ability to determine if a trial was successful. Additionally, one participant had difficulty reading the numbers on the peak flow meter and the clinician had difficulty visualizing the numbers when the patient held the device up to the screen. Clinician-directed facilitatory supports included providing additional modeling and instructions and incorporating care-partner support. Care-partner-directed facilitatory supports most commonly included rotating the EMST-150 device to set the training target, holding the participant's cheeks to prevent air escape around the EMST-150 device, and reading the numbers on the peak flow meter. When care-partners were not present, clinician-directed facilitatory supports were frequently repeated (e.g., provided another visual model) or adapted (e.g., re-phrased the instructions, provided more specific cueing, used an analogy such as "bear down like you're lifting weights") to facilitate target success. The number of participants for whom each "session factor" occurred can be found in Table 4. Inter-rater reliability (percent absolute agreement) of session factors identified from the three key sessions for each participant was ≥80% (patient factors impacting trial success = 82.4%; clinician-directed facilitatory supports = 80%; care-partner-directed facilitatory supports = 92.3%; technology-related issues = 100%). None of the above session factors prevented successful treatment delivery. The one participant for whom feasibility was questionable is described below in the discussion section.

Table 4: Session Factors Influencing Feasibility

Patient-factors impacting trial success	**Clinician-directed facilitatory supports**	**Care-partner directed facilitatory supports**	**Technology-related issues**
Inadequate lip seal/air escaping (n=15)	Additional visual model (n=5)	Rotating EMST devices (n=6)	Participant difficulty reading the numbers on the side of the peak flow meter and appearing blurred when showing the clinician (n=1)
Inadequate preparatory breath/insufficient air (n=8)	Repeat instructions / additional explanation or cues (n=8)	Repeat instructions / provide verbal cue or encouragement (n=4)	
Poor coordination of treatment steps (n=3)	Incorporating caregiver physical support (n=3)	Holding cheeks to obtain lip seal (n=3)	Momentary audio and/or video freezing

Poor posture (n=3)	Adjusting posture (n=2)	which impaired clinicians' ability to hear or see a cough or EMST burst (n=2)
Throat-clearing or blowing instead of coughing (n=9)	Tracking data (n=2)	
Incorrect use or positioning of peak flow meter (n=4)	Reading numbers on the peak flow meter (n=4)	

Discussion

Telehealth is a rapidly expanding service delivery model for healthcare delivery and has the potential to increase access to specialty SLP services such as the management of airway protective dysfunction – an urgent public health need and priority (*U.S. Department of Health & Human Services. Office of Disease Prevention and Health Promotion. HealthIT.*, 2019; Weidner & Lowman, 2020). To date, no studies have assessed the feasibility of airway protective treatments, specifically EMST and CST, via telehealth in patients with neurodegenerative movement disorders. The present study demonstrated that completing EMST and CST exercises and obtaining treatment-related assessments to obtain a proxy measure of MEP and PEFR are feasible via telehealth. These findings are particularly important because of the progressive decline of cough and swallowing function in neurodegenerative disease (Aiello et al., 2008; Ebihara et al., 2003; Hegland et al., 2014; Pitts et al., 2010; Tabor-Gray et al., 2019), the impact of this decline on health and quality of life (Fall et al., 2003; Sohn et al., 2018; Takizawa et al., 2016), and the known benefits of these interventions for improving airway protective function when performed in-person. Specifically, EMST has repeatedly demonstrated improvements to cough and swallowing (Claus et al., 2021; Plowman et al., 2019; Troche et al., 2010) and CST has been shown to improve various components of cough function (Borders, Curtis, et al., 2021; Curtis et al., 2020). Thus, delivery of EMST and CST via telehealth is a crucial step in expanding the provision of these important airway protective treatments.

Practical Feasibility

Completing EMST and obtaining pMEP, as well as completing CST and obtaining PEFR, were each feasible within a 30-minute treatment session. The total time taken to obtain outcome measures and complete each treatment was less than 30 minutes. At baseline, the mean time taken to obtain pMEP and complete EMST was 17.48 minutes and to obtain PEFR and complete CST was 17.69 minutes. Time then decreased by the end of treatment – taking 12.27 minutes to obtain pMEP and complete EMST and 12.43 minutes to obtain PEFR and complete CST. These data suggest that even with significant variability in patient diagnoses, disease duration, and cognitive status, it is feasible to complete EMST or CST training within 30 minutes. We also found that the time taken to obtain pMEP and PEFR and complete these exercises decreased over time, supporting the use of these treatments via telehealth within a clinical setting.

In all EMST studies to date, MEP has been obtained by a clinician or researcher using a respiratory manometer. However, it is not financially feasible to provide this device to patients for use at home via telehealth. Even when treatment can be initiated in-person, EMST may require weekly re-assessment of MEP to re-set the device training level, though manufacturer guidelines recommend increasing the device by a "quarter-turn" each week of training, this approach has not been empirically tested. Future research will be necessary to determine the impact of these different practices on treatment outcomes. The finding in this study that a proxy of MEP can be obtained from the EMST-150 device, provides preliminary support for expanding EMST delivery, as it relates to setting EMST training level and tracking change over time, via telehealth. Future study is needed to fully assess the validity of telehealth delivery, with important implications for expanding access to this robust treatment approach for patients who cannot access in-person appointments. The challenges of the proxy measure of MEP (i.e., pMEP)

cannot be ignored and are described more fully in the limitations section. While more straightforward, obtaining PEFR via telehealth has also not been previously studied. This study suggests that obtaining PEFR via telehealth is possible. The findings of this study are the first to suggest that individuals with movement disorders can obtain a proxy of MEP and PEFR at home. This is especially important given that pMEP and PEFR need to be obtained weekly when completing EMST and CST in order to re-adjust training targets accordingly.

Preliminary Treatment Effect

EMST

The significant increase in pMEP observed from pre to post treatment preliminarily suggests the presence of a treatment effect when EMST was completed via telehealth. While we cannot make direct comparisons between pMEP and actual MEP, when examining the magnitude of change, the large increase in pMEP in this study is consistent with improvements to MEP typically seen following in-person EMST treatment. Previous studies in healthy young and older adults as well as disease groups including PD, MS, and ALS have found that following 4 or 5 weeks of EMST, MEP measured by respiratory manometer increased anywhere from 15-50% (Chiara et al., 2006; Kim et al., 2009; Reyes et al., 2018, 2020; Troche et al., 2015). In this study, the average improvement in pMEP based on the EMST-150 conversion estimate was 36%. This provides initial support for the utility of EMST for improving expiratory muscle strength when administered via telehealth.

The increase in pMEP in this study occurred most significantly in the first two weeks of training (30%), and while pMEP continued to increase in weeks three and four, the additional 6% increase (i.e., from week two to week four) was non-significant. This finding is in line with studies that suggest neural adaptations to exercise occur in the initial stages of training (e.g., the

first four weeks) resulting in rapid strength gain, with sustained yet less steep improvements later on (Baker et al., 2005; Kim et al., 2009; Sale, 1988; Saleem et al., 2005). To date, MEP has usually been reported prior to the start of treatment and again after four or five weeks of training (Chiara et al., 2006; Kuo et al., 2017; Plowman et al., 2019), with no mid-treatment probes. However, a few cohort studies have explored changes in MEP over the course of training or following shorter training periods. Similar to the findings of the present study, a recent study identified an increase in MEP following two weeks of EMST training in persons with PD that is similar to the gains observed following longer training periods in other studies (Srp et al., 2021). Baker et al. (2005) also found the most significant increase in MEP was in the first two weeks of training, with a non-significant but steady increase in the third and fourth weeks (Baker et al., 2005) and Kim et al (2009) found the most significant improvement in the first week of training with a continued steady improvement in the remaining weeks (Kim et al., 2009). Our finding is in contrast to Anand et al (2012) who found a relatively equal gradual increase in MEP across all four training weeks (Anand et al., 2012), although week-to-week change was not statistically analyzed in that study and the participants were healthy adults. Therefore, change in pMEP in the present study seems to be in accordance with patterns of change previously identified in the literature; however, further studies should explore patterns and rate of change of MEP in response to EMST, as it relates to optimal treatment duration.

CST

The improvement of single and sequential voluntary cough PEFR in this study is consistent with findings from previous studies on patients with movement disorders, demonstrating improvements in measures of cough effectiveness following cough training (Borders, Curtis, et al., 2021; Curtis et al., 2020). Inadequate cough strength contributes to the

progressive decline in cough effectiveness and impaired airway protection (Pitts et al., 2008; Plowman, Watts, Robison, et al., 2016; Silverman et al., 2016), and reduced voluntary cough strength has specifically been associated with impaired ability to clear aspirate material from the airway (Borders & Troche, 2021). More specifically, Borders & Troche (2021) identified that small differences in PEFR (e.g., a change of 0.50 liters per second) correspond to functional differences in the amount of aspirate material expelled from the airway. This has significant implications for pulmonary sequelae including aspiration pneumonia (Bianchi et al., 2012; Ebihara et al., 2012; Sohn et al., 2018). Therefore, the improvement in PEFR identified following CST in this study, a change of 57 liters per minute (i.e., 0.95 liters per second) for single voluntary coughs and a change of 47 liters per minute (i.e., 0.78 liters per second) for sequential voluntary coughs, has important implications for the utility of cough training as a treatment approach to improve airway protection that can be delivered via telehealth.

Session Factors Influencing Feasibility

Qualitative data from video review of telehealth sessions may help to refine the use of EMST and CST via telehealth. The fact that both treatments utilized devices seems to have facilitated treatment feasibility – providing the clinician and participant with real-time feedback regarding whether the target was achieved. However, the use of these devices also presented challenges. There are technical parameters surrounding device use for both EMST and CST such as holding the device correctly, achieving sufficient lip seal, sequencing the steps to perform the exercise, and understanding if the target is achieved. During typical in-person treatment sessions, clinicians may provide tactile support, mouthpiece alternatives, and positioning adjustments to facilitate accurate performance. When additional physical support was needed during telehealth sessions in this study, clinicians utilized care-partners for assistance by having them assist with

various components of EMST, such as rotating the EMST device to set the training target, holding the device, or holding the participant's cheeks to achieve a lip seal. These results demonstrate that physical assistance may be necessary for a subgroup of patients. For greater detail regarding outcomes for those with versus without care-partners, see supplemental tables 1 and 2**.** All participants who did not have care-partners (n=12) were able to complete the treatments independently. Future studies should systematically consider caregiver participation.

One participant (participant 18) could not be included in quantitative feasibility analyses of EMST and CST exercise duration, given that he did not complete 25 repetitions (as per the protocol) in any treatment session. There are many possibilities as to why this occurred and feasibility of the exercises themselves versus of the telehealth modality cannot easily be disentangled for this participant. The clinician cited time constraints and clinician-perceived patient fatigue and used clinical judgment to complete fewer exercise repetitions, taking a conservative approach to ensure patient safety. Of note, MEP and PEFR durations were appropriate, the patient was able to participate in EMST and CST exercises, and sessions were frequently shorter than 30 minutes. However, MEP and PEFR did not improve over the course of treatment for this participant. This may be due to insufficient exercise intensity and/or patient factors such as disease severity and cognitive impairment that impacted feasibility for this participant. A care-partner was present at all sessions but participated minimally (see Table 3). Perhaps, in this case, greater care-partner involvement would enhance feasibility. Exploring the impact of diagnosis, disease severity, cognition, and care-partner involvement on feasibility are important variables to consider in subsequent studies, as it remains possible that feasibility may be limited for certain subgroups of patients with a more severe disease profile – all factors which may impact feasibility in-person and via telehealth.

Limitations & Future Directions

Given that this was an initial feasibility study, there was a small sample size, no control group, and no in-person comparison group. Some participants began EMST and CST concurrently, while others received two weeks of EMST prior to initiating CST. It is possible that there were cross-treatment effects and/or interferences, and that these may have occurred differentially for those who received the treatments concurrently versus consecutively. However, the primary goal of this study was to assess practical feasibility which was confirmed despite the combined treatment approach and treatment schedules. It is also possible that completing treatment consecutively versus concurrently may have influenced adherence and this should be explored in future studies. Given that adherence was not a primary outcome of this study, exercise logs were not systematically requested upon study completion and were only obtained for a portion of participants in our sample. Future studies should consider adherence as a component of treatment feasibility.

The approach used to obtain pMEP in the present study generally follows the guidelines outlined by the Aspire products company (Aspire products, LLC, USA) on how to obtain MEP using the EMST-150 device (*EMST150 Instructional Video*, 2021). This procedure is not outlined in the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines on respiratory muscle testing and while this approach is utilized clinically, it is unknown how closely pMEP values map onto MEP measured via respiratory manometer. Therefore, pMEP values obtained in this study should not be directly compared to normative data in the literature and should not be used to identify patients whose MEP may be below normal limits. Future research is needed to understand how a proxy of MEP obtained from the EMST-150 device correlates with MEP standardly obtained via respiratory manometer.

There have been conflicting reports in the literature as to how well peak flow rate measured by hand-held digital and analog devices correlate with peak flow rates measured via the gold standard pneumotachograph. Some studies have identified excellent concordant validity (Sancho et al., 2004; Silverman et al., 2014; Tabor-Gray et al., 2019) while others have not (Kulnik et al., 2015; Sancho et al., 2004), specifically suggesting that hand-held devices may have a tendency to over-inflate values below 270 L/min (Sancho et al., 2004). Therefore, direct comparisons to normative data obtained via a pneumotachograph may not be appropriate. Nonetheless, cough peak flow meters have been used in a number of clinically relevant studies, identifying their utility as a screening and treatment tool (Ebihara et al., 2003; Silverman et al., 2014; Tabor-Gray et al., 2019). Since the same devices were used for obtaining outcome measures and completing treatment for both EMST and CST, practice effects may have inflated the improvement observed in pMEP and PEFR outcomes. Therefore, the treatment effect of EMST and CST should be considered preliminary and needs to be confirmed by future research examining changes to other physiologic and functional outcomes.

All participants were community-dwelling individuals and no participants had severely impaired cognition – the two participants with diagnoses of dementia had care-partners who assisted. Future studies in larger and more diverse cohorts are necessary to confirm the feasibility of these exercises via telehealth across varying diagnoses and cognitive abilities as well as in acute and subacute populations and those with more severe airway protective deficits. Lastly, only a subset of participants in this study had care-partners who assisted with the evaluation and treatment sessions and the way in which care-partners assisted was not standardized. This allowed for ecologically valid conclusions regarding feasibility of these treatments in the natural environments of persons with neurodegenerative diagnoses. However, future study is required to

examine the influence of caregiver involvement on feasibility and whether caregivers are required for certain patient groups.

Conclusion

The present study provides initial support for the feasibility of two device-driven treatment approaches – EMST and CST – to improve airway protection via telehealth for individuals with movement disorders. The findings of this study demonstrate the practical feasibility of completing EMST and CST, and obtaining the associated outcome measures, with a resulting improvement in both pMEP and PEFR. This has important implications for initiating treatment via telehealth in cases where patients are unable to access in-person clinics due to geographical distance and mobility limitations as well as the possible persistence of the coronavirus pandemic, particularly given that these treatments are aerosol-generating. Increased access to airway protective treatment may also facilitate earlier intervention prior to the onset of severe airway protective dysfunction. Given the current lack of SLP services via telehealth for patients with movement disorders (Feeney et al., 2021), this study is an important initial step towards expanding the provision of these airway protective interventions to the telehealth modality as well as provide clinicians with guidance regarding key challenges and facilitatory strategies. Future studies should investigate EMST and CST treatment paradigms via telehealth as compared to in-person services and their impact on functional and patient-centered outcomes.

Data Availability Statement: The data generated and analyzed during the current study are available from the corresponding author upon reasonable request.

References

Aiello, M., Rampello, A., Granella, F., Maestrelli, M., Tzani, P., Immovilli, P., Franceschini, M., Olivieri, D., & Chetta, A. (2008). Cough Efficacy Is Related to the Disability Status in Patients with Multiple Sclerosis. *Respiration*, *76*(3), 311–316. https://doi.org/10.1159/000119641

Akbar, U., Dham, B., He, Y., Hack, N., Wu, S., Troche, M., Tighe, P., Nelson, E., Friedman, J. H., & Okun, M. S. (2015). Incidence and mortality trends of aspiration pneumonia in Parkinson's disease in the United States, 1979–2010. *Parkinsonism & Related Disorders*, *21*(9), 1082–1086. https://doi.org/10.1016/j.parkreldis.2015.06.020

Anand, S., El-Bashiti, N., & Sapienza, C. (2012). Effect of Training Frequency on Maximum Expiratory Pressure. *American Journal of Speech-Language Pathology*, *21*(4), 380–386. https://doi.org/10.1044/1058-0360(2012/11-0048)

Argolo, N., Sampaio, M., Pinho, P., Melo, A., & Nóbrega, A. C. (2013). Do swallowing exercises improve swallowing dynamic and quality of life in Parkinson's disease? *NeuroRehabilitation*, *32*(4), 949–955. https://doi.org/10.3233/NRE-130918

Athukorala, R. P., Jones, R. D., Sella, O., & Huckabee, M.-L. (2014). Skill Training for Swallowing Rehabilitation in Patients With Parkinson's Disease. *Archives of Physical Medicine and Rehabilitation*, *95*(7), 1374–1382. https://doi.org/10.1016/j.apmr.2014.03.001

Baker, S., Davenport, P., & Sapienza, C. (2005). Examination of Strength Training and Detraining Effects in Expiratory Muscles. *Journal of Speech, Language, and Hearing Research*, *48*(6), 1325–1333. https://doi.org/10.1044/1092-4388(2005/092)

Bakheit, A. M. O. (2001). Management of neurogenic dysphagia. *Postgraduate Medical Journal*, *77*(913), 694–699. https://doi.org/10.1136/pmj.77.913.694

Bascuñana-Ambrós, H., Renom-Guiteras, M., Nadal-Castells, M. J., Beranuy-Rodríguez, M., Perrot-González, J. C., Ramirez-Mirabal, E., Trejo-Omeñaca, A., & Monguet-Fierro, J. M. (2021). Swallowing muscle training for oropharyngeal dysphagia: A non-inferiority study of online versus face-to-face therapy. *Journal of Telemedicine and Telecare*, 1357633X2110350. https://doi.org/10.1177/1357633X211035033

Beck, C. A., Beran, D. B., Biglan, K. M., Boyd, C. M., Dorsey, E. R., Schmidt, P. N., Simone, R., Willis, A. W., Galifianakis, N. B., Katz, M., Tanner, C. M., Dodenhoff, K., Aldred, J., Carter, J., Fraser, A., Jimenez-Shahed, J., Hunter, C., Spindler, M., Reichwein, S., … Zhu, W. (2017). National randomized controlled trial of virtual house calls for Parkinson disease. *Neurology*, *89*(11), 1152–1161. https://doi.org/10.1212/WNL.0000000000004357

Bianchi, C., Baiardi, P., Khirani, S., & Cantarella, G. (2012). Cough Peak Flow as a Predictor of Pulmonary Morbidity in Patients with Dysphagia. *American Journal of Physical Medicine & Rehabilitation*, *91*(9), 783–788. https://doi.org/10.1097/PHM.0b013e3182556701

Borders, J. C., Curtis, J. A., Sevitz, J. S., Vanegas-Arroyave, N., & Troche, M. S. (2021). Immediate Effects of Sensorimotor Training in Airway Protection (smTAP) on Cough Outcomes in Progressive Supranuclear Palsy: A Feasibility Study. *Dysphagia*. https://doi.org/10.1007/s00455-021-10251-1

Borders, J. C., Sevitz, J. S., Malandraki, J. B., Malandraki, G. A., & Troche, M. S. (2021). Objective and Subjective Clinical Swallowing Outcomes via Telehealth: Reliability in Outpatient Clinical Practice. *American Journal of Speech-Language Pathology*, *30*(2), 598–608. https://doi.org/10.1044/2020_AJSLP-20-00234

Borders, J. C., & Troche, M. S. (2021). Voluntary Cough Effectiveness and Airway Clearance in Neurodegenerative Disease. *Journal of Speech, Language, and Hearing Research*, 1–19. https://doi.org/10.1044/2021_JSLHR-21-00308

Bowen, D. J., Kreuter, M., Spring, B., Cofta-Woerpel, L., Linnan, L., Weiner, D., ... & Fernandez, M. (2009). How we design feasibility studies. *American journal of preventive medicine*, *36*(5), 452-457.

Brandimore, A. E., Hegland, K. W., Okun, M. S., Davenport, P. W., & Troche, M. S. (2017). Voluntary upregulation of reflex cough is possible in healthy older adults and Parkinson's disease. *Journal of Applied Physiology*, *123*(1), 19–26. https://doi.org/10.1152/japplphysiol.00612.2016

Burns, C. L., Ward, E. C., Gray, A., Baker, L., Cowie, B., Winter, N., Rusch, R., Saxon, R., Barnes, S., & Turvey, J. (2019). Implementation of speech pathology telepractice services for clinical swallowing assessment: An evaluation of service outcomes, costs and consumer satisfaction. *Journal of Telemedicine and Telecare*, *25*(9), 545–551. https://doi.org/10.1177/1357633X19873248

Burns, C. L., Ward, E. C., Hill, A. J., Kularatna, S., Byrnes, J., & Kenny, L. M. (2017). Randomized controlled trial of a multisite speech pathology telepractice service providing swallowing and communication intervention to patients with head and neck cancer: Evaluation of service outcomes. *Head & Neck*, *39*(5), 932–939. https://doi.org/10.1002/hed.24706

Cassel, S. G. (2016). Case Reports: Trial Dysphagia Interventions Conducted via Telehealth. *International Journal of Telerehabilitation*, *8*(2), 71–76. https://doi.org/10.5195/IJT.2016.6193

Chiara, T., Martin, A. D., Davenport, P. W., & Bolser, D. C. (2006). Expiratory Muscle Strength Training in Persons With Multiple Sclerosis Having Mild to Moderate Disability: Effect on Maximal Expiratory Pressure, Pulmonary Function, and Maximal Voluntary Cough. *Archives of Physical Medicine and Rehabilitation*, *87*(4), 468–473. https://doi.org/10.1016/j.apmr.2005.12.035

Clark, H. M., Stierwalt, J. A. G., Tosakulwong, N., Botha, H., Ali, F., Whitwell, J. L., & Josephs, K. A. (2020). Dysphagia in Progressive Supranuclear Palsy. *Dysphagia*, *35*(4), 667–676. https://doi.org/10.1007/s00455-019-10073-2

Claus, I., Muhle, P., Czechowski, J., Ahring, S., Labeit, B., Suntrup-Krueger, S., Wiendl, H., Dziewas, R., & Warnecke, T. (2021). Expiratory Muscle Strength Training for Therapy of Pharyngeal Dysphagia in Parkinson's Disease. *Movement Disorders*, mds.28552. https://doi.org/10.1002/mds.28552

Clavé, P., Kraa, M. D., Arreola, V., Girvent, M., Farré, R., Palomera, E., & Serra-Prat, M. (2006). The effect of bolus viscosity on swallowing function in neurogenic dysphagia. *Alimentary Pharmacology & Therapeutics*, *24*(9), 1385–1394. https://doi.org/10.1111/j.1365-2036.2006.03118.x

Collins, A., Burns, C. L., Ward, E. C., Comans, T., Blake, C., Kenny, L., Greenup, P., & Best, D. (2017). Home-based telehealth service for swallowing and nutrition management following head and neck cancer treatment. *Journal of Telemedicine and Telecare*, *23*(10), 866–872. https://doi.org/10.1177/1357633X17733020

Constantinescu, G., Rieger, J., Seikaly, H., & Eurich, D. (2021). Adherence to Home-Based Swallowing Therapy Using a Mobile System in Head and Neck Cancer Survivors.

American Journal of Speech-Language Pathology, 1–11. https://doi.org/10.1044/2021_AJSLP-21-00026

Crizzle, A. M., Classen, S., & Uc, E. Y. (2012). Parkinson disease and driving: An evidence-based review. *Neurology*, *79*(20), 2067–2074. https://doi.org/10.1212/WNL.0b013e3182749e95

Curtis, J. A., Dakin, A. E., & Troche, M. S. (2020). Respiratory–Swallow Coordination Training and Voluntary Cough Skill Training: A Single-Subject Treatment Study in a Person With Parkinson's Disease. *Journal of Speech, Language, and Hearing Research*, *63*(2), 472–486. https://doi.org/10.1044/2019_JSLHR-19-00207

D'Amelio, M., Ragonese, P., Morgante, L., Reggio, A., Callari, G., Salemi, G., & Savettieri, G. (2006). Long–term survival of Parkinson's disease: A population–based study. *Journal of Neurology*, *253*(1), 33–37. https://doi.org/10.1007/s00415-005-0916-7

Dorsey, E. R., Bloem, B. R., & Okun, M. S. (2020). A New Day: The Role of Telemedicine in Reshaping Care for Persons With Movement Disorders. *Movement Disorders*, *35*(11), 1897–1902. https://doi.org/10.1002/mds.28296

Dorsey, E. R., Deuel, L. M., Voss, T. S., Finnigan, K., George, B. P., Eason, S., Miller, D., Reminick, J. I., Appler, A., Polanowicz, J., Viti, L., Smith, S., Joseph, A., & Biglan, K. M. (2010). Increasing access to specialty care: A pilot, randomized controlled trial of telemedicine for Parkinson's disease. *Movement Disorders*, *25*(11), 1652–1659. https://doi.org/10.1002/mds.23145

Ebihara, S., Ebihara, T., & Kohzuki, M. (2012). Effect of Aging on Cough and Swallowing Reflexes: Implications for Preventing Aspiration Pneumonia. *Lung*, *190*, 29–33. https://doi.org/10.1007/s00408-011-9334-z

Ebihara, S., Saito, H., Kanda, A., Nakajoh, M., Takahashi, H., Arai, H., & Sasaki, H. (2003). Impaired Efficacy of Cough in Patients With Parkinson Disease. *Chest*, *124*(3), 1009–1015. https://doi.org/10.1378/chest.124.3.1009

Ebihara, S., Sekiya, H., Miyagi, M., Ebihara, T., & Okazaki, T. (2016). Dysphagia, dystussia, and aspiration pneumonia in elderly people. *Journal of Thoracic Disease*, *8*(3), 632–639. https://doi.org/10.21037/jtd.2016.02.60

Elson, M. J., Stevenson, E. A., Feldman, B. A., Lim, J., Beck, C. A., Beran, D. B., Schmidt, P. N., Biglan, K. M., Simone, R., Willis, A. W., Dorsey, E. R., & Boyd, C. M. (2018). Telemedicine for Parkinson's Disease: Limited Engagement Between Local Clinicians and Remote Specialists. *Telemedicine and E-Health*, *24*(9), 722–724. https://doi.org/10.1089/tmj.2017.0210

EMST150 Instructional Video. (2021). [Aspire Respiratory Products]. https://emst150.com/about#public-training-videos

Fall, P.-A., Saleh, A., Fredrickson, M., Olsson, J.-E., & Granérus, A.-K. (2003). Survival time, mortality, and cause of death in elderly patients with Parkinson's disease. A 9-year follow-up: Mortality in Parkinson's Disease. *Movement Disorders*, *18*(11), 1312–1316. https://doi.org/10.1002/mds.10537

Feeney, M. P., Xu, Y., Surface, M., Shah, H., Vanegas-Arroyave, N., Chan, A. K., Delaney, E., Przedborski, S., Beck, J. C., & Alcalay, R. N. (2021). The impact of COVID-19 and social distancing on people with Parkinson's disease: A survey study. *Npj Parkinson's Disease*, *7*(1), 10. https://doi.org/10.1038/s41531-020-00153-8

Fontana, G. A., & Lavorini, F. (2006). Cough motor mechanisms. *Respiratory Physiology & Neurobiology*, *152*(3), 266–281. https://doi.org/10.1016/j.resp.2006.02.016

Fullard, M. E., Thibault, D. P., Hill, A., Fox, J., Bhatti, D. E., Burack, M. A., Dahodwala, N., Haberfeld, E., Kern, D. S., Klepitskava, O. S., Urrea-Mendoza, E., Myers, P., Nutt, J., Rafferty, M. R., Schwalb, J. M., Shulman, L. M., & Willis, A. W. (2017). Utilization of rehabilitation therapy services in Parkinson disease in the United States. *Neurology*, *89*(11), 1162–1169. https://doi.org/10.1212/WNL.0000000000004355

Guillén-Solà, A., Messagi Sartor, M., Bofill Soler, N., Duarte, E., Barrera, M. C., & Marco, E. (2017). Respiratory muscle strength training and neuromuscular electrical stimulation in subacute dysphagic stroke patients: A randomized controlled trial. *Clinical Rehabilitation*, *31*(6), 761–771. https://doi.org/10.1177/0269215516652446

Haas, B. M., Trew, M., & Castle, P. C. (2004). Effects of Respiratory Muscle Weakness on Daily Living Function, Quality of Life, Activity Levels, and Exercise Capacity in Mild to Moderate Parkinson's Disease. *American Journal of Physical Medicine & Rehabilitation*, *83*(8), 601–607. https://doi.org/10.1097/01.PHM.0000133436.61009.02

Haulman, A., Geronimo, A., Chahwala, A., & Simmons, Z. (2020). The Use of Telehealth to Enhance Care in ALS and other Neuromuscular Disorders. *Muscle & Nerve*, *61*(6), 682–691. https://doi.org/10.1002/mus.26838

Heemskerk, A.-W., & Roos, R. A. C. (2012). Aspiration pneumonia and death in Huntington's disease. *PLoS Currents*, *4*. https://doi.org/10.1371/currents.RRN1293

Hegland, K. W., Okun, M. S., & Troche, M. S. (2014). Sequential Voluntary Cough and Aspiration or Aspiration Risk in Parkinson's Disease. *Lung*, *192*(4), 601–608. https://doi.org/10.1007/s00408-014-9584-7

Hegland, K. W., Troche, M. S., & Davenport, P. W. (2013). Cough expired volume and airflow rates during sequential induced cough. *Frontiers in Physiology*, *4*. https://doi.org/10.3389/fphys.2013.00167

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, *15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

Kaneoka, A., Pisegna, J. M., Inokuchi, H., Ueha, R., Goto, T., Nito, T., Stepp, C. E., LaValley, M. P., Haga, N., & Langmore, S. E. (2018). Relationship Between Laryngeal Sensory Deficits, Aspiration, and Pneumonia in Patients with Dysphagia. *Dysphagia*, *33*(2), 192–199. https://doi.org/10.1007/s00455-017-9845-8

Kantarcigil, C., & Malandraki, G. A. (2017). First Step in Telehealth Assessment: A Randomized Controlled Trial to Investigate the Effectiveness of an Electronic Case History Form for Dysphagia. *Dysphagia*, *32*(4), 548–558. https://doi.org/10.1007/s00455-017-9798-y

Kantarcigil, C., Sheppard, J. J., Gordon, A. M., Friel, K. M., & Malandraki, G. A. (2016). A telehealth approach to conducting clinical swallowing evaluations in children with cerebral palsy. *Research in Developmental Disabilities*, *55*, 207–217. https://doi.org/10.1016/j.ridd.2016.04.008

Kim, J., Davenport, P., & Sapienza, C. (2009). Effect of expiratory muscle strength training on elderly cough function. *Archives of Gerontology and Geriatrics*, *48*(3), 361–366. https://doi.org/10.1016/j.archger.2008.03.006

Kulnik, S. T., MacBean, V., Birring, S. S., Moxham, J., Rafferty, G. F., & Kalra, L. (2015). Accuracy of portable devices in measuring peak cough flow. *Physiological Measurement*, *36*(2), 243–257. https://doi.org/10.1088/0967-3334/36/2/243

Kuo, Y.-C., Chan, J., Wu, Y.-P., Bernard, J. R., & Liao, Y.-H. (2017). Effect of expiratory muscle strength training intervention on the maximum expiratory pressure and quality of life of patients with Parkinson disease. *NeuroRehabilitation*, *41*(1), 219–226. https://doi.org/10.3233/NRE-171474

Levin, M. F., & Demers, M. (2020). Motor learning in neurological rehabilitation. *Disability and Rehabilitation*, 1–9. https://doi.org/10.1080/09638288.2020.1752317

Malandraki, G. A., Arkenberg, R. H., Mitchell, S. S., & Malandraki, J. B. (2021). Telehealth for Dysphagia Across the Life Span: Using Contemporary Evidence and Expertise to Guide Clinical Practice During and After COVID-19. *American Journal of Speech-Language Pathology*, *30*(2), 532–550. https://doi.org/10.1044/2020_AJSLP-20-00252

Malandraki, G. A., & Kantarcigil, C. (2017). Telehealth for Dysphagia Rehabilitation: The Present and the Future. *Perspectives of the ASHA Special Interest Groups*, *2*(18), 42–48. https://doi.org/10.1044/persp2.SIG18.42

Malandraki, G. A., Kaufman, A., Hind, J., Ennis, S., Gangnon, R., Waclawik, A., & Robbins, J. (2012). The Effects of Lingual Intervention in a Patient With Inclusion Body Myositis and Sjögren's Syndrome: A Longitudinal Case Study. *Archives of Physical Medicine and Rehabilitation*, *93*(8), 1469–1475. https://doi.org/10.1016/j.apmr.2012.02.010

Malandraki, G. A., Markaki, V., Georgopoulos, V. C., Bauer, J. L., Kalogeropoulos, I., & Nanas, S. (2013). An international pilot study of asynchronous teleconsultation for

oropharyngeal dysphagia. *Journal of Telemedicine and Telecare*, *19*(2), 75–79. https://doi.org/10.1177/1357633x12474963

Malandraki, G. A., Rajappa, A., Kantarcigil, C., Wagner, E., Ivey, C., & Youse, K. (2016). The Intensive Dysphagia Rehabilitation Approach Applied to Patients With Neurogenic Dysphagia: A Case Series Design Study. *Archives of Physical Medicine and Rehabilitation*, *97*(4), 567–574. https://doi.org/10.1016/j.apmr.2015.11.019

Marik, P. E., & Kaplan, D. (2003). Aspiration Pneumonia and Dysphagia in the Elderly. *Chest*, *124*(1), 328–336. https://doi.org/10.1378/chest.124.1.328

McEachern, W., Kirk, A., Morgan, D. G., Crossley, M., & Henry, C. (2008). Reliability of the MMSE Administered In-Person and by Telehealth. *Canadian Journal of Neurological Sciences / Journal Canadien Des Sciences Neurologiques*, *35*(5), 643–646. https://doi.org/10.1017/S0317167100009458

Miles, A., Jardine, M., Johnston, F., de Lisle, M., Friary, P., & Allen, J. (2017). Effect of Lee Silverman Voice Treatment (LSVT LOUD®) on swallowing and cough in Parkinson's disease: A pilot study. *Journal of the Neurological Sciences*, *383*, 180–187. https://doi.org/10.1016/j.jns.2017.11.015

Moon, J. H., Jung, J.-H., Won, Y. S., Cho, H.-Y., & Cho, K. (2017). Effects of expiratory muscle strength training on swallowing function in acute stroke patients with dysphagia. *Journal of Physical Therapy Science*, *29*(4), 609–612. https://doi.org/10.1589/jpts.29.609

Morrell, K., Hyers, M., Stuchiner, T., Lucas, L., Schwartz, K., Mako, J., Spinelli, K. J., & Yanase, L. (2017). Telehealth Stroke Dysphagia Evaluation Is Safe and Effective. *Cerebrovascular Diseases*, *44*(3–4), 225–231. https://doi.org/10.1159/000478107

Morse, J. M. (2015). Critical Analysis of Strategies for Determining Rigor in Qualitative Inquiry. *Qualitative Health Research*, *25*(9), 1212–1222. https://doi.org/10.1177/1049732315588501

Mosley, P. E., Moodie, R., & Dissanayaka, N. (2017). Caregiver Burden in Parkinson Disease: A Critical Review of Recent Literature. *Journal of Geriatric Psychiatry and Neurology*, *30*(5), 235–252. https://doi.org/10.1177/0891988717720302

Muratori, L. M., Lamberg, E. M., Quinn, L., & Duff, S. V. (2013). Applying principles of motor learning and control to upper extremity rehabilitation. *Journal of Hand Therapy*, *26*(2), 94–103. https://doi.org/10.1016/j.jht.2012.12.007

Nakashima, T., Maeda, K., Tahira, K., Taniguchi, K., Mori, K., Kiyomiya, H., & Akagi, J. (2018). Silent aspiration predicts mortality in older adults with aspiration pneumonia admitted to acute hospitals. *Geriatrics & Gerontology International*, *18*(6), 828–832. https://doi.org/10.1111/ggi.13250

Nordio, S., Innocenti, T., Agostini, M., Meneghello, F., & Battel, I. (2018). The efficacy of telerehabilitation in dysphagic patients: A systematic review. *Acta Otorhinolaryngologica Italica*, *38*(2), 79–85. https://doi.org/10.14639/0392-100X-1816

O'Hara, R., & Jackson, S. (2017). Integrating telehealth services into a remote allied health service: A pilot study. *Australian Journal of Rural Health*, *25*(1), 53–57. https://doi.org/10.1111/ajr.12189

Ortega, O., Martín, A., & Clavé, P. (2017). Diagnosis and Management of Oropharyngeal Dysphagia Among Older Persons, State of the Art. *Journal of the American Medical Directors Association*, *18*(7), 576–582. https://doi.org/10.1016/j.jamda.2017.02.015

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., Okun, M. S., & Sapienza, C. (2009). Impact of Expiratory Muscle Strength Training on Voluntary Cough and Swallow Function in Parkinson Disease. *Chest*, *135*(5), 1301–1308. https://doi.org/10.1378/chest.08-1389

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., & Sapienza, C. (2008). Voluntary Cough Production and Swallow Dysfunction in Parkinson's Disease. *Dysphagia*, *23*(3), 297–301. https://doi.org/10.1007/s00455-007-9144-x

Pitts, T., Troche, M., Mann, G., Rosenbek, J., Okun, M. S., & Sapienza, C. (2010). Using Voluntary Cough To Detect Penetration and Aspiration During Oropharyngeal Swallowing in Patients With Parkinson Disease. *Chest*, *138*(6), 1426–1431. https://doi.org/10.1378/chest.10-0342

Plowman, E. K., Tabor-Gray, L., Rosado, K. M., Vasilopoulos, T., Robison, R., Chapin, J. L., Gaziano, J., Vu, T., & Gooch, C. (2019). Impact of expiratory strength training in amyotrophic lateral sclerosis: Results of a randomized, sham-controlled trial. *Muscle & Nerve*, *59*(1), 40–46. https://doi.org/10.1002/mus.26292

Plowman, E. K., Watts, S. A., Robison, R., Tabor, L., Dion, C., Gaziano, J., Vu, T., & Gooch, C. (2016). Voluntary Cough Airflow Differentiates Safe Versus Unsafe Swallowing in Amyotrophic Lateral Sclerosis. *Dysphagia*, *31*(3), 383–390. https://doi.org/10.1007/s00455-015-9687-1

Plowman, E. K., Watts, S. A., Tabor, L., Robison, R., Gaziano, J., Domer, A. S., Richter, J., Vu, T., & Gooch, C. (2016). Impact of expiratory strength training in amyotrophic lateral sclerosis. *Muscle & Nerve*, *54*(1), 48–53. https://doi.org/10.1002/mus.24990

R Core Team. (2018). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Reyes, A., Castillo, A., & Castillo, J. (2020). Effects of Expiratory Muscle Training and Air Stacking on Peak Cough Flow in Individuals with Parkinson's Disease. *Lung*, *198*(1), 207–211. https://doi.org/10.1007/s00408-019-00291-8

Reyes, A., Castillo, A., Castillo, J., & Cornejo, I. (2018). The effects of respiratory muscle training on peak cough flow in patients with Parkinson's disease: A randomized controlled study. *Clinical Rehabilitation*, *32*(10), 1317–1327. https://doi.org/10.1177/0269215518774832

Reyes, A., Cruickshank, T., Nosaka, K., & Ziman, M. (2015). Respiratory muscle training on pulmonary and swallowing function in patients with Huntington's disease: A pilot randomised controlled trial. *Clinical Rehabilitation*, *29*(10), 961–973. https://doi.org/10.1177/0269215514564087

Rogus-Pulia, N. M., & Plowman, E. K. (2020). Shifting Tides Toward a Proactive Patient-Centered Approach in Dysphagia Management of Neurodegenerative Disease. *American Journal of Speech-Language Pathology*, *29*(2S), 1094–1109. https://doi.org/10.1044/2020_AJSLP-19-00136

Rönnefarth, M., Hanisch, N., Brandt, A. U., Mähler, A., Endres, M., Paul, F., & Doss, S. (2020). Dysphagia Affecting Quality of Life in Cerebellar Ataxia—A Large Survey. *The Cerebellum*, *19*(3), 437–445. https://doi.org/10.1007/s12311-020-01122-w

Sale, D. G. (1988). Neural adaptation to resistance training. *Medicine and Science in Sports and Exercise*, *20.5*(Suppl), S135-45.

Saleem, A. F., Sapienza, C. M., & Okun, M. S. (2005). Respiratory muscle strength training: Treatment and response duration in a patient with early idiopathic Parkinson's disease. *NeuroRehabilitation*, *20*(4), 323–333. https://doi.org/10.3233/nre-2005-20407

Sancho, J., Servera, E., Diaz, J., & Marin, J. (2004). Comparison of peak cough flows measured by pneumotachograph and a portable peak flow meter. *American Journal of Physical Medicine & Rehabilitation*, *83*(8), 608–612.

Schneider, R. B., & Biglan, K. M. (2017). The promise of telemedicine for chronic neurological disorders: The example of Parkinson's disease. *The Lancet Neurology*, *16*(7), 541–551. https://doi.org/10.1016/S1474-4422(17)30167-9

Sharma, S., Ward, E. C., Burns, C., Theodoros, D., & Russell, T. (2013). Assessing dysphagia via telerehabilitation: Patient perceptions and satisfaction. *International Journal of Speech-Language Pathology*, *15*(2), 176–183. https://doi.org/10.3109/17549507.2012.689333

Shinn, E. H., Jensen, K., McLaughlin, J., Garden, A. S., Fellman, B. M., Liang, L., & Peterson, S. K. (2019). Interactive website for head and neck cancer patients: Adherence and coping program to prevent dysphagia after radiation. *Internet Interventions*, *18*, 100289. https://doi.org/10.1016/j.invent.2019.100289

Silverman, E. P., Carnaby, G., Singletary, F., Hoffman-Ruddy, B., Yeager, J., & Sapienza, C. (2016). Measurement of Voluntary Cough Production and Airway Protection in Parkinson Disease. *Archives of Physical Medicine and Rehabilitation*, *97*(3), 413–420. https://doi.org/10.1016/j.apmr.2015.10.098

Silverman, E. P., Carnaby-Mann, G., Pitts, T., Davenport, P., Okun, M. S., & Sapienza, C. (2014). Concordance and Discriminatory Power of Cough Measurement Devices for Individuals With Parkinson Disease. *Chest*, *145*(5), 1089–1096. https://doi.org/10.1378/chest.13-0596

Sohn, D., Park, G.-Y., Koo, H., Jang, Y., Han, Y., & Im, S. (2018). Determining Peak Cough Flow Cutoff Values to Predict Aspiration Pneumonia Among Patients With Dysphagia Using the Citric Acid Reflexive Cough Test. *Archives of Physical Medicine and Rehabilitation*, *99*(12), 2532-2539.e1. https://doi.org/10.1016/j.apmr.2018.06.015

Srp, M., Korteová, R., Kliment, R., Jech, R., Růžička, E., & Hoskovcová, M. (2021). Expiratory Muscle Strength Training in Patients with Parkinson's Disease: A Pilot Study of Mobile Monitoring Application. *Movement Disorders Clinical Practice*, *8*(7), 1148–1149. https://doi.org/10.1002/mdc3.13313

Starmer, H. M., Abrams, R., Webster, K., Kizner, J., Beadle, B., Holsinger, F. C., Quon, H., & Richmon, J. (2018). Feasibility of a Mobile Application to Enhance Swallowing Therapy for Patients Undergoing Radiation-Based Treatment for Head and Neck Cancer. *Dysphagia*, *33*(2), 227–233. https://doi.org/10.1007/s00455-017-9850-y

Sura, L., Madhavan, A., Carnaby, G., & Crary, M. A. (2012). Dysphagia in the elderly: Management and nutritional considerations. *Clinical Interventions in Aging*, *7*, 287–298. https://doi.org/10.2147/CIA.S23404

Tabor-Gray, L. C., Gallestagui, A., Vasilopoulos, T., & Plowman, E. K. (2019). Characteristics of impaired voluntary cough function in individuals with amyotrophic lateral sclerosis. *Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration*, *20*(1–2), 37–42. https://doi.org/10.1080/21678421.2018.1510011

Tabor-Gray, L., Vasilopoulos, T., & Plowman, E. K. (2019). Concordant Validity of a Digital Peak Cough Flow Meter to Assess Voluntary Cough Strength in Individuals with ALS. *Dysphagia*. https://doi.org/10.1007/s00455-019-10060-7

Tabor-Gray, L., Vasilopoulos, T., & Plowman, E. K. (2020). Differences in voluntary and reflexive cough strength in individuals with amyotrophic lateral sclerosis and healthy adults. *Muscle & Nerve*, *62*(5), 597–600. https://doi.org/10.1002/mus.27040

Takizawa, C., Gemmell, E., Kenworthy, J., & Speyer, R. (2016). A Systematic Review of the Prevalence of Oropharyngeal Dysphagia in Stroke, Parkinson's Disease, Alzheimer's Disease, Head Injury, and Pneumonia. *Dysphagia*, *31*(3), 434–441. https://doi.org/10.1007/s00455-016-9695-9

Troche, M. S., Brandimore, A. E., Godoy, J., & Hegland, K. W. (2014). A framework for understanding shared substrates of airway protection. *Journal of Applied Oral Science*, *22*(4), 251–260. https://doi.org/10.1590/1678-775720140132

Troche, M. S., Brandimore, A. E., Okun, M. S., Davenport, P. W., & Hegland, K. W. (2014). Decreased Cough Sensitivity and Aspiration in Parkinson Disease. *Chest*, *146*(5), 1294–1299. https://doi.org/10.1378/chest.14-0066

Troche, M. S., Okun, M. S., Rosenbek, J. C., Musson, N., Fernandez, H. H., Rodriguez, R., Romrell, J., Pitts, T., Wheeler-Hegland, K. M., & Sapienza, C. M. (2010). Aspiration and swallowing in Parkinson disease and rehabilitation with EMST: A randomized trial. *Neurology*, *75*(21), 1912–1919. https://doi.org/10.1212/WNL.0b013e3181fef115

Troche, M. S., Rosenbek, J. C., Okun, M. S., & Sapienza, C. M. (2015). Detraining outcomes with expiratory muscle strength training in Parkinson disease. *J Rehabil Res Dev.*, *51*(2), 11. https://doi.org/10.1682/JRRD.2013.05.0101

Troche, M. S., Schumann, B., Brandimore, A. E., Okun, M. S., & Hegland, K. W. (2016). Reflex Cough and Disease Duration as Predictors of Swallowing Dysfunction in Parkinson's Disease. *Dysphagia*, *31*(6), 757–764. https://doi.org/10.1007/s00455-016-9734-6

Turner, A. P., Wallin, M. T., Sloan, A., Maloni, H., Kane, R., Martz, L., & Haselkorn, J. K. (2013). Clinical Management of Multiple Sclerosis Through Home Telehealth Monitoring. *International Journal of MS Care*, *15*(1), 8–14. https://doi.org/10.7224/1537-2073.2012-012

Tye, C. B., Gardner, P. A., Dion, G. R., Simpson, C. B., & Dominguez, L. M. (2021). Impact of Fiberoptic Endoscopic Evaluation of Swallowing Outcomes and Dysphagia Management in Neurodegenerative Diseases. *The Laryngoscope*, *131*(4), 726–730. https://doi.org/10.1002/lary.28791

U.S. Department of Health & Human Services. Office of Disease Prevention and Health Promotion. HealthIT. (2019). Healthy People 2030. https://health.gov/healthypeople/objectives-and-data/browse-objectives/health-it/increase-use-telehealth-improve-access-health-services-ahs-r02

van de Wetering-van Dongen, V. A., Kalf, J. G., van der Wees, P. J., Bloem, B. R., & Nijkrake, M. J. (2020). The Effects of Respiratory Training in Parkinson's Disease: A Systematic Review. *Journal of Parkinson's Disease*, *10*(4), 1315–1333. https://doi.org/10.3233/JPD-202223

Vogel, A. P., Fendel, L., Paige Brubacher, K., Chan, V., & Maule, R. (2015). Dysphagia in spinocerebellar ataxia and multiple system atrophy-cerebellar. *Speech, Language and Hearing*, *18*(1), 39–43. https://doi.org/10.1179/2050572814Y.0000000047

Wall, L. R., Ward, E. C., Cartmill, B., Hill, A. J., Isenring, E., Byrnes, J., & Porceddu, S. V. (2020). Prophylactic swallowing therapy for patients with head and neck cancer: A three-arm randomized parallel-group trial. *Head & Neck*, *42*(5), 873–885. https://doi.org/10.1002/hed.26060

Walshe, M. (2014). *Oropharyngeal Dysphagia in Neurodegenerative Disease*. 7.

Ward, E. C., & Burns, C. L. (2014). *Dysphagia Management via Telerehabilitation: A Review of the Current Evidence*. 7.

Ward, E. C., Sharma, S., Burns, C., Theodoros, D., & Russell, T. (2012a). Managing Patient Factors in the Assessment of Swallowing via Telerehabilitation. *International Journal of Telemedicine and Applications*, *2012*, 1–6. https://doi.org/10.1155/2012/132719

Ward, E. C., Sharma, S., Burns, C., Theodoros, D., & Russell, T. (2012b). Validity of Conducting Clinical Dysphagia Assessments for Patients with Normal to Mild Cognitive Impairment via Telerehabilitation. *Dysphagia*, *27*(4), 460–472. https://doi.org/10.1007/s00455-011-9390-9

Weidner, K., & Lowman, J. (2020). Telepractice for Adult Speech-Language Pathology Services: A Systematic Review. *Perspectives of the ASHA Special Interest Groups*, *5*(1), 326–338. https://doi.org/10.1044/2019_PERSP-19-00146

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *Journal of Experimental Psychology: General*, *143*(5), 2020–2045. https://doi.org/10.1037/xge0000014

Zoom Video Communications Inc. (2016). *Security guide. Zoom Video Communications Inc*. https://d24cgw3uvb9a9h.cloudfront.net/static/81625/doc/Zoom-Security-White-Paper.pdf

Supplemental Tables 1 and 2: Supplemental Table 1 details the practical feasibility outcomes for those with versus without care-partners. Supplemental Table 2 details the treatment effect outcomes for those with versus without care-partners.

Supplemental Table 1. Practical Feasibility Outcomes by Care-Partner Status

	Demographics		EMST				CST			
	Disease duration (years)	MMSE Score (mean)	Initial MEP duration (minutes)	Final MEP duration (minutes)	EMST 1st session duration (minutes)	EMST 4th session duration (minutes)	Initial PEFR duration (minutes)	Final PEFR duration (minutes)	CST 1st session duration (minutes)	CST 4th session duration (minutes)
Participants **with** a Care-Partner	5.44	25.43	10.93	6.17	8.10	9.89	5.23	3.28	12.26	11.91
Participants **without** a Care-Partner	9.00*	28.83	10.03	4.61	6.24	4.98	4.47	2.15	13.24	8.48

*One participant with cerebellar ataxia in the group of participants without a care-partner had a disease duration of 42 years. When excluding this participant, the mean disease duration for the group of participants without a care-partner was 6.00.

Supplemental Table 2. Treatment Effect Outcomes by Care-Partner Status

	EMST			CST					
				Single Voluntary Cough			Sequential voluntary cough		
	pMEP pre-treatment mean cmH_2O (SD)	pMEP post-treatment mean cmH_2O (SD)	Magnitude of Change in pMEP (cmH_2O)	PEFR pre-treatment mean L/min (SD)	PEFR post-treatment mean L/min (SD)	Magnitude of Change in PEFR (L/min)	PEFR pre-treatment mean L/min (SD)	PEFR post-treatment mean L/min (SD)	Magnitude of Change in PEFR (L/min)
Participants **with** a Care-Partner	52.0 (21.5)	65.6 (17.4)	13.6	245 (82.5)	322 (129)	77	238 (82.8)	294 (125)	56
Participants **without** a Care-Partner	74.7 (22.8)	102 (30.6)	27.3	322 (112)	368 (165)	46	310 (106)	354 (126)	44