*Research Article*

# Home-Based Pilot Pulmonary Program for Dyspneic Patients Post-COVID-19

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**Abstract**

It is estimated that at least 10% of people who have had COVID-19 will experience ongoing symptoms such as shortness of breath, fatigue, and cognitive disturbances. Pulmonary exercise has demonstrated improved dyspnea outcomes in other respiratory conditions. Thus, the purpose of this study was to assess the efficacy of a home-based pulmonary rehabilitation program in post-COVID-19 survivors who continue to experience dyspnea. This was a longitudinal, single group pilot study in which 19 patients received a home-based expiratory muscle strength training program over 12 weeks. Outcomes measured at baseline, 6 weeks, and 12 weeks included pulmonary symptoms, functional performance, thoracic expansion, forced expiratory volume, and expiratory resistance measures. Significant improvements were found in pulmonary symptoms ($p < .001$), functional performance ($p = .014$), and progressive expiratory resistance capabilities ($p < .001$). A home-based pulmonary program may be an inexpensive strategy for post-COVID-19 survivors who continue to experience dyspnea.

**Keywords**

COVID-19, pulmonary rehabilitation, expiratory muscle strength training, home-based rehabilitation, dyspnea

## Introduction and Purpose

The prolonged nature of COVID-19 symptoms and associated dyspnea has resulted in the need for feasible, home-based pulmonary rehabilitation strategies. Pulmonary programs have been successfully used for individuals with other chronic respiratory conditions (Gluncic et al., 2021). While the physiologic basis of post-COVID-19 persistent dyspnea is not fully understood, there is developing scientific evidence to support the use of pulmonary exercises to address persistent dyspnea in patients affected by post-COVID-19 (Wittmer et al., 2021). Rehabilitation programs that focus on breathing exercises are an important strategy for managing the pulmonary complications of COVID-19 (Kolodziej et al., 2021).

Expiratory muscle strength training (EMST) and pursed lip breathing (PLB) exercises utilize restricted airflow breathing to challenge the respiratory muscles, which creates a strengthening response of the respiratory musculature (Laciuga et al., 2014; Mota et al., 2007). PLB creates a positive expiratory pressure that prevents early bronchial collapse and maintains the patency of the airway (Lalwani et al., 2020). Respiratory muscle strength training can help to reduce the work of breathing, which relates to the improvements noted in exercise endurance (Held & Pendergast, 2014). In the post-COVID-19 population, respiratory muscle exercises recruit the intercostal and abdominal wall muscles which reduces dyspnea, increases chest wall expansion, decreases the respiratory rate, and improves pulmonary ventilation (Liu et al., 2020).

The evidence for using pulmonary rehabilitation for patients with post-COVID symptoms is based on improvement in pulmonary function (Dixit et al., 2021; Kolodziej et al., 2021; Liu et al., 2020; Wittmer et al., 2021). The surge of healthcare needs by COVID-19 survivors has created a deficit in pulmonary rehabilitative care for patients in need (Dixit et al., 2021). Thus, innovative, home-based strategies

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designed to deliver pulmonary rehabilitation care are needed. Home-based pulmonary rehabilitation exercise programs are feasible, inexpensive, and capable of reaching remote or underserved populations, or for those who are awaiting a traditional pulmonary rehabilitation program (Dixit et al., 2021; Siso-Almirall et al., 2021; Wittmer et al., 2021). There are currently no published research studies evaluating the effects of EMST in the post-COVID-19 population.

The primary aim of this longitudinal, single-group design pilot study was to assess the efficacy of a home-based respiratory rehabilitation program in survivors post-COVID-19 who continue to experience dyspnea. We explored the effects of a 12-week, home-based EMST program, on pulmonary symptoms, pulmonary, and physical functioning by focusing on building the strength and endurance of the expiratory musculature.

## Methods

### Participants

In all, 19 participants were recruited from the community by providing study information to patients being discharged from COVID hospital units, social media outreach, newsletters, and flyers from July 1, 2021 to May 1, 2022. Inclusion criteria are as follows: (1) adults over 18 years of age; (2) self-reported history of a positive COVID-19 diagnosis in the past; (3) able to walk independently; (4) cognitively intact; (5) English speaking; and (6) dyspnea at rest or with activity. Exclusion criteria are as follows: (1) patients who cannot walk independently or (2) patients who had COVID-19 and received mechanical ventilation during hospitalization due to the concern that these patients were not generally mobilized, which could have impacted the study outcomes. For those meeting eligibility requirements, written informed consent was obtained.

Participants were then assessed in the Physical Therapy and Rehabilitation laboratory where a research study nurse and physical therapist obtained the participant's baseline information, physiologic measurements, and survey information.

### Study Design

In this longitudinal, single-group design pilot study, participants were assessed at baseline, 6 weeks, and 12 weeks for pulmonary symptoms, pulmonary function, and functional performance. In addition, participant's progress in developing their expiratory resistance capabilities was measured throughout the study (Appendix Figure A1).

### Study Intervention

The pulmonary rehabilitation intervention consisted of a 3-month, home-based set of pulmonary exercises designed to increase the strength of the respiratory muscles. All participants received an EMST device, written instructions for EMST, PLB instructions, and a pulmonary exercise diary to record their breathing exercises. A YouTube link with a video demonstrating the breathing exercises with directions was provided. Weekly phone calls were also held with the participants throughout the study.

### EMST Pulmonary Exercise

For performing the EMST exercises, the participants used a hand-held resistance device (EMST 150, Aspire Products LLC, Cape Carteret, NC, USA). Training was performed according to the program designed by Mota et al. (2007) and was initially set for less than 50% of their maximum peak expiratory flow. Each week, the participant increased the minutes of work and decreased the rest time. In addition, the expiratory resistance was increased based on the participant's report of their level of exertion on the dyspnea exertion scale (Borg, 1982). The EMST exercise involved 3 minutes of active training with instructions to inhale through the mouth for a count of two, and then blow out through the device against the resistance set while wearing a nose clip. This was followed by 2 minutes of rest, continuing to alternate the EMST breathing exercises and rest times over a 30-minute timespan. The first session was held in the laboratory under the supervision of the nurse and physical therapist. Afterwards, the participants were asked to perform the EMST exercises three times per week.

### PLB Exercise

For the PLB exercise, participants were instructed to inhale by taking a deep breath in through their nose for two counts, followed by blowing the air out slowly through their pursed lips in a fine and steady stream. The initial training was carried out in the laboratory, under the supervision of the nurse and physical therapist. The participants were then asked to perform two sets of 10 repetitions of these exercises, twice per day.

### Measurements

*Baseline sample characteristics*: Baseline data were collected using a 22-question form that included age, gender, ethnicity, race, comorbidities, hospitalizations related to COVID-19, smoking status, and vaccination status.

*Pulmonary symptoms*. The chronic obstructive pulmonary disease (COPD) Assessment Test (CAT) was used to measure the participant's pulmonary symptoms at baseline, 6 weeks, and 12 weeks. The CAT scale is an 8-item questionnaire with a 6-point differential scale for each item. Scores range from 0 to 40, where higher scores indicate more severe symptoms. Cronbach's alpha = 0.88 (Jones et al., 2009).

*Forced expiratory volume over one second.* The participant's forced expiratory volume over one second (FEV1) was assessed using the Microlife PEF1 Digital Peak Flow and FEV1 Meter (Clearwater, US). Three separate measures were taken during each visit and the average of the three measures recorded.

*Expiratory resistance.* Resistance settings on the handheld expiratory muscle strength trainer device (EMST 150, Aspire Products, LLC, USA) were recorded at baseline. The documentation of the participant's progress in increasing the expiratory resistance from baseline to the study endpoint was recorded weekly during the phone calls and diary review.

*Functional performance.* The six-minute walk test (6-MWT) was used to assess the participant's functional performance capabilities through measurement of the distance the participant was able to walk within 6 minutes. Oxygen saturation, blood pressure, heart rate, respiratory rate, level of breathlessness, and perceived exertion measures (Borg, 1982) were collected before and after the walk test (Crapo et al., 2002; Jenkins, 2007).

*Thoracic expansion.* Thoracic expansion was measured using a tape measure (Baseline Evaluation Instruments, White Plains, NY, USA) placed around the participant at the level of the 4th intercostal space to record the circumferential chest wall excursion during inspiration and expiration (Moll & Wright, 1972). The difference between these values was recorded as thoracic expansion. The measurements were performed with the participant unclothed from the waist up, with the participant's arms hanging loosely at their side while standing (Illeez Memetoglu et al., 2016). Three separate measures were taken during each visit to the laboratory and the average of the three measures was recorded.

*Safety endpoints.* Participants were instructed to report any increase in shortness of breath, chest pain, or lightheadedness throughout the study. Vital signs were assessed in accordance with the American Thoracic Society Guideline for the 6-MWT.

### Statistical Analysis

Descriptive statistics were presented as means and standard deviations and the frequency distributions of categorical data were reported as numbers and percentages. Intra- and inter-tester reliability was analyzed for the chest expansion measurements. While limited by a sample size of 19, and due to the repeated measures design of the study, the nonparametric Friedman test was used to measure the study outcomes at three different points in time. A post-hoc Bonferroni correction was used to evaluate the effectiveness of the intervention over time. The Kendall's $W$ was used to calculate the effect size. The statistical significance was set at $p < .05$. SPSS 27.0 (IBM, NY, USA) was used for all statistical analyses.

## Results

A total of 53 participants were assessed for eligibility. Among these, 25 declined study participation for a variety of reasons. Eight potential participants did not meet the established eligibility criteria, and two were too sick to come for the in-person assessments. Of the 19 patients who were enrolled in the study, one was not able to continue past the baseline measurement phase due to illness and rehospitalization. Finally, a total of 18 participants completed the study and all 18 patients received the intervention.

### Baseline Characteristics

Sixty-three percent of the sample population were female. Ages ranged from 21 to 84 years, with 44% of the participants being older than 65 years of age. Asthma was found to be the most prevalent of the pulmonary comorbidities, followed by COPD, bronchitis, bronchiectasis, and pulmonary hypertension. 47% of the participants had been hospitalized during the acute phase of the COVID-19 virus (Table 1).

### Pulmonary Symptoms

There was a statistically significant decrease in the CAT scores across the three timepoints (pre-intervention, 6 weeks, and 12 weeks $\chi^2$ (2, $n = 17$) = 17.55, $p < .001$). Examination of the median values showed a decrease in COPD symptoms from a pre-intervention average of 17 to a post-intervention average of 9, and a moderate effect size of .51 (Table 2).

### Forced Expiratory Volume

There was no statistically significant difference in the FEV1 measurements across the three timepoints (pre-intervention, 6 weeks, and 12 weeks, $\chi^2$ (2, $n = 17$) = .121, $p = .941$) (Table 2).

### Expiratory Resistance

There was a statistically significant improvement in the participant's ability to perform EMST at increasing resistance across the three timepoints (pre-intervention, 6 weeks, and 12 weeks, $\chi^2$ (2, $n = 18$) = 24.5, $p < .001$). Resistance measures showed an improvement from a pre-intervention resistance of 30 to a 12-week intervention resistance capability of 60, with a large effect size of .68 (Table 2).

### Functional Performance

There was a statistically significant improvement in the 6-MWT across the three timepoints (pre-intervention, 6 weeks, and 12 weeks, $\chi^2$ (2, $n = 17$) = 8.59, $p = .014$). The meters walked showed an improvement from the baseline measure of 398.83 to 431.9 m walked at 12 weeks, which was a small effect size (Table 2).

**Table 1.** Baseline Characteristics of Participants ($n = 19$).

| Variable | *n* (%) |
|---|---|
| Gender | |
| Female | 12 (63.2%) |
| Male | 7 (36.8%) |
| Smoking status | |
| Yes | 0 (0%) |
| No | 19 (100%) |
| Former smoker | 9 (47.4%) |
| Comorbidities | |
| Hypertension | 5 (28%) |
| Chronic obstructive pulmonary disease | 3 (15.8%) |
| Bronchitis | 2 (11%) |
| Bronchiectasis | 1 (6%) |
| Asthma | 6 (33%) |
| Lung cancer | 1 (6%) |
| Pulmonary Hypertension | 1 (6%) |
| Other | 8 (44%) |
| Hospitalized for COVID | |
| Yes | 9 (47.4%) |
| No | 10 (52.6%) |
| Age | 59.39 ± 16.05 |
| Age range (years) | 21–84 |
| Body mass index | 32.95 ± 7.96 |
| Race (white) | 17 (94.4%) |
| Ethnicity (non-Hispanic) | 16 (84.2%) |

### *Thoracic Expansion*

There was no significant increase in chest expansion measures across the timepoints (pre-intervention, 6 weeks, and 12 weeks, $\chi^2$ (2, $n = 17$) = 3.79, $p = .15$).

## Discussion

The pulmonary symptom scores in our study using the CAT demonstrated a statistically significant reduction during the course of the study, which was consistent with prior studies that have demonstrated that pulmonary exercises are effective in improving quality of life and pulmonary symptom scores in patients with COPD, asthma, bronchiectasis, and restrictive lung diseases (Essam et al., 2022; Pehlivan et al., 2019; Renolleau-Courtois et al., 2014; Tarigan et al., 2020). Recently, a 5-week, randomized controlled study of 52 individuals with post-COVID-19-related dyspnea who received a respiratory exercise breathing program via tele-medicine reported significantly improved quality of life scores in those individuals who were in the intervention group (Okan et al., 2022).

There was no significant change in the forced expiratory volume measures in our participants following the intervention. These results are similar to a randomized control trial of 120 formerly hospitalized individuals with post-COVID-19 persistent dyspnea who underwent a 6-week home-based telerehabilitation program, finding no significant improvements in pulmonary function measures (Li et al., 2022). However, a randomized controlled trial of 72 elderly patients with post-COVID-19 who underwent a 6-week inpatient hospital rehabilitation program found improvements in the forced expiratory volume measure those who received respiratory muscle strength training (Liu et al., 2020). The variability of the forced expiratory volume results among studies may be related to the types of pulmonary rehabilitation protocols used, the small sample sizes, and measurement methodologies.

Expiratory resistance progression by the participants demonstrated statistically significant improvements at both the 6-week and the 12-week measures. Xu et al. (2018) also found significant improvements in respiratory muscle strength following 8 weeks of combined inspiratory muscle strength training and EMST in a group of 92 patients with COPD. Respiratory muscle strength training, specifically resulting in an increase in expiratory muscle strength, has been found to be beneficial in relieving dyspneic symptoms and improving quality of life (Held & Pendergast, 2014).

The participants in our pilot study demonstrated improvement in their functional performance as measured by the 6-MWT at 12 weeks. These results are similar to those reported in a randomized controlled trial of 72 elderly, post-COVID-19 patients, of whom 36 received a 6-week respiratory rehabilitation program and experienced significant improvements in the 6-MWT (Liu et al., 2020). A systematic review and meta-analysis that analyzed the effects of pulmonary rehabilitation on patients post-COVID-19 concluded that pulmonary rehabilitation improved functional capacity as measured by the 6-MWT (Chen et al., 2022).

Thoracic expansion measures demonstrated a clinical improvement at 12 weeks in our study, although the results were not statistically significant. Conversely, a study of 20 patients with post-COVID-19 who underwent an 8-week, unsupervised pulmonary rehabilitation program reported statistically significant improvements in chest expansion measurements (Stavrou et al., 2021). It is possible that the older age and elevated body mass index of our participants may have prevented us from achieving statistical significance in thoracic expansion.

### *Implications for Nursing*

The findings of this pilot study point to the implementation of a home-based respiratory muscle strength training program for patients with persistent dyspnea after COVID-19. Inspiratory respiratory muscle strength training research studies have recently begun to report a reduction in dyspnea in patients with post-COVID-19 ((Li et al., 2022; Liu et al., 2020; McNarry et al., 2022), but have not yet been standardized. This pilot study suggests that a standardized respiratory exercise program may be used to support the post-COVID-19 population who continue to experience dyspnea.

**Table 2.** Comparison of Pulmonary and Functional Outcomes (0–6–12 Weeks).

| Measures | Baseline median score | 6 weeks median score | 12 weeks median score | Chi-square/*p* value | Effect size |
|---|---|---|---|---|---|
| Pulmonary symptoms (COPD test) | 17 | 11 | 9 | $\chi^2$ (2, $n$ = 17) = 17.55, $p < .001$ | 0.51 |
| Forced expiratory volume over 1 second (liters) | 2.25 | 2.35 | 2.28 | $\chi^2$ (2, $n$ = 17) = 0.121, $p = .941$ | 0.003 |
| Expiratory resistance–pressure resistance | 30 | 45 | 60 | $\chi^2$ (2, $n$ = 18) = 24.5, $p < .001$ | 0.68 |
| Functional performance (6-minute walk test), meters | 389.83 | 398.19 | 431.9 | $\chi^2$ (2, $n$ = 17) = 8.59, $p = .014$ | 0.22 |
| Thoracic expansion (centimeters) | 2.0 | 1.79 | 2.3 | $\chi^2$ (2, $n$ = 17) = 3.79, $p = .15$ | 0.11 |

### *Limitations and Future Research*

This pilot study has several limitations. The sample size is small as a result of difficulties in part by the ongoing pandemic and social isolation concerns. The lack of a control group to compare participants not receiving this intervention is another limitation of this study. Another consideration is that a high proportion of the participants had concomitant chronic respiratory diseases, and it is possible that having COVID may have simply exacerbated their underlying lung disease, thereby increasing their dyspnea. In addition, although the assessors were unaware of the participant's progression through the study, they were not blinded due to the lack of a control group. These limitations may be addressed in the future by a randomized control trial with a large sample size, as well as blinding of the assessors. Another area of future research would be to investigate the effect of inspiratory muscle strength training, combined with EMST and PLB on persistent dyspnea in the post-COVID population.


## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Ethical Considerations

This study was conducted with the approval of the institutional review board of the University of South Florida (approval number: 001573).


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## Appendix 1

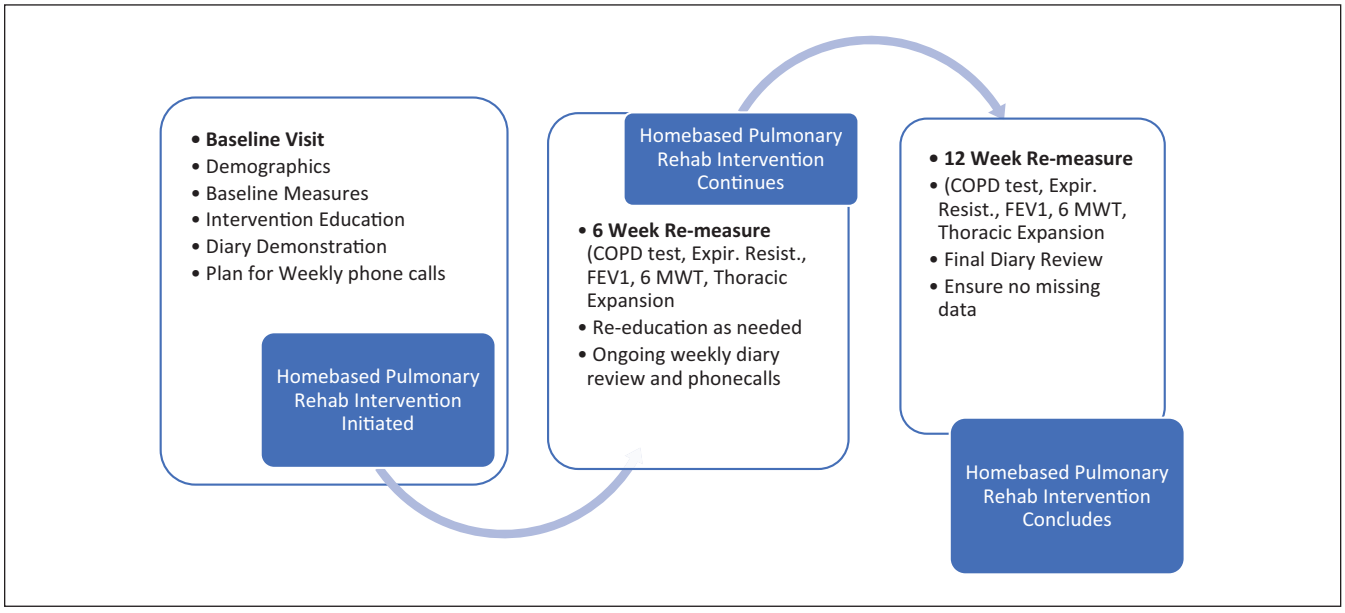


**Figure A1.** Study design.
*Note.* Expir. Resist. = expiratory resistance; FEV1 = forced expiratory volume over 1 second; 6 MWT = 6 Minute Walk Test.

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