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Effect of Home-Based Pulmonary Rehabilitation on Pulmonary Fibrosis

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ABSTRACT

Background: Pulmonary fibrosis is a chronic, progressive lung condition that involves lung tissue scarring and thickening. The effects of home-based pulmonary rehabilitation (PR) in post-COVID pulmonary fibrosis (PCPF) and other forms of fibrosis together have not been evaluated. This study aims to evaluate the effectiveness of home-based pulmonary rehabilitation on pulmonary function, functional capacity, and health-related quality of life in people with pulmonary fibrosis [post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to pulmonary tuberculosis (TB), pulmonary fibrosis secondary to interstitial lung disease (ILD), pulmonary fibrosis secondary to bronchiectasis].

Methods: A single-group pretest–posttest experimental study was performed after recruiting 98 pulmonary fibrosis subjects from K.M.C hospitals. After being screened for the inclusion and exclusion criteria, 45 subjects were analyzed, and 6 subjects were lost to follow up. A home-based pulmonary rehabilitation program was carried out for 8 weeks (warm-up, stretching exercises, aerobic exercise, strength training for upper limb and lower limb, breathing exercises mainly involved; others: energy saving techniques, controlled coughing techniques, dyspnea relieving positions). The program was supervised via weekly phone calls. Pulmonary function (Pulmonary function test), exercise capacity (6-minute walk test), dyspnea (modified Borg scale), and health-related quality of life (SF-36) were evaluated before and after the intervention. During the enrollment and after the 6-minute walk test, saturation of peripheral oxygen (SPO_2) level was also evaluated pre-intervention and after the 8-weeks program.

Results: Pulmonary function [FVC(L) t = -12.52, p<0.05; FEV_1(L) t = -2.56, p<0.05; FEV_1/FVC t = 7.98, p<0.05 and DL_{CO} (ml/min/mmHg) t = -5.13, p<0.05], 6MWD [MD 88.66; p<0.05] and HRQOL measured by SF-36 scores (p<0.05) were improved significantly. Both the baseline SPO_2 level before the 6MWT [MD 1.07, p<0.05] and the SPO_2 level after the 6MWT [MD 1.16, p<0.05] showed a significant improvement. The rating of perceived exertion(dyspnea) [MD 1.30, p<0.05] was reduced significantly after the 8-week program.

Conclusion: Our study shows that home-based pulmonary rehabilitation is an effective option for improving lung function and physical functional capacity by reducing dyspnea perception and improving the saturation of peripheral oxygen (SPO_2) level, and enhancing the quality of life in people with pulmonary fibrosis.

Key words: home-based pulmonary rehabilitation, post-COVID pulmonary fibrosis, idiopathic pulmonary fibrosis, interstitial lung disease, pulmonary function test, quality of life.

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Ethics approval and consent to participate: This study had been reviewed and approved by the Institutional Ethics Committee, Kasturba Medical College, Mangalore (Protocol No: IEC KMC MLR 01/2022/18). All participating subjects had received a verbal explanation, written detailed information on the study, and signed consent forms for the participation. The processing of sensitive personal data was based on following the Helsinki Declaration's ethical principles.

Consent for publication: Written informed consent was obtained from all individuals participating in the study and all authors in this study provided formal consent for publication.

Availability of data and material: The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest: All authors declare that they have no competing interests.

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Background

Pulmonary Fibrosis (PF) is the common term used to describe a large family of diseases that causes inflammation and scarring of the lung. It is typically not a primary disease but rather develops as a result of other respiratory or interstitial lung disorders [1–3]. Worldwide, pulmonary fibrosis has a high prevalence and mortality rate [4]. In the post-COVID era, the healthcare system has been changed by post-COVID complications [5]. One of them is post-COVID Pulmonary Fibrosis (PCPF) [6]**.** However, pulmonary fibrosis is caused not just by post-COVID or interstitial lung diseases but also by other lung diseases such as bronchiectasis and pulmonary tuberculosis (TB).

Basically, the extracellular matrix (ECM) becomes coated with abnormal collagens, causing pulmonary fibrosis. This results in a stiff lung that lacks the compliance (or "stretchability") required for regular breathing [7]. Lung scarring blocks the pathways necessary for deactivating pro-fibrotic cells and eliminating the proliferating matrix. This intricate process includes myofibroblast transition of epithelial cells, a procoagulant framing in the lung, oxidative signaling, supported by the accumulation of reactive oxygen species in the lungs, and replacement of the normal type I alveolar epithelium with hyperplastic type II cells [8]. It is driven by neutrophils and macrophages because of their released cytokines (IL-6, IL-2, IL-1, and TNFα) and chemokines (IL-8 and oxanthin) [9].

People with pulmonary fibrosis seek medical attention for their progressive, persistent coughs and dyspnea. Dyspnea and fatigue impair the functional capacity and quality of life of pulmonary fibrosis patients. Individuals with pulmonary fibrosis gradually become less physically active and unable to do daily living activities as fibrosis advances, dyspnea, and exhaustion worsen [10].

Pulmonary rehabilitation (PR) is one of the advantageous management techniques to improve shortness of breath, health status, exercise tolerance, etc. In 2013, the 'American Thoracic Society (ATS)' defined pulmonary rehabilitation as - "A comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies, which include but are not limited to, exercise training, education, and behavior change, designed to improve the physical and emotional condition of people the long-term adherence of health-enhancing behaviors" [11].

As a homecare-based rehabilitation purpose, patients with pulmonary fibrosis (post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, pulmonary fibrosis secondary to bronchiectasis) frequently require assistance from family members, who can be trained by health professionals in their own home environment. Basically, home-based programs are a good and suitable option for pulmonary rehabilitation in everyday life [12]. Furthermore, these programs are effective, useful, simple, cost-effective, and practical [13, 14].

A standard home-based pulmonary rehabilitation program for patients with pulmonary fibrosis (post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, pulmonary fibrosis secondary to bronchiectasis) has not been studied in India. Therefore, this study aimed to investigate the effectiveness of home-based pulmonary rehabilitation for pulmonary fibrosis patients. As we included patients with post-COVID pulmonary

fibrosis, pulmonary fibrosis due to TB, pulmonary fibrosis secondary to ILD, and pulmonary fibrosis secondary to bronchiectasis; our study differs from earlier studies in these areas.

Methods

The study was approved by the Institutional Ethics Committee of Kasturba Medical College, Mangalore (Protocol number: IEC KMC MLR 01/2022/18) and complied with the Declaration of Helsinki (as revised in 2013). The trial was registered at www.clinicaltrials.gov (CTRI/2022/03/041284).

Study Design

A single group pretest-posttest experimental study was conducted in the KMC hospitals (OPD), Ambedkar Circle and Attavar, Mangalore. It was performed between February 2022 to January 2023.

Participant selection

Study participants were recruited from KMC hospitals, Mangalore, those were visiting the outpatient department (OPD) diagnosed with pulmonary fibrosis referred by pulmonologists based on standard diagnostic criteria [15]. Prior to the start of the 8-week home-based pulmonary rehabilitation program, a total of 98 pulmonary fibrosis participants were achieved. However, 37 of them were eliminated since 32 did not match the inclusion criteria, and 5 did not want to take part in this study.

Inclusion criteria

a. Pulmonary Fibrosis secondary (2°) to interstitial lung disease (ILD).
b. Pulmonary Fibrosis post-COVID.
c. Pulmonary Fibrosis secondary (2°) to other lung disease like bronchiectasis, tuberculosis, etc.
d. Age: 18-80 years
e. Moderate to severe diagnosed through PFT (FEV_1<50).
f. Independent ambulation.

Exclusion criteria

a. Cardiac conditions (Moderate to severe) like coronary artery disease and congestive heart failure.
b. Respiratory conditions like chronic obstructive pulmonary disease (COPD), asthma, lung cancer, severe pulmonary hypertension.
c. Other neuromuscular conditions affecting respiratory as well as physical function.

Procedures

Subjects were included based on the inclusion criteria. They were screened for points mentioned in the exclusion criteria. Eligible subjects were called on a subsequent day and explained about this research study if the patient voluntarily agreed, then they were asked to sign a written informed consent in English and their vernacular language. Pre-testing was done before starting the home-based pulmonary rehabilitation program and all outcomes were recorded. Pulmonary Function Test (PFT), SF-36 scale, and 6 MWT were conducted. Readings were recorded and stored for statistical analysis. The intervention was started at the home of the candidate, and all the guidelines of the American Thoracic Society (ATS) for home-based pulmonary rehabilitation were followed [13, 16, 17]. We had developed a home-based pulmonary rehabilitation protocol based on previous literature and expert advice. Patients were provided with a booklet to refer at home with a family member supervising. After 8 weeks later, a post-test was conducted, and readings were recorded. Based on the pre-readings and post-readings, statistical analysis was done.

Intervention

Over the course of the 8-week program, the patients were instructed about the benefits and importance of adhering to the pulmonary rehabilitation program. The patient and patient's party who was there in the hospital was taught about the benefits of the program, and we asked the patient party to supervise the program at their home. Participants and

the participant's party were provided with a catalogue which had detailed instructions for the exercise program. The patients and patient's party were given a notebook or diary in which the patient was marked after doing performance, daily, and patient's party also had to signed. The patients were instructed to do all the exercises at least six days a week in three sessions with ten repetitions each. If the significant fatigue or shortness of breath, they were advised to take a rest and to keep doing the exercises according to their fatigue tolerance level. The supervision of the program was done by phone calls once a week and daily exercise queries. Once in a week, when we had called, we spoke to both patients and patient's party about the program, and any distress, progression, and hindrance (Figure 1).

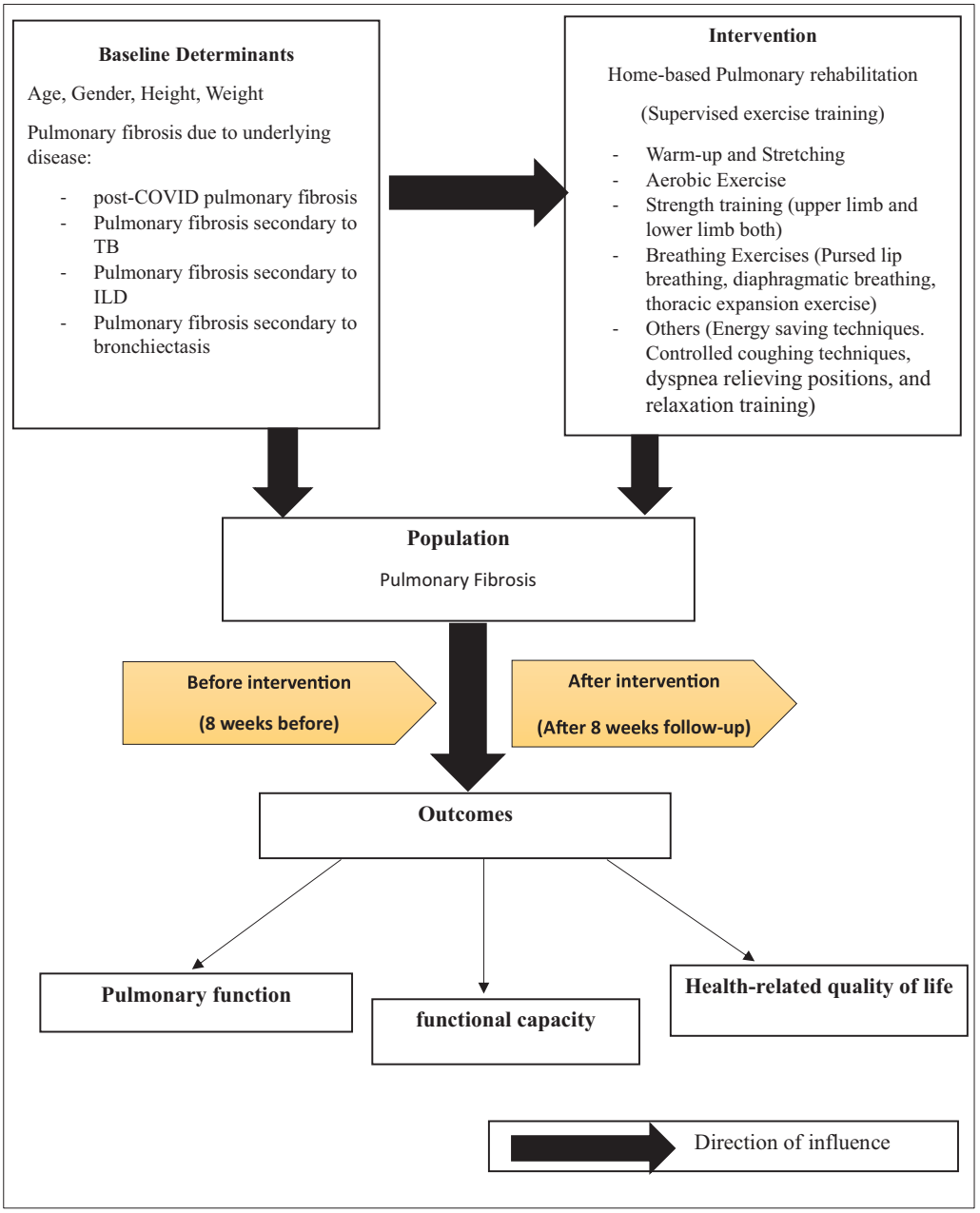

Figure 1. Framework for the effect of home-based pulmonary rehabilitation on pulmonary fibrosis (Authors creation of the figure).

Warm-up and stretching

The warm-up was for ~ 5min. It was composed of active upper and lower limb exercises. Stretching was ~ 5min, including the pectoralis major, trapezius, quadriceps, hamstrings, and gastrocnemius (calf) muscles. Each stretch posture was maintained for the 30s [18].

Aerobic exercises

Aerobic exercises consisted of walking and slow jogging. The training intensity was light (≤ 3 on modified Borg scale).

Time was at least for 20-30 min. And the exercise frequency was 1-2 times per day for 8 weeks [18, 10].

Strength training

For upper limb strengthening

Shoulder flexion, extension, abduction, elbow flexion, elbow extension with free weight; 8-10 rep. for each movement 2-3 sets, 2 times/day for 8 weeks [10, 13].

For lower limb strengthening

Seated dynamic quadriceps, hamstrings strengthening, hip abductors strengthening with weight cuff, heal raises 8-10 reps. for each and 2-3 sets, 2 times/day for 8 weeks. Sit-to-Sand exercise 3sets, 10 reps. 2 times/day for 8 weeks [18, 13, 10].

For strength training we checked for 1 RM. Since, these subjects are having pulmonary fibrosis, we further saw which weight subjects can do 7-10 repetitions for 1 set twice a day.

Progression

For progression at home, subjects were instructed that if given weight will be too easy to do and perceived dyspnea was ≤ 3 on the modified Borg scale (0-10), then increase the weight by adding another ½ kg. These clarifications were also done during follow up through telerehabilitation. This was done to ensure patient safety.

Others

It consists of teaching breath control (pursed lip breathing, diaphragmatic breathing), thoracic expansion exercise 10 reps, 2-3 sets /day for 8weeks, energy-saving techniques, and controlled coughing exercises. Coping strategies to deal with shortness of breath and relaxation training were taught to the patients [10, 19].

Termination criteria

- Dyspnoea more than 3 on 'modified Borg scale (0-10)'.
- Chest tightness, blurring of vision, profuse sweating, giddiness, and any balance problem.
- Patient decision to stop.

Outcome measures

Before and after the 8 weeks home-based pulmonary rehabilitation program, all patients were assessed using the same criteria.

Primary Outcomes

Pulmonary Function Test (PFT)

The forced expiratory volume in 1 second (FEV_1) ratio of FEV_1 to FVC (FEV_1/FVC) and carbon monoxide diffusing capacity (DL_{CO}) values were recorded. It was carried out by an expert in accordance with the ATS standards [20].

Instrument used: The instrument used for pulmonary function test was spirometry (EasyOne Pro Lab) *Portable Pulmonary Function Testing Machine - EasyOne Pro® | ndd Medical* ID:3100-1.

6-minute walk test

Exercise capacity was measured using the 6 min walk test(6 MWT). It was performed once at the starting and at the end of the pulmonary rehabilitation program, according to the guidelines of the American Thoracic Society [21]. Before and after the 6 MWT, the saturation of peripheral oxygen (SPO_2) level was assessed by using pulse oximeter (Omron CMS50N) [10].

Secondary Outcomes

Modified Borg scale (0-10)

Dyspnoea severity/rate of perceived exertion was measured by using a 'modified borg scale (0-10)' [22].

SF -36

Health-related quality of life was measured using the '36 -item Short Form Survey (SF-36) questionnaire' [23].

Saturation of peripheral oxygen (SPO2) level

Before and after the 6 MWT, the saturation of peripheral oxygen (SPO_2) level was assessed [10].

Data Analysis

Statistical analysis was done for all the variables in the study. Data was checked for normal distribution. All the variables under this study for pre to post changes had achieved normal distribution with a bell-shaped curve, then paired-t test was used to see the changes (pre to post) after 8 weeks of intervention. Descriptive statistics were used to analyze the demographic and baseline characteristics. Variables studied as outcomes (pre and post) for 8 weeks are presented as mean, standard deviation, confidence interval (C.I.), and p. P (<0.05) was considered significant. Data was analyzed using the software IBM SPSS version 26.0.1 (Statistical Package for the Social Sciences).

Results

A total sample size of 98 participants were achieved prior to the commencement of 8 weeks home-based pulmonary rehabilitation program. Out of 98, 37 participants were excluded as 32 were not meeting the exclusion criteria, and 5 refused to participate in this study. Out of 32, 27 participants were excluded due to medical conditions, 3 participants due to FEV_1>50%, and 2 participants due to age criteria. We analyzed 45 subjects because 6 subjects were lost to follow up. Figure 2 shows the recruitment process in the CONSORT flow diagram [24, 25].

Baseline characteristics of participants

Table 1 summarizes the demographic and baseline characteristics of the subjects in this study. The data analysis was performed on the 45 subjects (25 male, 20 female) (mean age 62.0±11.0 years) who completed the 8 weeks home-based pulmonary rehabilitation program. No adverse events were observed during the 8 weeks rehabilitation program. The causes of pulmonary fibrosis were post-COVID pulmonary fibrosis (35.6%), Pulmonary fibrosis secondary to TB (22.2%), Pulmonary Fibrosis secondary to ILD (33.3%), Pulmonary Fibrosis Secondary to bronchiectasis (8.9%). In this 8-week home-based pulmonary rehabilitation program, the completion rate is 74%, and the dropout rate is 26%.

Primary Outcome

6 MWT was performed using the standard test protocol (American Thoracic Society ATS guidelines) before and after 8 weeks of the intervention [21]. Table 2 describes the results of 6 MWT conducted pre-intervention and post-8 weeks of intervention. After the intervention, significant improvement in walking distance in the 6 MWT was found (MD 88.6 m), ($p<0.05$).

Table 3 describes the results of the pulmonary function test (PFT) conducted pre-intervention and post-8 weeks. After the home-based exercise program, pulmonary function test results (PFT) were significantly improved for FVC (1.29 liters vs. 1.38 liters, $p<0.05$), FEV_1(1.13 liters vs. 1.18 liters, $p<0.05$) FEV_1/FVC (0.84 vs. 0.82, $p<0.05$) and DL_{CO} (6.32 ml/min/mmHg vs. 6.7 ml/min/mmHg, $p<0.05$).

Secondary Outcome

Health-related quality of life (HRQOL) assessment was also done along with other outcome measure assessments. The analysis was divided into 9 domains of the scale respectively (Table 4). A significant improvement was found in physical functioning, role limitations due to physical health, role limitations due to emotional health, emotional well-being, social functioning, pain, general health, and health change

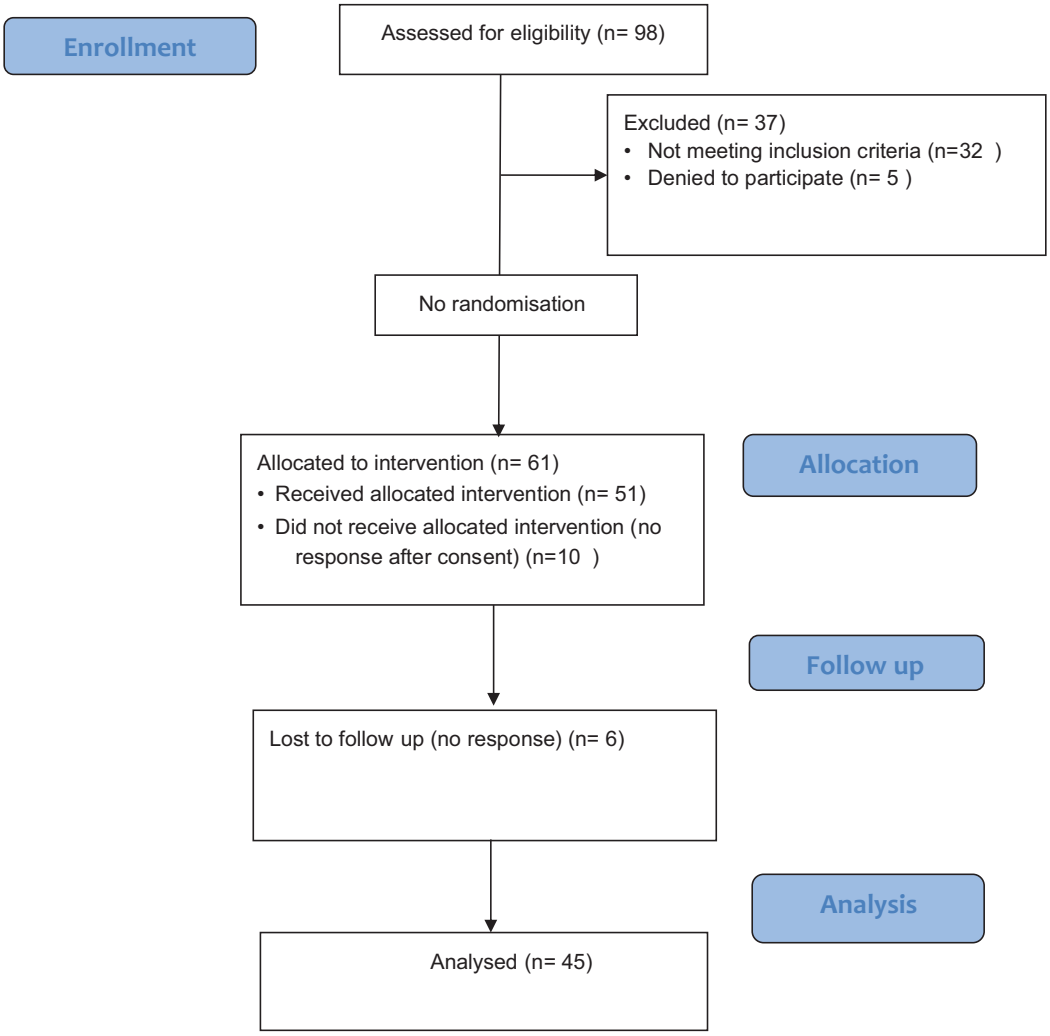

Figure 2. CONSORT Flowchart for Single-Arm Study. n= number of samples. Modified from [24].

Table 1. Demographic and baseline characteristics of the subjects in this study.

Characteristics	n	Value
Age (Years)	45	62.0±11.0
Gender (M: F)	45	25:20 (55.6%:44.4%)
Height (cm)	45	157.5±7.0
Weight (Kgs)	45	60.9±8.0
Pulmonary Fibrosis due to underlying disease		
1. Post-COVID Pulmonary Fibrosis	16	35.6%
2. Pulmonary Fibrosis secondary to TB	10	22.2%
3. Pulmonary Fibrosis secondary to ILD	15	33.3%
4. Pulmonary Fibrosis Secondary to bronchiectasis	4	8.9%

Table 2. 6 Minute Walk Test results before and after the home-based pulmonary rehabilitation.

Variable		n	Mean±S.D	MD	S.D of difference	C.I. at 95% of the difference		t	P
						Lower	Upper		
6MWT	Pre- Intervention	45	185.0±45.2	88.66	30.39	-97.80	-79.53	-19.56	0.000*
	post-Intervention	45	273.6±66.2						

*p<0.05, n, number of samples; SD, standard deviation; MD, mean difference; C.I, confidence interval; t, test statistic; p, level of significance.

Table 3. Pulmonary function test results (PFT) results before and after the home-based pulmonary rehabilitation.

Variables		Mean±S.D	MD	S.D of difference	C.I. at 95% of the difference		t	P
					Lower	Upper		
FVC(L)	Pre- Intervention	1.29±0.36	0.08	0.04	-0.09	-0.06	-12.52	0.000*
	post-Intervention	1.38±0.38						
FVC (% pred)	Pre- Intervention	42.88±4.70	2.71	1.10	-3.04	-2.38	-16.53	0.000*
	post-Intervention	45.60±4.63						
FEV_1 (L)	Pre- Intervention	1.13±0.31	0.05	0.14	-0.09	-0.01	-2.56	0.014*
	post-Intervention	1.18±0.37						
FEV_1 (% pred)	Pre- Intervention	45.86±4.35	3.11	1.86	-3.67	-2.55	-11.2	0.000*
	post-Intervention	48.97±4.58						
FEV_1/FVC	Pre- Intervention	0.84±0.05	0.019	0.016	0.014	0.024	7.98	0.000*
	post-Intervention	0.82±0.05						
FEV_1/FVC (% pred)	Pre- Intervention	110.7±7.81	2.86	2.22	2.19	3.53	8.65	0.000*
	post-Intervention	107.9±7.03						
DL_{CO} (ml/min/mmHg)	Pre- Intervention	6.32±1.34	0.45	0.59	-0.63	-0.27	-5.13	0.000*
	post-Intervention	6.78±1.73						
DL_{CO} (% pred)	Pre- Intervention	25.35±4.86	1.80	2.43	-2.53	-1.06	-4.95	0.000*
	post-Intervention	27.15±6.53						

*p<0.05, SD, standard deviation, MD, mean difference, C.I., confidence interval, t, test statistic, p, level of significance.

scores (p<0.05), but energy/fatigue domain score was not statistically significant. (>0.05). The highest difference was noted in the domains of role limitations due to emotional health (33.94 MD, p<0.05) and general health (35.45 MD, p<0.05).

The rate of perceived exertion (RPE) was taken using the 'Modified Borg scale' (0-10) after 6MWT. Table 5 shows the RPE changes taken before and after 8 weeks of intervention. MD of 1.3 (p<0.05) was observed. Table 6 and Table 7 show the distribution of subjects based on RPE scores pre-intervention and post-intervention.

Peripheral oxygen saturation (SPO_2) level was taken before and after the 6MWT(Immediately, 3min and 5min). Table 8 shows the SPO_2 level variation before and after the 8-week of intervention. A significant improvement was found for baseline SPO_2 level before the 6MWT [MD 2.73, p<0.05] , immediately after the 6MWT [MD 3.47, p<0.05], 3 min after the 6MWT [MD 3.57, p<0.05] and 5 min after the 6MWT [MD 3.65, p<0.0]. Figure 3 gives a graphical representation of SPO_2 level results taken at pre-intervention and after 8 weeks post-intervention.

Table 4. Quality of life (SF-36) results before and after the home-based pulmonary rehabilitation.

Domains		Mean±S.D	MD	S.D of difference	C.I. at 95% of the difference		t	P
					Lower	Upper		
physical functioning %	Pre- Intervention	21.33±10.02	28.11	14.78	-32.55	-23.67	-12.757	0.000*
	post-Intervention	49.44±16.62						
role limitations due to physical health %	Pre- Intervention	41.66±19.21	28.88	24.97	-36.39	-21.38	-7.760	0.000*
	post-Intervention	70.55±15.34						
role limitations due to emotional health %	Pre- Intervention	45.39±22.26	33.94	25.81	-41.69	-26.18	-8.821	0.000*
	post-Intervention	79.33±17.77						
energy/fatigue %	Pre- Intervention	50.55±9.54	0.88	11.14	-4.23	2.45	-0.535	0.595
	post-Intervention	51.44±6.79						
emotional well-being %	Pre- Intervention	54.13±9.51	8.35	10.64	-11.55	-5.15	-5.26	0.000*
	post-Intervention	62.48±7.64						
social functioning %	Pre- Intervention	56.28±12.35	27.34	13.38	-31.36	-23.32	-13.702	0.000*
	post-Intervention	83.63±7.92						
pain %	Pre- Intervention	82.50±18.27	13.16	17.88	-18.54	-7.79	-4.93	0.000*
	post-Intervention	95.66±7.21						
general health %	Pre- Intervention	27.55±9.45	35.44	11.47	-38.89	-31.99	-20.72	0.000*
	post-Intervention	63.00±7.02						
Health change %	Pre- Intervention	22.22±10.95	26.11	19.18	-31.87	-20.34	-9.13	0.000*
	post-Intervention	48.33±18.76						

*p<0.05, SD, standard deviation; MD, mean difference; C.I., confidence interval; t, test statistic; p, level of significance.

Table 5. Rate of Perceived Exertion (RPE) before and after the home-based pulmonary rehabilitation.

		n	Mean±S.D	MD	S.D of difference	C.I. at 95% of the difference	t	P
Rating of Perceived Exertion (RPE)	Pre-intervention	45	3±0.82	1.30	0.49	1.15-1.44	17.68	0.000*
	Post-intervention	45	1.7±0.73					

*p<0.05, n, number of samples; SD, standard deviation; MD, mean difference; C.I., confidence interval; t, test statistic; p, level of significance.

Table 6. Subjects distribution based on Rating of Perceived Exertion (RPE)scores before the home-based pulmonary rehabilitation.

Grade	n	Values (%)
2-3	32	71.1
4-5	13	28.9

Table 7. Subjects distribution based on Rating of Perceived Exertion (RPE)scores after the home-based pulmonary rehabilitation.

Grade	n	Values (%)
0-1	18	40
2-3	27	60

Table 8. SPO_2 results before and after the home-based pulmonary rehabilitation.

Variables (SPO_2 %)	Intervention	n	Mean±S.D	MD	S.D of difference	C.I. at 95% of the difference	t	P
Baseline before 6MWT	Pre-intervention	45	93.20±1.33	2.73	1.07	2.41-3.05	17.06	0.0001*
	Post-intervention	45	95.93±0.88					
Immediate after 6MWT	Pre-intervention	45	90.22±1.02	3.47	1.16	3.21-3.82	20.05	0.0001*
	Post-intervention	45	93.69±1.01					
3 min after 6MWT	Pre-intervention	45	91.56±0.78	3.57	1.07	3.25-3.90	22.30	0.0001*
	Post-intervention	45	95.13±0.86					
5 min after 6MWT	Pre-intervention	45	92.62±0.88	3.65	1.15	3.29-3.99	21.24	0.0001*
	Post-intervention	45	96.27±0.91					

*p<0.05, SD, standard deviation; MD, mean difference; C.I., confidence interval; t, test statistic; p, level of significance.

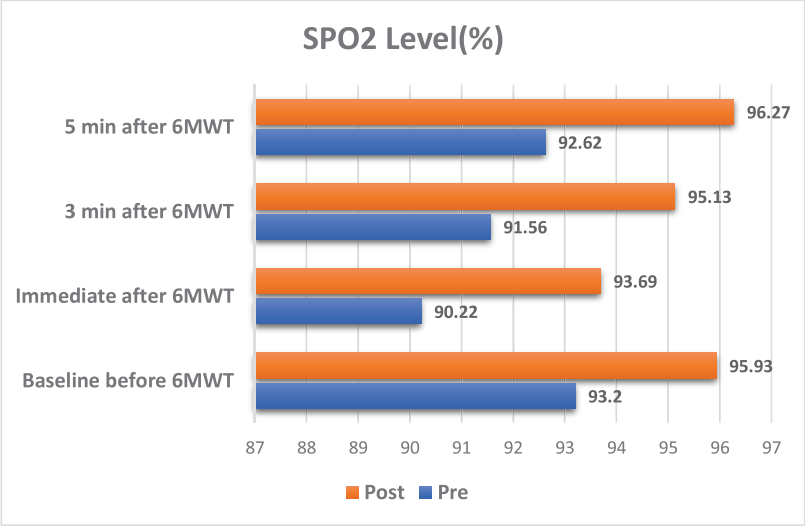

Figure 3. SPO_2 Level (%) pre- post intervention.

Subgroups: outcomes for pulmonary fibrosis due to underlying disease.

MDs for each outcome measures were estimated in the subgroups [post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, and pulmonary fibrosis secondary to bronchiectasis]; because the improvement results for each form of pulmonary fibrosis caused by the different pathological condition were not equal. However, due to the limited and uneven sample size no subgroup analysis (paired t-test) for post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, or pulmonary fibrosis secondary to bronchiectasis were not performed.

Primary outcomes for subgroups

Table 9 illustrates the MDs for PFT (Pulmonary function test) before and after the 8-week intervention in each kind of pulmonary fibrosis caused by an underlying condition. For each kind of pulmonary fibrosis, the FVC, FEV_1, FEV_1/FVC, and DL_{CO} data obtained before and eight weeks after the intervention are shown graphically in Figure 4-7.

Table 9. Pulmonary function test results (PFT).

	Pulmonary Fibrosis due to underlying disease											
	Post-COVID PF			PF secondary to TB			PF secondary to ILD			PF Secondary to bronchiectasis		
	Intervention (n=16)			Intervention (n=10)			Intervention (n=15)			Intervention (n=4)		
Variables (PFT)	Pre (n=16) Mean±S.D	Post (n=16) Mean±S.D	MD	Pre (n=10) Mean±S.D	Post (n=10) Mean±S.D.	MD	Pre (n=15) Mean±S.D	Post (n=15) Mean±S.D	MD	Pre (n=4) Mean±S.D	Post (n=4) Mean±S.D	MD
FVC(L)	1.42±0.27	1.51±0.28	0.09	1.12±0.35	1.20±0.38	0.08	1.44±0.32	1.53±0.34	0.09	1.05±0.39	1.11±0.40	0.06
FVC (% pred)	42.13±6.04	45.06±6.30	2.93	44.68±2.70	47.31±2.21	2.63	43±3.91	45.75±3.77	2.75	41.1±4.88	43.6±4.47	2.50
FEV_1(L)	1.26±0.33	1.34±0.36	0.08	0.95±0.25	1.00±0.27	0.05	1.20±0.17	1.26±0.18	0.06	0.98±0.30	1.00±0.42	0.02
FEV_1 (% pred)	44.2±6.86	47.73±7.35	3.53	46±3.16	48.75±3.30	2.75	47.06±1.84	50.31±1.92	3.25	46.4±1.64	48.8±1.75	2.40
FEV_1/FVC	0.83±0.05	0.81±0.04	0.02	0.85±0.08	0.83±0.07	0.02	0.83±0.03	0.82±0.02	0.01	0.84±0.05	0.82±0.04	0.02
FEV_1/FVC (% pred)	109.75±1.89	108.25±1.5	1.50	108.56±5.08	105.62±4.39	2.93	111.06±6.79	108.2±6.46	2.86	114.3±12.63	111±11.13	3.3
DL_{CO} (ml/min/ mmHg)	6.13±2.31	6.78±3.03	0.65	6.42±0.18	6.8±0.25	0.38	6.41±0.51	6.8±0.47	0.39	6.43±0.25	6.77±0.36	0.34
DL_{CO} (% pred)	24.73±8.19	27.46±11.19	2.73	25.6±1.64	27.1± 1.66	1.50	26.75±3.59	28.25± 4.57	1.50	25.43±1.26	26.62±1.36	1.19

*MD, mean difference for each type of pulmonary fibrosis due to underlying disease; *SD, standard deviation.

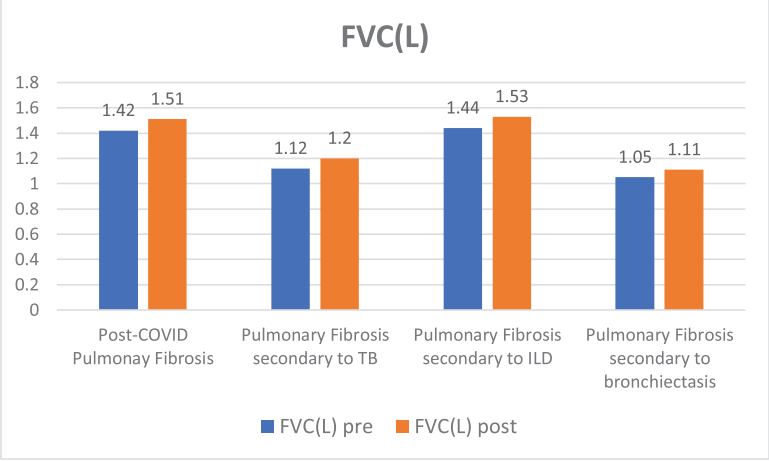

Figure 4. FVC(L) pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

Table 10 depicts the MDs for 6MWT distance before and after the 8-week intervention in each type of pulmonary fibrosis induced by an underlying disease. Figure 8 shows a graphical representation of 6MWT distance data acquired before and after 8 weeks of intervention for each type of pulmonary fibrosis due to different pathological condition. After the home-based exercise program, 6MWT distance results were improved for each type of pulmonary fibrosis [post-COVID pulmonary fibrosis 193.46 vs 291.27, MD 97.81 meter; pulmonary fibrosis secondary to TB 174 vs 258.5, MD 84.5 meter; Pulmonary fibrosis secondary to ILD 182.8 vs 270, MD 87.2 meter; pulmonary fibrosis secondary to bronchiectasis 187 vs 255, MD 68 meter].

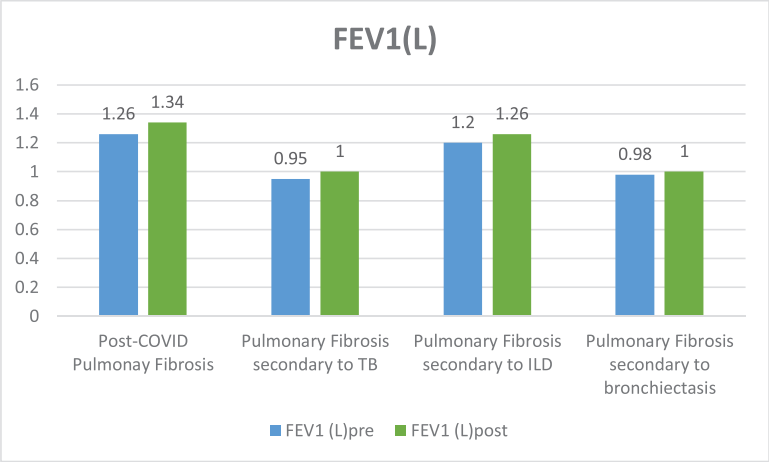

Figure 5. FEV_1(L) pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

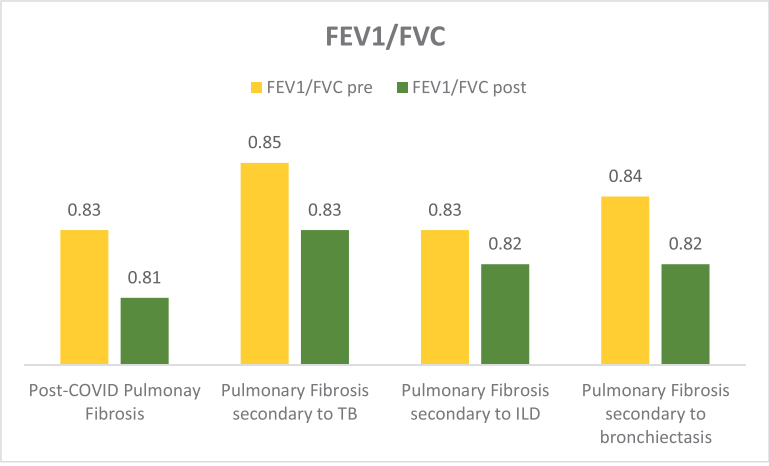

Figure 6. FEV_1/FVC pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

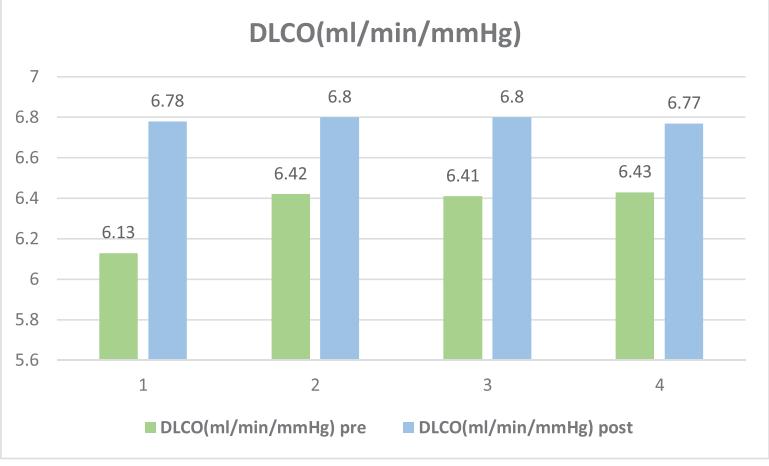

Figure 7. DL_{CO} pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

Table 10. 6MWT.

	Pulmonary Fibrosis due to underlying disease											
	Post-COVID PF			PF secondary to TB			PF secondary to ILD			PF Secondary to bronchiectasis		
	Intervention (n=16)			Intervention (n=10)			Intervention (n=15)			Intervention (n=4)		
Variables	Pre (n=16) Mean±S.D	Post (n=16) Mean±S.D	MD	Pre (n=10) Mean±S.D	Post (n=10) Mean±S.D.	MD	Pre (n=15) Mean±S.D	Post (n=15) Mean±S.D	MD	Pre (n=4) Mean±S.D	Post (n=4) Mean±S.D	MD
6MWT	193.46±49.18	291.27±67.58	97.81	174±31.60	258.5±37.27	84.5	182.8±51.05	270±80.26	87.2	187±44.07	255±66.08	68

*MD, mean difference for each type of pulmonary fibrosis due to underlying disease; *SD, standard deviation; *PF, pulmonary fibrosis.

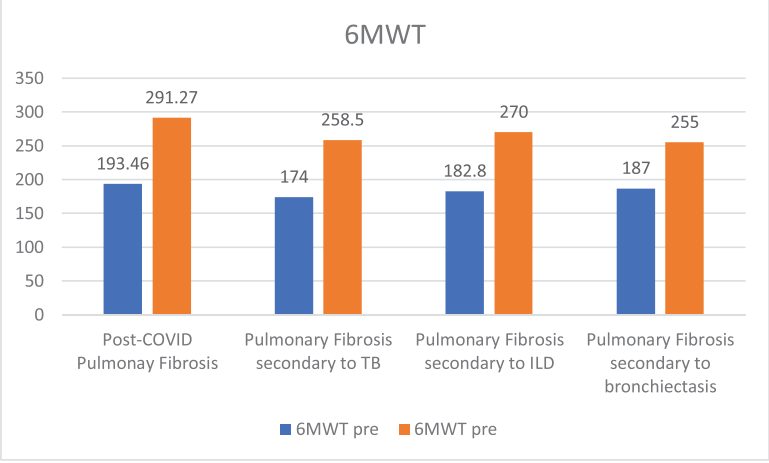

Figure 8. 6MWT Distance pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

SECONDARY OUTCOMES FOR SUBGROUPS:

Table 11 shows the MDs in 9 domains for SF-36 scale before and after the 8-week intervention in each type of pulmonary fibrosis caused by an underlying condition. The SF-36 scale measures health-related quality of life (HRQOL), which illustrates improvement in each of the nine domains pre and post intervention. An improvement was found in physical functioning, role limitations due to physical health, role limitations due to emotional health, emotional well-being, energy/fatigue, social functioning, pain, general health, and health change score. The highest difference was noted in the post-COVID pulmonary fibrosis group for the domains of role limitations due to physical health % (MD 45.32) and health change % (MD 31.25).

The MDs for rate of perceived exertion (RPE) in each form of pulmonary fibrosis caused by an underlying condition before and after the 8-week intervention are shown in Table 12. After the home-based exercise programme, RPE values were improved for each type of pulmonary fibrosis [post-COVID pulmonary fibrosis 2.87 vs 1.53, MD 1.34; pulmonary fibrosis secondary to TB 2.90 vs 1.60, MD 1.30; Pulmonary fibrosis secondary to ILD 3.20 vs 1.93, MD 1.27; pulmonary fibrosis secondary to bronchiectasis 3 vs 1.75, MD 1.25].

After the home-based exercise programme, baseline SPO_2 levels before the 6MWT and SPO_2 levels after the 6MWT were improved for each type of pulmonary fibrosis. Table 13 shows the MDs for SPO_2 level before and after the 8-week intervention for each type of pulmonary fibrosis induced by an underlying disease. Baseline SPO_2 levels before the 6MWT versus SPO_2 levels after 6MWT for each kind of pulmonary fibrosis conditions pre and post treatments were post-COVID pulmonary fibrosis (MD 3.75 vs MD 4); pulmonary fibrosis related to (TB MD 3 vs

Table 11. SF-36.

	Pulmonary Fibrosis due to underlying disease											
	Post-COVID PF			PF secondary to TB			PF secondary to ILD			PF Secondary to bronchiectasis		
	Intervention (n=16)			Intervention (n=10)			Intervention (n=15)			Intervention (n=4)		
Domains (SF-36)	**Pre (n=16) Mean±S.D**	**Post (n=16) Mean±S.D**	**MD**	**Pre (n=10) Mean±S.D**	**Post (n=10) Mean±S.D.**	**MD**	**Pre (n=15) Mean±S.D**	**Post (n=15) Mean±S.D**	**MD**	**Pre (n=4) Mean±S.D**	**Post (n=4) Mean±S.D**	**MD**
physical functioning %	22.50±14.38	49.69±16.48	27.19	19±8.90	48±20.03	29	21±6.32	50.67±17.10	29.67	23.75±4.78	47.5±10.40	23.75
role limitations due to physical health %	32.81±19.83	78.13±15.48	45.32	47.50±21.89	67.50±12.08	20	46.67±16	63.33±12.91	16.66	43.75±12.5	75±20.41	31.25
role limitations due to emotional health %	43.71±20.10	81.35±16.99	37.64	44.36±20.55	76.88±22.50	32.52	48.88±27.81	75.67±15.19	26.79	41.65±16.7	91.67±16.65	50.02
energy /fatigue %	50.63±9.10	51.56±6.25	0.93	52±12.52	51±4.59	1	50.33±9.15	51.67±9.19	1.34	47.5±6.45	51.25±4.78	3.75
emotional well-being %	53.25±11.47	63±9.52	9.75	55.20±10.46	64±5.65	8.8	53.07±7.47	61.60±7.52	8.53	59±6	60±4.61	1
social functioning %	55.19±11.93	82.84±9	27.65	52.50±9.86	85±7.90	32.5	59.17±15.28	84.20±5.74	25.03	59.37±6.25	81.25±12.5	21.88
pain %	86.25±13.26	97.34±6.28	11.09	77.75±15.52	92.25±9.23	14.5	81.33±25.70	97.33±4.57	16	83.75±7.21	91.25±10.89	7.5
general health %	27.81±11.54	65±7.52	37.19	29.50±6.85	58.50±6.68	29	26.33±9.34	64±6.03	37.67	26.25±8.53	62.5±6.45	36.25
Health change %	23.44±11.06	54.69±22.76	31.25	20±10.54	47.50±14.19	27.5	20±10.35	41.67±15.43	21.67	31.25±12.5	50±20.41	18.75

*MD, mean difference for each type of pulmonary fibrosis due to underlying disease; *SD, standard deviation; *PF, pulmonary fibrosis.

Table 12. Rate of Perceived Exertion (RPE).

	Pulmonary Fibrosis due to underlying disease											
	Post-COVID PF			PF secondary to TB			PF secondary to ILD			PF Secondary to bronchiectasis		
	Intervention (n=16)		MD	Intervention (n=10)		MD	Intervention (n=15)		MD	Intervention (n=4)		MD
Variables	Pre (n=16) Mean±S.D	Post (n=16) Mean±S.D		Pre (n=10) Mean±S.D	Post (n=10) Mean±S.D.		Pre (n=15) Mean±S.D	Post (n=15) Mean±S.D		Pre (n=4) Mean±S.D	Post (n=4) Mean±S.D	
Rate of Perceived Exertion (RPE)	2.87±1.02	1.53±0.90	1.34	2.90±0.56	1.60±0.51	1.30	3.20±0.77	1.93±0.59	1.27	3±0.81	1.75±0.95	1.25

*MD, mean difference for each type of pulmonary fibrosis due to underlying disease; *SD, standard deviation; *PF, pulmonary fibrosis.

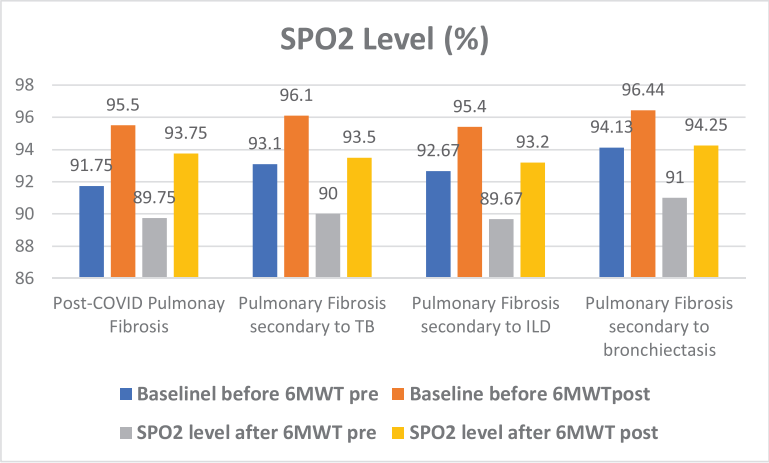

Figure 9. SPO_2 level(%) pre- post-intervention for each type of pulmonary fibrosis due to underlying disease.

MD 3.5); pulmonary fibrosis secondary to ILD (MD 2.73 vs MD 3.53); and pulmonary fibrosis secondary to bronchiectasis (MD 2.31 vs MD 3.25). Figure 9 depicts a graphical representation of SPO_2 level fluctuations prior to and after 8 weeks of intervention for each kind of pulmonary fibrosis caused by a distinct pathological condition.

Discussion

Our study shows that home-based pulmonary rehabilitation effectively improves pulmonary function, physical functional capacity, and quality of life in patients with pulmonary fibrosis. This study also indicates that a home-based pulmonary rehabilitation program is feasible (with a high adherence rate) and safe for pulmonary fibrosis patients.

To the best of our knowledge, this is the first interventional study investigating the effects of a home-based pulmonary rehabilitation in patients with pulmonary fibrosis due to underlying disease (post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, pulmonary fibrosis secondary to bronchiectasis).

This study has shown an increase in the 6 MWD after 8 weeks of the home-based pulmonary rehabilitation program. The mean difference obtained in our study was 88.66 meters which was above the minimal clinically significant differences (MCID) value(30m) [26]. Sevgi Ozalevli et al. conducted a prospective study on IPF patients by giving home-based pulmonary rehabilitation. The study demonstrated an increase in the 6 MWT distance(MD 45 meters) [10]. These findings are in-line with this study. However, it should be noted that the study of Sevgi Ozalevli et al.

Table 13. SPO_2 level (%).

s	Pulmonary Fibrosis due to underlying disease											
	Post-COVID PF			PF secondary to TB			PF secondary to ILD			PF Secondary to bronchiectasis		
Variables	Intervention (n=16)			Intervention (n=10)			Intervention (n=15)			Intervention (n=4)		
(SPO_2 level %)	Pre (n=16) Mean±S.D	Post (n=16) Mean±S.D	MD	Pre (n=10) Mean±S.D	Post (n=10) Mean±S.D.	MD	Pre (n=15) Mean±S.D	Post (n=15) Mean±S.D	MD	Pre (n=4) Mean±S.D	Post (n=4) Mean±S.D	MD
Baseline before 6MWT	91.75±0.50	95.50±0.57	3.75	93.10±1.19	96.10±0.87	3	92.67±1.23	95.40±0.63	2.73	94.13±1.02	96.44±0.89	2.31
Immediate after 6MWT	89.75±0.50	93.75±0.51	4	90±0.66	93.5±0.70	3.5	89.67±0.97	93.20±0.86	3.53	91±0.89	94.25±1.18	3.25
3 min after 6MWT	90.75±0.50	95.25±0.95	4.5	91.10±0.31	95±0.66	3.9	91.33±0.61	94.87±0.63	3.54	92.25±0.68	95.44±1.09	3.19
5 min after 6MWT	92±0.5	96.25±0.98	4.25	92.70±0.67	96.30±0.68	3.6	92.13±0.64	95.93±0.70	3.8	93.19±0.98	96.56±1.15	3.37

*MD, mean difference for each type of pulmonary fibrosis due to underlying disease; *SD, standard deviation; *PF, pulmonary fibrosis.

differed from our study as it had less sample size of 17 IPF, and the home-based pulmonary rehabilitation program was of 12-week duration [10].

Marc Spielmanns et al. performed a prospective study in severe post-COVID patients compared with other lung diseases with a sample size of 99 for post-COVID-19 patients and 419 for other lung diseases patients by giving comprehensive pulmonary rehabilitation which showed significant improvement in 6MWD [27]. Li Shen et al. also performed a randomized control trial (RCT) on idiopathic pulmonary fibrosis patients [19]. At the 12 months after pulmonary rehabilitation, they found a substantial improvement in 6MWD for the exercise group compared to the control group. The reduction in 6MWD was significantly less in the exercise group than in the control group from the baseline. Seema K. Singh et al. showed significant improvement in 6MWD (MD 38 meters) in patients with chronic lung impairment from pulmonary tuberculosis [28]. In this study, we found that the post-COVID pulmonary fibrosis group showed the greatest mean difference (MD 97.81) compared to other pulmonary fibrosis groups after 8 weeks of intervention.

The improvements in the walking distance could be due to the improved cellular bioenergetics that occurred during 8 weeks of exercise-based pulmonary rehabilitation [29]. Physical deconditioning caused due to the disease pathology could be one of the reasons for impaired cellular bioenergetics in the skeletal muscles [29, 30]. The reason for improvements in the 6 MWT distance also indicates improvement in aerobic capacity over time [31]. On the other hand, the reasons for the improvement in physical functioning may be because of improvement in neuromuscular performance [32, 33]. The post-COVID pulmonary fibrosis group showed more improvement in 6MWT distance might due to improvement of cellular bioenergetics in the skeletal muscles, neuromuscular performance and lung function capacity compared to the other group.

A retrospective study done by Sevgi Ozalevli et al. showed that PFT were not changed after the home-based exercise program [10]. Seema K. Singh et al. also showed no significant improvement in PFT in patients with chronic lung impairment from pulmonary tuberculosis [28]. Anyway, this study shows significant improvement in PFT for FVC, FEV_1, FEV_1/FVC, and DL_{CO} after 8 weeks of intervention. The reasons for the improvement may be due to the large sample size in this study compared to the Sevgi Ozalevli et al. and Seema K. Singh et al. study [10, 28]. In this study, we included not only IPF patients but also post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, and pulmonary fibrosis secondary to bronchiectasis patients were included. On the other hand, a RCT study conducted by Li Shen et al. showed improvement in pulmonary function test results [19]. These findings are in-line with this study. Exercise protocol, including aerobic and breathing exercises, can slow the decline of

lung functional capacity [21, 34, 35]. So, the improvement of pulmonary functional capacity may be helpful to prevent the further progression of lung fibrosis [36, 37].This study has shown FVC value was more improved in post-COVID pulmonary fibrosis (MD 0.09 litres) and pulmonary fibrosis secondary to ILD (MD 0.09 litres) groups. FEV_1 improved better in post-COVID pulmonary fibrosis (MD 0.08 litres) group. Greater improvement was observed for FEV_1/FVC pulmonary fibrosis secondary to ILD (MD 0.01) in comparison to other categories of pulmonary fibrosis. For DL_{CO} (MD 0.65 ml/min/mmHg) post-COVID pulmonary fibrosis group showed more recovery compared to other groups. post-COVID pulmonary fibrosis and pulmonary fibrosis secondary to ILD showed more improvement may be because these two groups had more samples compared to other subgroups. However, there were only minor changes observed in all four subgroups of pulmonary fibrosis (post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to ILD, pulmonary fibrosis secondary to TB, and pulmonary fibrosis secondary to bronchiectasis). This could be because all subgroups underwent in the same home exercise program for eight weeks.

In this study, we found a mean difference of 1.30 units in RPE scores after 8 weeks of intervention which was above the MCID value [38]. Rate of Perceived Exertion (RPE) scores are more reduced after 8 weeks of intervention in post-COVID pulmonary fibrosis group (MD 1.34).This might be because these groups were showed more improvement in their lung functional capacity.

Rogliani et al. conducted an observational study on patients recovering from COVID-19 [39]. This study showed that the sensation of dyspnoea after post-6MWT was clinically and statistically significant. (Δ pre-post 6MWT Borg scale: median 1.5, IQR 0.3-2, range 0-5) [39]. These results were consistent with our study. Ozalevli et al. reported that the perceived dyspnea severity during daily activities was significantly reduced [10].

The rate of perceived exertion interprets the individual's efforts, breathlessness, fatigue, and levels of perceived exertion [22]. The overall reduction in the levels of perceived exertion may be due to an alteration in breathing patterns and an improvement of pulmonary functional capacity [40]. On the other hand, the increase in the tolerance for dyspnoea may have also helped reduce the levels of perceived exertion [30, 40]. Exercise protocol, including lower limb strengthening, may have also helped improve RPE scores [18, 41].

Holland et al. explained that the functional capacity is improved through the contribution of peripheral muscle adaption [42]. Previous studies in ILD and COPD have shown that weakness of peripheral muscles indicates exercise intolerance and exercise capacity improvement following pulmonary rehabilitation because of peripheral muscle adaptation [43- 45].

According to our study, after 8 weeks of intervention, there was a substantial improvement in both the baseline saturation of peripheral oxygen level (SPO_2) and after the 6MWT SPO_2 level (MD 2.73% vs. MD 3.47%, $p<0.05$). According to Ozalevli et al., individuals with idiopathic pulmonary fibrosis had a substantial ($p<0.05$) rise in peripheral oxygen saturation (SPO_2) levels [10].These results are consistent with our study. Our study revealed that the SPO_2 level of post-COVID pulmonary fibrosis patients (before 6MWT MD 3.75% vs. after 6MWT MD 4%) improved more than the other subgroups. This improvement may be due to enhanced lung function capacity, which stops the lung fibrosis from progressing further.

HRQOL was assessed using the SF-36 questionnaire version 1.0, which covers total 9 domains. The score of each domain is depicted as a percentage of the overall impairments on a scale of 0-100%, where a lower score indicates reduced health status [46, 47]. Greater, more significant improvements were observed in the domains of Role limitations due to physical health (MD 28.88), Role limitations due to emotional health (MD 33.94), and general health (MD 35.44). Energy/fatigue domains were clinically significant. Improvements in domains are depicted in Table 4. The post-COVID pulmonary fibrosis group exhibited greater improvement in the categories of role limitations due to physical health % (MD 45.32) and health change % (MD 31.25), which may be related to improvement in exercise capacity and lung function.

Ozalevli et al. showed that physical role, general health, and emotional role domains were significantly improved [10]. These findings are in-line with

this study. On the other hand, Gloeckl et al. proved that SF-36 mental components were significantly improved [36]. Improvements in QOL can be attributed to exercise-based pulmonary rehabilitation programs and its benefits, breathing control due to breathing, exercises, and overall fitness and wellness [48–50].

One of the strengths of our study is the physical exercise training protocol, which is used in home-based pulmonary rehabilitation programs for pulmonary fibrosis patients. We have developed a low-cost program to perform, making it easy for the participants to understand. In this study, we included pulmonary fibrosis patients with the full spectrum of underlying disease (post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, pulmonary fibrosis secondary to bronchiectasis).

Limitations

The most relevant limitations of our study are the absence of randomization and a control group. This study also has a smaller sample size. Subgroup analysis for post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB, pulmonary fibrosis secondary to ILD, and pulmonary fibrosis secondary to bronchiectasis was not done due to the small and unequal sample size in these subgroups.

Moreover, this study did not investigate the long-term effects of the home-based pulmonary rehabilitation program on pulmonary fibrosis patients.

Future recommendations

For future research, we recommend more extensive studies with a control group, and individual studies for each category of pulmonary fibrosis patients are warranted with a large sample size. More variables like peripheral muscle strength and peripheral oxygen saturation can be incorporated with functional capacity and quality of life for each category of pulmonary fibrosis, giving a better insight into clinical improvement in the future.

Conclusions

Therefore, a home-based pulmonary rehabilitation program is effective, safe, and feasible and can be used to treat pulmonary fibrosis patients secondary to ILD, post-COVID pulmonary fibrosis, pulmonary fibrosis secondary to TB secondary to bronchiectasis in the Indian setup. It may provide beneficial effects in improving these patients' pulmonary function as well as aerobic conditioning, physical functional capacity by decreasing dyspnea severity and increasing the SPO_2 level, and quality of life.

Abbreviations

PF: Pulmonary Fibrosis
PCPF: post-COVID Pulmonary Fibrosis
ILD: Interstitial Lung Disease
IPF: Idiopathic Pulmonary Fibrosis
COVID-19: Corona Virus-19
HRQoL: Health-Related Quality of Life
SF-36: Short Form-36
6 MWT: 6-Minute walk test
6 MWD: 6-Minute walk distance
RPE: Rate of Perceived Exertion
ATS: American Thoracic Society
PFT: Pulmonary Function Test
FVC: Forced Vital Capacity
FEV: Forced Expiratory Volume
FEV_1: Forced Expiratory Volume in the first second
DL_{CO}: Diffusing Capacity of the Lungs for Carbon Monoxide

References

1. Raghu G, Remy-Jardin M, Richeldi L, Thomson CC, Antoniou KM, Bissell BD, et al. Idiopathic Pulmonary Fibrosis (an Update) and Progressive Pulmonary Fibrosis in Adults: An Official ATS/ERS/JRS/ALAT Clinical Practice Guideline. Am J Respir Crit Care Med 2022;205(9):E18–47.
2. Nashatyreva MS, Trofimenko IN, Chernyak BA, Avdeev SN. Pulmonary Fibrosis and Progressive Pulmonary Fibrosis in a Prospective Registry of Interstitial Lung Diseases in Eastern Siberia. Life 2023;13(1):1–11.
3. Tran S, Ksajikian A, Overbey J, Li P, Li Y. Pathophysiology of Pulmonary Fibrosis in the Context of COVID-19 and Implications for Treatment: A Narrative Review. Cells 2022;11(16):1–10.
4. Maher TM, Bendstrup E, Dron L, Langley J, Smith G, Khalid JM, et al. Global incidence and prevalence of

idiopathic pulmonary fibrosis. Respir Res [Internet] 2021;22(1):1–10. Available from: https://doi.org/10.1186/s12931-021-01791-z
5. Oronsky B, Larson C, Hammond TC, Oronsky A, Kesari S, Lybeck M, et al. A Review of Persistent Post-COVID Syndrome (PPCS). Clin Rev Allergy Immunol [Internet] 2023;64(1):66–74. Available from: https://doi.org/10.1007/s12016-021-08848-3
6. Ambardar SR, Hightower SL, Huprikar NA, Chung KK, Singhal A, Collen JF. Post-COVID-19 pulmonary fibrosis: Novel sequelae of the current pandemic. J Clin Med 2021;10(11):2452.
7. Meyerholz DK. Rigid respiration: fulminant pulmonary fibrosis after COVID-19. eBioMedicine [Internet] 2023;87:104428. Available from: https://doi.org/10.1016/j.ebiom.2022.104428
8. Oatis D, Simon-Repolski E, Balta C, Mihu A, Pieretti G, Alfano R, et al. Cellular and Molecular Mechanism of Pulmonary Fibrosis Post-COVID-19: Focus on Galectin-1, -3, -8, -9. Int J Mol Sci 2022;23(15):8210.
9. Hirawat R, Jain N, Aslam Saifi M, Rachamalla M, Godugu C. Lung fibrosis: Post-COVID-19 complications and evidences. Int Immunopharmacol [Internet] 2023;116:109418. Available from: https://doi.org/10.1016/j.intimp.2022.109418
10. Ozalevli S, Karaali HK, Ilgin D, Ucan ES. Effect of home-based pulmonary rehabilitation in patients with idiopathic pulmonary fibrosis. Multidiscip Respir Med 2010;5(1):31–7.
11. Singh SJ, ZuWallack RL, Garvey C, Spruit MA, Brindicci C, Higenbottam T, et al. Learn from the past and create the future: The 2013 ATS/ERS statement on pulmonary rehabilitation Eur Respir J 2013;42(5):1169–74.
12. Holland AE, Singh SJ, Casaburi R, Clini E, Cox NS, Galwicki M, et al. Defining modern pulmonary rehabilitation: An official American thoracic society workshop report. Ann Am Thorac Soc 2021;18(5):E12–29.
13. Ranaweera A. American Thoracic Society. Int J Pharm Med 2005;19(3):173–7.
14. Uzzaman MN, Agarwal D, Chan SC, Engkasan JP, Habib GMM, Hanafi NS, et al. Effectiveness of home-based pulmonary rehabilitation: systematic review and meta-analysis. Eur Respir Rev [Internet] 2022;31(165). Available from: http://dx.doi.org/10.1183/16000617.0076-2022
15. Raghu G, Remy-Jardin M, Myers JL, Richeldi L, Ryerson CJ, Lederer DJ, et al. Diagnosis of idiopathic pulmonary fibrosis An Official ATS/ERS/JRS/ALAT Clinical practice guideline. Am J Respir Crit Care Med 2018;198(5):e44–68.
16. Nici L, Donner C, Wouters E, Zuwallack R, Ambrosino N, Bourbeau J, et al. American thoracic society/European respiratory society statement on pulmonary rehabilitation. Am J Respir Crit Care Med 2006;173(12):1390–413.
17. Rochester CL, Vogiatzis I, Holland AE, Lareau SC, Marciniuk DD, Puhan MA, et al. An official American Thoracic Society/European Respiratory Society policy statement: Enhancing implementation, use, and delivery of pulmonary rehabilitation. Am J Respir Crit Care Med 2015;192(11):1373–86.
18. José A, Holland AE, Selman JPR, Camargo CO De, Fonseca DS, Athanazio RA, et al. Home-based pulmonary rehabilitation in people with bronchiectasis: a randomised controlled trial. ERJ Open Res 2021;7(2):00021-2021. Available from: http://dx.doi.org/10.1183/23120541.00021-2021
19. Shen L, Zhang Y, Su Y, Weng D, Zhang F, Wu Q, et al. New pulmonary rehabilitation exercise for pulmonary fibrosis to improve the pulmonary function and quality of life of patients with idiopathic pulmonary fibrosis: A randomized control trial. Ann Palliat Med 2021;10(7):7289–97.
20. Graham BL, Steenbruggen I, Barjaktarevic IZ, Cooper BG, Hall GL, Hallstrand TS, et al. Standardization of spirometry 2019 update an official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med 2019;200(8):E70–88.
21. Issues S, Test MW, Equipment R, Preparation P. American Thoracic Society ATS Statement : Guidelines for the Six-Minute Walk Test 2002;166:111–7.
22. Williams N. The Borg Rating of Perceived Exertion (RPE) scale. Occup Med (Chic Ill) 2017;67(5):404–5.
23. Lins L, Carvalho FM. SF-36 total score as a single measure of health-related quality of life: Scoping review. SAGE Open Med 2016;4:205031211667172.
24. Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, et al. CONSORT 2010 statement: Extension to randomised pilot and feasibility trials. BMJ 2016;355:i5239.
25. Lancaster GA. Guideliens for reporting non randomised 2019;1:1–6.
26. Puente-Maestu L, Palange P, Casaburi R, Laveneziana P, Maltais F, Neder JA, et al. Use of exercise testing in the evaluation of interventional efficacy: An official ERS statement. Eur Respir J [Internet] 2016;47(2):429–60. Available from: http://dx.doi.org/10.1183/13993003.00745-2015
27. Spielmanns M, Pekacka-Egli AM, Schoendorf S, Windisch W, Hermann M. Effects of a comprehensive pulmonary rehabilitation in severe post-COVID-19 patients. Int J Environ Res Public Health 2021;18(5):1–14.
28. Singh SK, Naaraayan A, Acharya P, Menon B, Bansal V, Jesmajian S. Pulmonary Rehabilitation in Patients with Chronic Lung Impairment from Pulmonary Tuberculosis. Cureus 2018;10(11).
29. Sala E, Roca J, Marrades RM, Alonso J, Gonzalez De Suso JM, Moreno A, et al. Effects of endurance training on skeletal muscle bioenergetics in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 1999;159(6):1726–34.
30. Jahn K, Sava M, Sommer G, Schumann DM, Bassetti S, Siegemund M, et al. Exercise capacity impairment after COVID-19 pneumonia is mainly caused by deconditioning. Eur Respir J 2022;59(1).
31. Jolley SE, Bunnell AE, Hough CL. ICU-Acquired Weakness. Chest [Internet] 2016;150(5):1129–40. Available from: http://dx.doi.org/10.1016/j.chest 2016.03.045

32. Spruit MA, Thomeer MJ, Gosselink R, Troosters T, Kasran A, Debrock A, et al. Skeletal muscle weakness in patients with sarcoidosis and its relationship with exercise intolerance and reduced health status. Thorax 2005;60(1):32–8.
33. Watanabe F, Taniguchi H, Sakamoto K, Kondoh Y, Kimura T, Kataoka K, et al. Quadriceps weakness contributes to exercise capacity in nonspecific interstitial pneumonia. Respir Med [Internet] 2013;107(4):622–8. Available from: http://dx.doi.org/10.1016/j.rmed.2012.12.013
34. Hanada M, Kasawara KT, Mathur S, Rozenberg D, Kozu R, Ahmed Hassan S, et al. Aerobic and breathing exercises improve dyspnea, exercise capacity and quality of life in idiopathic pulmonary fibrosis patients: Systematic review and meta-analysis. J Thorac Dis 2020;12(3):1041–55.
35. Gomes-Neto M, Silva CM, Ezequiel D, Conceição CS, Saquetto M, MacHado AS. Impact of Pulmonary Rehabilitation on Exercise Tolerance and Quality of Life in Patients with Idiopathic Pulmonary Fibrosis A SR and M-A. J Cardiopulm Rehabil Prev 2018;38(5):273–8.
36. Gloeckl R, Leitl D, Jarosch I, Schneeberger T, Nell C, Stenzel N, et al. Benefits of pulmonary rehabilitation in COVID-19: a prospective observational cohort study. ERJ Open Res 2021;7(2):00108–2021.
37. Yu X, Li X, Wang L, Liu R, Xie Y, Li S, et al. Pulmonary Rehabilitation for Exercise Tolerance and Quality of Life in IPF Patients: A Systematic Review and Meta-Analysis. Biomed Res Int 2019;2019.
38. Ries AL. Minimally clinically important difference for the UCSD Shortness of Breath Questionnaire, Borg Scale, and Visual Analog Scale. COPD J Chronic Obstr Pulm Dis 2005;2(1):105–10.
39. Rogliani P, Calzetta L, Coppola A, Puxeddu E, Sergiacomi G, D'Amato D, et al. Are there pulmonary sequelae in patients recovering from COVID-19? Respir Res 2020;21:(1):286.
40. Gigliotti F, Coli C, Bianchi R, Romagnoli I, Lanini B, Binazzi B, et al. Exercise training improves exertional dyspnea in patients with COPD: Evidence of the role of mechanical factors. Chest 2003;123(6):1794–802.
41. Cook H, Reilly CC, Rafferty GF. A home-based lower limb-specific resistance training programme for patients with copd: An explorative feasibility study. ERJ Open Res 2019;5(2).
42. Holland AE, Hill CJ, Conron M, Munro P, McDonald CF. Short term improvement in exercise capacity and symptoms following exercise training in interstitial lung disease. Thorax 2008;63(6):549–54.
43. Nishiyama O, Taniguchi H, Kondoh Y, Kimura T, Ogawa T, Watanabe F, et al. Quadriceps weakness is related to exercise capacity in idiopathic pulmonary fibrosis. Chest [Internet] 2005;127(6):2028–33. Available from: http://dx.doi.org/10.1378/chest.127.6.2028
44. Bernard S, Leblanc P, Whittom F, Carrier G, Jobin J, Belleau R, et al. Peripheral muscle weakness in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med 1998;158(2):629–34.
45. Seymour JM, Spruit MA, Hopkinson NS, Natanek SA, Man WDC, Jackson A, et al. The prevalence of quadriceps weakness in COPD and the relationship with disease severity. Eur Respir J 2010;36(1):81–8.
46. Cox IA, Arriagada NB, De Graaff B, Corte TJ, Glaspole I, Lartey S, et al. Health-related quality of life of patients with idiopathic pulmonary fibrosis: A systematic review and meta-analysis. Eur Respir Rev [Internet] 2020;29(158): 1–22. Available from: http://dx.doi.org/10.1183/16000617.0154-2020
47. Swigris J, Olson AL, Brown K. Understanding and optimizing health-related quality of life and physical functional capacity in idiopathic pulmonary fibrosis. Patient Relat Outcome Meas 2016;29.
48. Wallaert B, Duthoit L, Drumez E, Behal H, Wemeau L, Chenivesse C, et al. Long-term evaluation of home-based pulmonary rehabilitation in patients with fibrotic idiopathic interstitial pneumonias. ERJ Open Res [Internet] 2019;5(2). Available from: http://dx.doi.org/10.1183/23120541.00045-2019
49. Vainshelboim B. Exercise training in idiopathic pulmonary fibrosis: Is it of benefit? Breathe 2016;12(2):130–8.
50. Essam H, Wahab NHA, Younis G, El-Sayed E, Shafiek H. Effects of different exercise training programs on the functional performance in fibrosing interstitial lung diseases: A randomized trial. PLoS One [Internet] 2022;17:1–14. Available from: http://dx.doi.org/10.1371/journal.pone.0268589

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