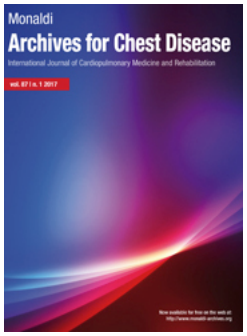

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# Role of hybrid virtual pulmonary rehabilitation in improving performance status of patients eligible for lung transplantation

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**Abstract**

Pulmonary rehabilitation (PR) in chronic respiratory diseases improves symptoms, quality of life, and exercise capacity and has an integral role in lung transplantation (LT). Virtual PR has recently emerged to cater to patients who otherwise may not have regular access to PR. However, little is known about the effect of virtual PR strategies on candidates for LT. The primary objective was to study the effect of a protocolized hybrid PR program on performance status using the Karnofsky Performance Status (KPS) score. Secondary objectives were Eastern Cooperative Oncology Group (ECOG) status, quality of life, symptom severity, sarcopenia, spirometry (pulmonary function test and diffusing capacity of the lung for carbon monoxide), 6-minute walk distance, and eligibility for LT waitlisting. This is a prospective, single-arm, interventional study on patients with end-stage lung disease, meeting referral criteria for LT. A protocolized 12-week hybrid hospital and home-based virtual PR intervention was conducted, and all outcomes were assessed at baseline and at completion of the intervention. A total of 75 patients were enrolled, and the intervention was completed by 51 patients (68%). A total of 35 patients met LT listing criteria, 27 being "unfit" for LT at baseline, 18 of whom completed the intervention. Significant improvement was seen in KPS, ECOG, St. George's Respiratory Questionnaire score, visual analogue scale score for cough and dyspnoea, and sarcopenia for all 51 patients. Of the 18 patients unfit for waitlisting, 12 became fit, and 7 were waitlisted for LT. Patients eligible for LT who do not have access to regular PR may benefit from a hybrid (virtual and hospital-based) PR program, with improvement in KPS, quality of life, sarcopenia, and eligibility for LT waitlisting.

**Key words:** pulmonary rehabilitation, lung transplantation, performance status, quality of life, chronic respiratory diseases.

## Introduction

Lung transplantation (LT) is an important therapeutic modality for end-stage chronic respiratory diseases (CRDs) progressing despite maximal medical therapy. It improves health-related quality of life [1], exercise capacity, lung function [2,3], and survival [4-6]. However, poor pre-operative performance status (PS) and a low exercise capacity have worse perioperative outcomes [7]. Therefore, the International Society of Heart and Lung Transplant (ISHLT) 2021 consensus criteria for lung transplant lists "limited functional status with low potential for post-transplant rehabilitation" as a relative contraindication for LT [8]. This state can be corrected with pulmonary rehabilitation (PR), allowing many patients with poor PS to enter a transplant waitlist.

Pulmonary Rehabilitation is a comprehensive strategy involving exercises, disease education, and health promoting behaviours [9]. Despite its beneficial effects on symptoms, quality of life, lung function, and survival, it is woefully underutilised [10,11]. Most PR programmes are hospital/centre-based, with a paucity of data on tele-rehabilitation programmes. Regular visits to a PR centre are challenging for most patients due to logistical, financial, and social reasons. After the COVID-19 pandemic, telerehabilitation using smartphones has emerged to provide virtual home-based rehabilitation. Till date, studies evaluating the benefit of pulmonary rehabilitation before lung transplantation have focussed on centre-based PR, with lack of data on home-based tele-rehabilitation. Our study was thus designed to explore the effect of a hybrid hospital and home-based telerehabilitation program in patients with CRDs who are LT candidates, and their subsequent eligibility of getting fit for inclusion in our transplant waitlist.

## Materials and Methods

The study was a prospective, single arm, pre- and post-interventional study, done in the Department of Pulmonary Medicine at a tertiary care hospital. Patients with end-stage chronic respiratory diseases (COPD, diffuse parenchymal lung disease, bronchiectasis) who met ISHLT 2021 LT referral criteria were recruited from the outpatient clinics and wards between January 2022 to December 2023 [8]. The primary objective was to study the effect of a protocolised "hybrid" hospital (centre-based) and home-based pulmonary rehabilitation (PR) program on performance status using the Karnofsky Performance Scale. Secondary objectives included effect of this hybrid PR program on quality of life, sarcopenia using anthropometric indices, Short Physical Performance Battery (SPPB) score, Body Composition Analysis (BCA), lung

function using spirometry, DLCO, and six-minute walk test, and estimation of proportion of patients deemed eligible for listing for lung transplant (via improvement in performance status). Patients who were unable to or unwilling to come to the hospital for PR were excluded. Institutional ethics committee (IEC) approval was obtained prior to commencement of the study.

***Parameters recorded***

At enrolment, baseline demographic profile and clinical parameters were recorded, including severity of cough and dyspnoea using Visual Analogue Scale (VAS) and modified Medical Research Council (mMRC) scale for dyspnoea, proportion of patients with oxygen requirement at rest, etc. Socio-economic status was assessed using the modified Kuppuswamy scale [12]. The primary outcome of performance status (PS) was assessed using the Karnofsky performance status/scale [13]. In addition, ECOG (Eastern Cooperative Oncology Group) score for PS was also recorded [14]. Quality of Life (QoL) was assessed using St George Respiratory Questionnaire (SGRQ) after permission from the developers, using both the English and translated Hindi versions [15]. Sarcopenia was assessed as per the Asian Working Group for Sarcopenia (AWGS) consensus criteria of 2019 [16]. Sarcopenia was defined as low appendicular skeletal mass index (ASMI) along with either low muscle strength (using hand grip dynamometer) or low physical performance (using SPPB). Low physical performance was diagnosed clinically if the total SPPB score was  9 out of 12 [16]. The SPPB score is a composite of balance score, 3 or 4-metre gait speed and 5 times chair stand test, each parameter scored from 0-4. Body composition analysis (BCA) was done via bio-impedance analysis (ACCUNIQ BC720 analyser, SELVAS Healthcare, South Korea). ASMI, which is the skeletal muscle mass of all 4 limbs divided by the height in metre squared, was used to define low muscle mass ($<7.0$ kg/m$^2$ in males and $< 5.7$ kg/m$^2$ in females). If BCA was not available, but patient had low muscle strength or low physical performance, a diagnosis of "possible" sarcopenia was made. Baseline assessment of lung function and exercise capacity was done using spirometry (COSMED), diffusion capacity of carbon monoxide (DLCO), and six-minute walk (6MWT) test. All patients were assessed for presence of ISHLT 2021 listing criteria for LT, and presence of any contraindications. Poor performance status (PS) and low rehabilitation potential as a contraindication to LT was noted at baseline. Since no objective criteria exists as per ISHLT to label a patient "unfit" for LT, this assessment  was done by the treating physician based on a

combination of performance status (KPS and ECOG), presence of sarcopenia, and exercise capacity at initiation of PR. Previously, Rathi et al. has used the same criteria while studying the clinical profile of LT candidates at our centre [17].

***Intervention***

Patients were started on a protocolised "hybrid" hospital and home-based pulmonary telerehabilitation programme. Each patient underwent 1 supervised hospital visit and 2 supervised (video call using a smartphone) home exercise sessions per week, with a total of 12 supervised hospital visits and 24 supervised home exercise sessions over 3 months, with a relaxation of 1 additional month to complete the 36 sessions. A patient was labelled as "adherent" to the intervention if they completed 2/3$^{rd}$ of both types of sessions (i.e., 8 hospital and 16 home sessions) by the end of 4 months. Attendance was recorded for each patient for every session. The post-intervention follow-up visit and recording of all parameters was done within 1 month from the last exercise session. Patients who had an exacerbation during the intervention had to restart the exercises after improvement in their PS (baseline KPS+/-10).

***Statistical analysis***

Descriptive analysis was done for demographic and clinical data (mean, SD, median, IQR). Tests for statistical significance (paired/unpaired t-test, Wilcoxon rank sum test, chi square/Fisher exact test, symmetry test) were used to look for significant differences in primary and secondary outcome parameters for continuous and categorical variables, assessed at baseline and end of rehabilitation programme. Subgroup analysis was done by adherence to the programme as well as by diagnosis. Change (pre- and post-rehabilitation) in individual outcomes (median [IQR]) between adherent and non- adherent was further compared using tests for statistical significance.

**Results**

Over the study duration, 136 patients were screened and 75 were enrolled in the rehabilitation program. Their baseline data is depicted in Table 1. Most common reason for exclusion was inability to visit the hospital for physical rehabilitation. The intervention was completed by 51 patients (68%) and post-rehabilitation parameters were recorded. Of the 24 patients who did not complete the intervention, 10 died during rehabilitation period, 10 were lost to follow-up,

two had recurrent exacerbations while two stopped early as they underwent a transplant. Among those completing the intervention, 25 (49.0%) met the strict pre-defined criteria for adherence (both hospital and home sessions). Additionally, 46 (90.2%) were adherent to the home-based tele-rehabilitation. Eight patients had an exacerbation during the intervention and had to restart the sessions once the exacerbation had resolved.

Mean age of our population was ~ 48 years, with nearly equal males (n=38) and females (n=37). The most common diagnosis was diffuse parenchymal lung disease (DPLD) seen in 51 (68.0%) cases. Fibrotic hypersensitivity pneumonitis was the most common (41.1%), followed by connective tissue disease associated ILD (31.4%), idiopathic fibrotic non-specific interstitial pneumonitis (17.6%) and idiopathic pulmonary fibrosis (IPF). The diagnosis was established after a multidisciplinary discussion with the radiologist, and a histopathological diagnosis was present in 10 (19.6%) cases. Comorbidities were present in 31 (41.3%) patients, diabetes mellitus being the most common (20.0%).

Following the completion of rehabilitation sessions, significant improvement was observed in the primary outcome (Table 2) of KPS Score category ($p < 0.001$) and the ECOG score for performance status ($p=0.001$). Among secondary outcomes, mean SGRQ score showed significant improvement (61.8 to 45.2 points, $p < 0.001$). The decrease in minimal clinically important difference (MCID) by 4 points for SGRQ was seen in 40 patients (78.4%). Significant improvement was noted in symptom severity scores of cough (VAS 5.0 to 3.7), shortness of breath (VAS 7.0 to 5.4), mMRC grade category, patients on oxygen at rest (49% to 35%), short physical performance battery (SPPB) mean score (9.3 to 9.9 points), and categorically ($p=0.008$). Proportion of patients with sarcopenia decreased significantly (53% to 41%, $p = 0.014$). Paired body composition analysis, spirometry, DLCO manoeuvres and six-minute walk distance did not show significant difference. At baseline, 35 patients also met the ISHLT "listing criteria" for lung transplant. Of these, 27 had poor functional status and were labelled "unfit" for LT, 18 of whom completed the intervention. Out of these 18 patients, 12 (~66%) later became fit for LT after rehabilitation, and 7 (~39%) were subsequently waitlisted.

Subgroup analysis was done (Table 3) for adherent (n=25) and non-adherent (Table 4) patients (n=26), with significant improvement seen in both groups in the KPS Score (primary outcome), SGRQ score (quality of life), symptom severity scores (visual analogue scale) for cough and shortness of breath, the mMRC grade of shortness of breath, proportion of patients with supplemental oxygen requirement at rest and proportion of patients with sarcopenia. A

statistically significant improvement in the adherent subgroup alone was seen in ECOG score, FVC% and FEV1%.

Additionally, the difference (proportions and median change) in pre-rehabilitation and post-rehabilitation values (post-rehabilitation value subtracted from pre-rehabilitation) was compared in adherent and non-adherent groups (*Supplementary Table 1*). Proportion of patients whose KPS category improved was compared, with no significant difference. Among secondary outcomes, change in FEV1 (-35mL vs +40mL; negative due to higher post-rehabilitation value in adherent) and %FEV1 (-2.0% vs +0.5%; p= 0.049) was significantly better in adherent group, while change in FVC and %FVC had a trend towards significant improvement (p=0.053) in the adherent group. Sub-group analysis was also done based on primary diagnosis (*Supplementary Table 1*). In the DPLD subgroup, significant improvement was seen in performance status using KPS score (p <0.001) and ECOG score (p=0.042), mean SGRQ score (60.8 to 46.9 points, p value <0.001), and mMRC grade of SOB (p value <0.001).

**Discussion**

Studies on Pulmonary Rehabilitation are heterogeneous and mostly hospital based. Numerous randomised controlled trials and systematic reviews have evaluated effect of rehabilitation in various chronic respiratory diseases (CRDs), including COPD (10), DPLD [18], bronchiectasis (cystic fibrosis and non-cystic fibrosis) and asthma with improvement in dyspnoea scores, quality of life and exercise capacity [19-21]. Benefit has not been seen in spirometry-based tests (FVC, FEV1 and DLCO). Multiple studies on effect of PR on lung transplant waitlisted candidates have also been done [3,22-25], with similar findings.

Our study brings forth many unexplored aspects. We studied a novel hybrid hospital-based and home-based tele-rehabilitation intervention, in a novel group (subjects eligible for lung transplant). The PR programme was under supervision of a respiratory physiotherapist and a senior Pulmonology fellow. Our patient cohort was relatively sicker than those previously included in most studies. Medical management was optimised before enrolment and no major change in treatment was allowed during the intervention, except during an exacerbation. Patients who had an exacerbation during the intervention had to restart their PR after improvement. Lastly, effect of tele-rehabilitation on increasing eligibility for inclusion in transplant waitlist has not been studied till date.

In our study, patients who completed the intervention showed significant improvement in the primary outcome of KPS Score, as well as other outcomes like ECOG, quality of life (SGRQ), symptom severity scores, proportion (%) of patients requiring supplemental oxygen, sarcopenia and short physical performance battery (SPPB) score. Sarcopenia is an important although sparsely studied parameter in patients listed for LT. It is independently associated with increased disability, risk of delisting and even death [26]. Our intervention has shown benefit in key factors that decide outcomes in patients with end-stage lung diseases who are LT candidates. Significant change was not observed in spirometry-based tests (FVC, FEV1 and DLCO), which is consistent with existing evidence. There was no change in the six-minute walk distance, showing that exercise capacity was maintained during the period of rehabilitation. Similar finding was observed by Li et al [22], where 345 pre-transplant candidates underwent hospital based PR while on the LT waitlist. The final 6MWD was 15m less than that at listing (no significant change), which was considered a successful outcome in LT listed patients, where decline in 6MWT is expected due to the severity of their illness. In another study, 4-week of tele-rehabilitation was conducted on 78 LT candidates and 33 LT recipients at the Toronto LT program and a decrease in 6MWD was observed [27]. Our patient cohort was a relatively sicker group with majority (56%) of patients being on continuous supplemental oxygen, explaining the lack of improvement in 6MWD.

Subgroup analysis of adherent and non-adherent patients showed significant improvements in both subgroups in terms of KPS Score, as well as most secondary outcomes. However, ECOG score, FVC% and FEV1% improved in the adherent subgroup only. Criterion for adherence was strict (2/3$^{rd}$ attendance needed individually for both centre and home-based PR), and patients labelled as non-adherent still participated consistently in the tele-rehabilitation sessions, explaining the improvement in their outcomes.

Tele-rehabilitation has emerged prominently after the COVID-19 pandemic [28,29]. A systematic review and meta-analysis by Cox et al [30], comparing telerehabilitation and centre-based PR in a COPD population, found no difference in outcomes like exercise capacity (6MWD), quality of life (SGRQ) or dyspnoea scores. PR programme completion rates were higher for telerehabilitation vs centre-based PR (93% vs 70%). This study almost exclusively studied COPD (~99%). Multiple such systematic reviews including patients with COPD have been published that showed home-based PR to be as effective as centre-based, in improving exercise capacity and quality of life [31-33]. There is however paucity of evidence on the role

of telerehabilitation across different respiratory illnesses or among those with end-stage lung diseases who are LT candidates. As mentioned above, the Toronto LT program used a smartphone app for home-based PR on LT candidates and recipients [27]. However, real-time tele-rehabilitation sessions were not conducted in these studies, and pre-recorded videos were used to guide PR. Bourgeois et al. studied 20 potential LT candidates who underwent supervised tele-rehabilitation for 12 weeks, followed by an unsupervised maintenance phase [34]. No significant change was seen in 6MWD, SPPB or SGRQ score at 12 weeks. The authors concluded that preventing further fall in 6MWD and SPPB in a frail LT eligible cohort is a mark of success of any PR program.

The major advantage of tele-rehabilitation is that patients can perform exercises specific to their respiratory comorbidity, from the comfort of their homes. Patients with CRDs often require oxygen continuously and find it difficult to travel to the hospital. Many patients lack financial or social support and find tele-rehabilitation cost-effective. However, limitations of this model exist, like difficulty in ensuring correct technique of exercises, effective communicating with the physiotherapist, and difficulty in monitoring the patient's vitals. Also, the elderly or less educated may face issues with advanced technologies, as often observed in the Indian demographic. We overcame this by using a smartphone-based video call. India has one of the cheapest internet data plans in the world and smartphone utilization is impressive.

Lastly, a key and unique aspect of our study was to see the effect of our hybrid rehabilitation programme on increasing lung transplant waitlisting. In our cohort, 18 out of 35 patients who initially met the ISHLT listing criteria and also had poor performance status (PS) and poor rehabilitation potential completed the PR program. They demonstrated significant improvement in their KPS Score and important secondary outcomes like SGRQ score and symptom severity scores (VAS and mMRC grade of dyspnoea). Consequently, 12 of these patients became "fit" for listing, of whom 7 were waitlisted. Additionally, 8 patients from our PR program were waitlisted who either already had good PS before enrolment or continued to have poor PS after our PR program, making a total of 15 patients to be added to the waitlist over a 2-year period. Previously, from 2019-2021, our LT program was able to waitlist 5 patients. This further underlines how our PR intervention boosted the LT program of our hospital. This aspect highlights the need for a strong pulmonary rehabilitation program at any Lung Transplant centre, with inclusion into the PR program being mandatory before LT listing.

Our study had few limitations, namely, a small sample size and high loss to follow up due to death or disease-related morbidity. Adherence to our intervention was ~50% due to challenges in visiting the centre physically, although adherence to tele-rehabilitation remained high (90.2%). This further emphasises the high adherence rates with home-based PR programs. Our patient cohort was heterogeneous, with less COPD and bronchiectasis cases. Similar finding was noted by Rathi et al. in a cohort of 103 patients referred for LT at our institute, where 57.2% cases were of DPLD [17].

**Conclusions**

Patients with end-stage lung disease eligible for lung transplantation benefit from a hybrid (hospital and home-based) pulmonary rehabilitation (PR) program, with improvement in performance status, quality of life and sarcopenia, and enhances the eligibility for lung transplant wait-listing.

**Abbreviations:**

6MWD - Six-minute Walk Distance
ASMI - Appendicular skeletal muscle mass index
AWGS - Asian Working Group for Sarcopenia
BCA - Body Composition Analysis
BMI - Body mass index
COPD - Chronic obstructive pulmonary disease
CRDs - Chronic respiratory diseases
DLCO - Diffusion capacity of lung carbon monoxide
DPLD - Diffuse parenchymal lung disease
ECOG - Eastern Cooperative Oncology Group
FEV1 - Forced expiratory volume in 1 second
FVC - Forced vital capacity
IQR- Interquartile range
ISHLT - International Society for Heart and Lung Transplantation
KPS - Karnofsky performance status/scale
LT - Lung transplant/transplantation
MCID - Minimal clinically important difference
mMRC - Modified medical research council
PR - Pulmonary rehabilitation
PS - Performance status
SD - Standard deviation
SGRQ - St George's Respiratory Questionnaire
SPPB - Short Physical Performance Battery
VAS - Visual analogue scale

**References**

1. Singer JP, Katz PP, Soong A, et al. Effect of lung transplantation on health-related quality of life in the era of the lung allocation score: a U.S. prospective cohort study. Am J Transplant 2017;17:1334-45.

2. Thabut G, Mal H. Outcomes after lung transplantation. J Thorac Dis 2017;9:2684-91.

3. Hoffman M, Chaves G, Ribeiro-Samora GA, et al. Effects of pulmonary rehabilitation in lung transplant candidates: a systematic review. BMJ Open 2017;7:e013445.

4. Perch M, Hayes D, Cherikh WS, et al. The international thoracic organ transplant registry of the International Society for Heart and Lung Transplantation: thirty-ninth adult lung transplantation report-2022; focus on lung transplant recipients with chronic obstructive pulmonary disease. J Heart Lung Transplant 2022;41:1335-47.

5. Titman A, Rogers CA, Bonser RS, et al. Disease-specific survival benefit of lung transplantation in adults: a national cohort study. Am J Transplant 2009;9:1640-9.

6. Liu V, Zamora MR, Dhillon GS, Weill D. Increasing lung allocation scores predict worsened survival among lung transplant recipients. Am J Transplant 2010;10:915-20.

7. Grimm JC, Valero V, Kilic A, et al. Preoperative performance status impacts perioperative morbidity and mortality after lung transplantation. Ann Thorac Surg 2015;99:482-9.

8. Leard LE, Holm AM, Valapour M, et al. Consensus document for the selection of lung transplant candidates: an update from the International Society for Heart and Lung Transplantation. J Heart Lung Transplant 2021;40:1349-79.

9. Spruit MA, Singh SJ, Garvey C, et al. An Official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. Am J Respir Crit Care Med 2013;188:e13-64.

10. McCarthy B, Casey D, Devane D, et al. Pulmonary rehabilitation for chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2015;2015:CD003793.

11. Lindenauer PK, Stefan MS, Pekow PS, et al. Association between initiation of pulmonary rehabilitation after hospitalization for COPD and 1-year survival among medicare beneficiaries. JAMA 2020;323:1813-23.

12. Sood P, Bindra S. Modified Kuppuswamy socioeconomic scale: 2022 update of India. Int J Community Med Public Health 2022;9:3841-4.

13. Crooks V, Waller S, Smith T, Hahn TJ. The use of the Karnofsky Performance Scale in determining outcomes and risk in geriatric outpatients. J Gerontol 1991;46:M139-44.

14. Oken MM, Creech RH, Tormey DC, et al. Toxicity and response criteria of the Eastern Cooperative Oncology Group. Am J Clin Oncol 1982;5:649-55.
15. Jones PW, Quirk FH, Baveystock CM. The St George's Respiratory Questionnaire. Respir Med 1991;85:25-31.
16. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020;21:300-7.e2.
17. Rathi V, Tiwari P, Seth S, et al. Profile of patients referred for lung transplant and their transplant-free survival. Lung India 2024;41:265-71.
18. Dowman L, Hill CJ, May A, Holland AE. Pulmonary rehabilitation for interstitial lung disease. Cochrane Database Syst Rev 2021;2021:CD006322.
19. Lee AL, Gordon CS, Osadnik CR. Exercise training for bronchiectasis. Cochrane Database Syst Rev 2021;2021:CD013110.
20. Radtke T, Nevitt SJ, Hebestreit H, Kriemler S. Physical exercise training for cystic fibrosis. Cochrane Database Syst Rev 2017;2017:CD002768.
21. Osadnik CR, Gleeson C, McDonald VM, Holland AE. Pulmonary rehabilitation versus usual care for adults with asthma. Cochrane Database Syst Rev 2022;8:CD013485.
22. Li M, Mathur S, Chowdhury NA, et al. Pulmonary rehabilitation in lung transplant candidates. J Heart Lung Transplant 2013;32:626-32.
23. Langer D, Burtin C, Schepers L, et al. Exercise training after lung transplantation improves participation in daily activity: a randomized controlled trial. Am J Transplant 2012;12:1584-92.
24. Langer D. Rehabilitation in patients before and after lung transplantation. Respiration 2015;89:353-62.
25. Kenn K, Gloeckl R, Soennichsen A, et al. Predictors of success for pulmonary rehabilitation in patients awaiting lung transplantation. Transplantation 2015;99:1072-7.
26. Singer JP, Diamond JM, Gries CJ, et al. Frailty phenotypes, disability, and outcomes in adult candidates for lung transplantation. Am J Respir Crit Care Med 2015;192:1325-34.
27. Wickerson L, Helm D, Gottesman C, et al. Telerehabilitation for lung transplant candidates and recipients during the COVID-19 pandemic: program evaluation. JMIR Mhealth Uhealth 2021;9:e28708.

28. Taito S, Yamauchi K, Kataoka Y. Telerehabilitation in subjects with respiratory disease: a scoping review. Respiratory Care 2021;66:686-98.
29. Tsutsui M, Gerayeli F, Sin DD. Pulmonary rehabilitation in a post-COVID-19 world: telerehabilitation as a new standard in patients with COPD. COPD 2021;16:379-91.
30. Cox NS, Dal Corso S, Hansen H, et al. Telerehabilitation for chronic respiratory disease. Cochrane Database Syst Rev 2021;1:CD013040.
31. Mendes Xavier D, Lanza Galvão E, Aliane Fonseca A, et al. Effects of home-based pulmonary rehabilitation on dyspnea, exercise capacity, quality of life and impact of the disease in COPD patients: a systematic review. COPD 2022;19:18-46.
32. Wuytack F, Devane D, Stovold E, et al. Comparison of outpatient and home-based exercise training programmes for COPD: a systematic review and meta-analysis. Respirology 2018;23:272-83.
33. Neves LF, Reis MHD, Gonçalves TR. Home or community-based pulmonary rehabilitation for individuals with chronic obstructive pulmonary disease: a systematic review and meta-analysis. Cad Saude Publica 2016;32:S0102-311X2016000602001.
34. Bourgeois N, Lands LC, Prévost K, et al. Virtual physical prehabilitation in lung transplant candidates: a proof-of-concept study. Transpl Int 2024;37:12355.

Online supplementary material:
Supplementary Table 1. Disease-specific analysis of primary and secondary outcomes.

**Table 1. Baseline demographic parameters**

| Clinical variable [Mean (SD) or N (%)] | | All patients (n=75) | Intervention completed (n=51) |
|---|---|---|---|
| Mean age (y) | | 47.8±13.6 | 47.0±13.8 |
| Males (%) | | 38 (50.6%) | 26 (51.0%) |
| Diagnosis | DPLD | 51 (68.0%) | 37 (72.5%) |
| | COPD | 9 (12.0%) | 6 (11.8%) |
| | Bronchiectasis | 15 (20.0%) | 8 (15.7%) |
| Karnofsky performance status (KPS) | Complete assistance | 5 (6.7%) | 2 (3.9%) |
| | Partial assistance | 61 (81.3%) | 43 (84.3%) |
| | No assistance | 9 (12.0%) | 6 (11.8%) |
| ECOG score | 1 | 11 (14.7%) | 8 (15.7%) |
| | 2 | 39 (52.0%) | 32 (62.7%) |
| | 3 | 25 (33.3%) | 11 (21.6%) |
| SGRQ score (Quality of life) | | 64.2±18.9 | 61.8±18.5 |
| Patients on oxygen at rest | | 42 (56.0%) | 25 (49.0%) |
| Patients with sarcopenia | | 44 (58.6%) | 27 (53.0%) |
| Cough severity (VAS) | | 5.3±2.1 | 5.0±2.2 |
| SOB severity | VAS | 7.2±1.6 | 7.0±1.7 |
| | mMRC grade 0-2 | 22 (29.3%) | 15 (29.4%) |
| | mMRC grade 3-4 | 53 (70.7%) | 36 (70.6%) |
| Patients on oxygen at rest | | 42 (56.0%) | 25 (49.0%) |
| BMI ($kg/m^2$) | | 22.4 ± 6.1 | 22.7 ± 6.3 |
| Hand grip strength [kgf] [median (IQR)] | | 22 (8-30) * | 22 (8-30) ## |
| Short Physical Performance Battery (SPPB) | Mean score | 8.9±2.6 | 9.3±2.6 |
| | <9 | 28 (37.3%) | 14 (27.5%) |
| | ≥9 | 47 (62.7%) | 37 (72.5%) |
| Patients with sarcopenia | | 44 (59.4%) | 27 (53.0%) |
| Body composition analysis | ASMI [kg/m2] | 5.5±1.1 * | 5.7±1.2 $ |
| | Body fat% | 32.5±12.7 | 33.2±12.1 |
| FVC [L] | | 1.43±0.73 * | 1.48±0.74 |
| FVC %predicted | | 41.6±16.4 * | 43.0%±15.5% |
| FEV1 [L] | | 1.07±0.60 * | 1.13±0.62 |
| FEV1 %predicted | | 38.3±18.4 * | 40.3%±18.8% |
| DLCO [mL/min/mmHg] | | 7.72±4.98 ## | 8.06±4.76 # |
| DLCO %predicted | | 30.4±18.7 ## | 31.4%±17.4% # |
| Six-minute walk distance (6MWD) | | 287±109 | 307.9±98.8 |

DPLD, diffuse parenchymal lung disease; COPD, chronic obstructive pulmonary disease; ECOG, Eastern Cooperative Oncology Group; SGRQ, St George's Respiratory Questionnaire, VAS, visual analogue scale; mMRC, modified medical research council; BMI, body mass index; ASMI, appendicular skeletal muscle mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in 1s; DLCO, diffusion capacity of lung carbon monoxide. *n=69, # n=33, ## n=48, $ n=35

**Table 2. Primary and secondary outcomes (intervention completed [n=51])**

| Clinical variable [Mean (SD) or N (%)] | | Pre-rehabilitation | Post-rehabilitation | p |
|---|---|---|---|---|
| Karnofsky Performance Status (KPS) | Complete assistance | 2 (3.9%) | 0 | <0.001 |
| | Partial assistance | 43 (84.3%) | 28 (54.9%) | |
| | No assistance | 6 (11.8%) | 23 (45.1%) | |
| ECOG score | 1<br>2<br>3 | 8 (15.7%)<br>32 (62.7%)<br>11 (21.6%) | 19 (37.3%)<br>25 (49.0%)<br>7 (13.7%) | 0.001 |
| SGRQ score (quality of life) | | 61.8±18.5 | 45.2±23.6 | <0.001 |
| Cough severity (VAS) | | 5.0±2.2 | 3.7±1.6 | <0.001 |
| SOB severity | VAS<br>mMRC grade 0-2<br>mMRC grade 3-4 | 7.0±1.7<br>15<br>36 | 5.4±1.7<br>35<br>16 | <0.001<br><0.001 |
| Patients on oxygen at rest | | 25 (49%) | 18 (35%) | 0.019 |
| BMI (kg/m$^2$) | | 22.7±6.3 | 22.7±6.1 | 0.986 |
| Hand grip strength (kgf) [median (IQR), n=48] | | 22 (8-30) | 26 (16-34) | 0.128 |
| SPPB score (0-12) | Mean score | 9.3±2.6 | 9.9±2.5 | 0.007 |
| | < 9<br>≥ 9 | 14<br>37 | 7<br>44 | 0.008 |
| Body composition analysis (n=35) | ASMI [kg/m2] | 5.7±1.2 | 5.5±1.1 | 0.019 |
| | Body fat% | 33.2±12.1 | 35.3±11.5 | 0.041 |
| Patients with sarcopenia | | 27 (53%) | 21 (41%) | 0.014 |
| FVC %predicted | | 43.0%±15.5% | 45.5%±21.5% | 0.095 |
| FEV1 %predicted | | 40.3%±18.8% | 42.5%±24.9% | 0.305 |
| DLCO %predicted (n=33) | | 31.4%±17.4% | 36.3%±19.5% | 0.088 |
| Six-minute walk distance [metre] | | 307.9±98.8 | 306.7±92.5 | 0.499 |

ECOG, Eastern Cooperative Oncology Group; SGRQ, St George's Respiratory Questionnaire; VAS, visual analogue scale; mMRC, modified medical research council; BMI, body mass index; SPPB, Short Physical Performance Battery; ASMI, appendicular skeletal muscle mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in 1s; DLCO, diffusion capacity of lung carbon monoxide.

**Table 3. Primary and secondary outcomes [adherent to the intervention (n=25)].**

| Clinical variable [Mean (SD) or N (%)] | | Pre-rehabilitation | Post-rehabilitation | p |
|---|---|---|---|---|
| Karnofsky performance status (KPS) score | Complete assistance | 0 | 0 | 0.002 |
| | Partial assistance | 21 (84%) | 12 (48%) | |
| | No assistance | 4 (16%) | 13 (52%) | |
| ECOG score | 1<br>2<br>3 | 6 (24%)<br>15 (60%)<br>4 (16%) | 12 (48%)<br>12 (48%)<br>1 (4%) | 0.011 |
| SGRQ score (Quality of life) | | 60.9±17.6 | 41.6±23.8 | <0.001 |
| Cough VAS | | 4.5±2.3 | 3.2±1.5 | <0.001 |
| SOB VAS<br>SOB mMRC grade 0-2<br>SOB mMRC grade 3-4 | | 7.0±1.5<br>8<br>17 | 5.2±1.5<br>18<br>7 | <0.001<br><br>0.001 |
| Patients with oxygen requirement at rest | | 12 (48%) | 8 (32%) | 0.045 |
| Hand grip strength [kgf] [IQR]) | | 24 (13-40) | 28 (17-40) | 0.016 |
| SPPB score (0-12) | Mean score | 9.8±1.7 | 10.6±1.4 | 0.004 |
| | <9<br>≥9 | 5<br>20 | 1<br>24 | 0.045 |
| Patients with sarcopenia | | 11 (44%) | 9 (36%) | 0.157 |
| ASMI [kg/m$^2$] | | 5.8±1.2 | 5.7±1.2 | 0.141 |
| FVC %predicted | | 45.6±17.1 | 50.7±24.5 | 0.013 |
| FEV1 %predicted | | 43.7±19.6 | 48.8±27.3 | 0.033 |
| DLCO %predicted | | 37.9±17.3 | 39.7%±19.7 | 0.331 |
| Six-minute walk distance [metre] | | 309.2±91.5 | 316.8±73.9 | 0.935 |

ECOG, Eastern Cooperative Oncology Group; SGRQ, St George's Respiratory Questionnaire; VAS, visual analogue scale; mMRC, modified medical research council; BMI, body mass index; SPPB, Short Physical Performance Battery; ASMI, appendicular skeletal muscle mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in 1s; DLCO, diffusion capacity of lung carbon monoxide.

**Table 4. Primary and secondary outcomes (non-adherent to the intervention [n=26])**

| Clinical variable [Mean (SD) or N (%)] | | Pre-rehabilitation | Post-rehabilitation | p |
|---|---|---|---|---|
| Karnofsky performance status (KPS) score | Complete assistance | 2 (7.7%) | 0 | 0.006 |
| | Partial assistance | 22 (84.6%) | 16 (61.5%) | |
| | No assistance | 2 (7.7%) | 10 (38.5%) | |
| ECOG score | 1<br>2<br>3 | 2 (7.7%)<br>17 (65.4%)<br>7 (26.9%) | 7 (26.9%)<br>13 (50%)<br>6 (23.1%) | 0.069 |
| SGRQ score (Quality of life) | | 62.7±19.4 | 48.7±23.4 | <0.001 |
| Cough VAS | | 5.4±2.1 | 4.2±1.5 | <0.001 |
| SOB VAS<br>SOB mMRC grade 0-2<br>SOB mMRC grade 3-4 | | 7.0±1.9<br>7<br>19 | 5.6±2.0<br>17<br>9 | <0.001<br><br>0.001 |
| Patients with oxygen requirement at rest | | 13 (50.0%) | 10 (38.5%) | 0.179 |
| Hand grip strength [kgf] [IQR]) | | 21 (11-29) | 21 (13-28) | 0.824 |
| SPPB score (0-12) | Mean score | 8.8±3.2 | 9.2±3.0 | 0.265 |
| | <9<br>≥9 | 9<br>17 | 6<br>20 | 0.083 |
| Patients with sarcopenia | | 16 (61.5%) | 12 (46.2%) | 0.050 |
| ASMI [kg/m$^2$] | | 5.6±1.2 | 5.3±1.1 | 0.079 |
| FVC %predicted | | 40.4%±13.7% | 40.3%±17.0% | 0.965 |
| FEV1 %predicted | | 36.8%±17.5% | 36.3%±21.1% | 0.605 |
| DLCO %predicted | | 25.8%±15.9% | 33.2%±19.3% | 0.117 |
| Six-minute walk distance [metre] | | 306.8±107.5 | 296.5±108.6 | 0.275 |

ECOG, Eastern Cooperative Oncology Group; SGRQ, St George's Respiratory Questionnaire; VAS, visual analogue scale; mMRC, modified medical research council; BMI, body mass index; SPPB, Short Physical Performance Battery; ASMI, appendicular skeletal muscle mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in 1s; DLCO, diffusion capacity of lung carbon monoxide.