Pulmonary rehabilitation in a postcoronavirus disease 2019 world: feasibility, challenges, and solutions

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Purpose of review
Pulmonary rehabilitation improves clinical outcomes in patients with chronic obstructive pulmonary disease (COPD). Traditional centre-based (in-person) pulmonary rehabilitation was largely shut down in response to the COVID-19 pandemic, forcing many centres to rapidly shift to remote home-based programs in the form of telerehabilitation (tele-pulmonary rehabilitation). This review summarizes the recent evidence for the feasibility and effectiveness of remote pulmonary rehabilitation programs, and their implications for the delivery of pulmonary rehabilitation in a postpandemic world.

Recent findings
A number of innovative adaptations to pulmonary rehabilitation in response to COVID-19 have been reported, and the evidence supports tele-pulmonary rehabilitation as a viable alternative to traditional centre-based pulmonary rehabilitation. However, these studies also highlight the challenges that must be surmounted in order to see its widespread adoption.

Summary
There are outstanding questions regarding the optimal model for tele-pulmonary rehabilitation. In the post-COVID-19 world, a 'hybrid' model may be more desirable, with some components held in person and others via telehealth technology. This would be determined by the infrastructure and expertise of individual centres, and the needs of their patients. In order to achieve a truly patient-centred pulmonary rehabilitation program, high-quality studies addressing these outstanding questions, as well as multidisciplinary collaboration, are required.

Keywords
chronic obstructive pulmonary disease, coronavirus disease 2019, long coronavirus disease, pulmonary rehabilitation, telerehabilitation

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a leading cause of morbidity and mortality worldwide [1]. Pulmonary rehabilitation is a cornerstone in the management and treatment of patients with COPD. There is robust evidence supporting the effectiveness of pulmonary rehabilitation programs in the real-world by reducing dyspnoea, improving patients' health-related quality of life (HRQoL) and exercise capacity, and enhancing their social life [2].

Over the past 18 months, the world has been consumed by the novel coronavirus disease (COVID-19) pandemic. Despite global efforts to control the pandemic and the implementation of mass vaccinations, infection rates remain high and healthcare systems remain under enormous pressure in many areas of the world. Patients with COPD are highly vulnerable to poor outcomes from COVID-19 [3▪]. Accordingly, special attention has been paid to protecting COPD patients from contracting the virus through masking, physical distancing and vaccinations. These measures extend to the healthcare setting, including institutions providing pulmonary rehabilitation [4]. As pulmonary

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KEY POINTS

- Barriers to effective pulmonary rehabilitation existed prior to the COVID-19 pandemic, and have been exacerbated by the pandemic because of pressures on healthcare systems, widespread lockdowns, and the need for social distancing.
- Remote pulmonary rehabilitation delivered using telecommunications and other technologies (telerehabilitation) has been adopted rapidly during the COVID-19 pandemic, and may be the key to overcoming many of these barriers.
- A hybrid model of in-person and telerehabilitation, delivered either in-centre or in the home, is the most likely method of delivering effective pulmonary rehabilitation in a post-COVID-19 world

rehabilitation programs have been traditionally conducted in-person, these protective modifications necessary to reduce the spread of SARS-CoV-2 have posed enormous challenges for pulmonary rehabilitation practitioners and patients. Nevertheless, some centres have successfully adapted their programs to the new pandemic realities through the implementation of virtual care.

Here, we describe the current state of pulmonary rehabilitation programs for COPD patients during the COVID-19 pandemic, and highlight some of the challenges and potential solutions for delivering effective pulmonary rehabilitation in the postpandemic world.

SEARCH STRATEGY

This review is based on peer-reviewed articles in PubMed including randomized controlled trials (RCT), feasibility studies, pilot studies, reviews, and meta-analyses focusing on pulmonary rehabilitation that were published between January 2020 and August 2021. Some important clinical studies on this topic are summarized in Table 1.

THE IMPORTANCE OF PULMONARY REHABILITATION IN THE MANAGEMENT OF CHRONIC OBSTRUCTIVE PULMONARY DISEASE

Pulmonary rehabilitation can be defined as a comprehensive, multidisciplinary approach to managing patients with chronic respiratory diseases (CRDs), which according to the official American Thoracic Society/European Respiratory Society (ATS/ERS) statement, is 'designed to improve the physical and psychological condition of people with CRD and to promote the long-term adherence to health-enhancing behaviors' [5].

Although the setting and delivery of pulmonary rehabilitation vary across centres, most effective pulmonary rehabilitation (PR) programs contain five core elements: prerehabilitation assessment, supervised exercise training, body composition interventions, self-management education, and psychological and social support. These components can be delivered at an individual patient level or more commonly in a group setting approximately two to three times a week for 6–8 weeks or even longer [5,6]. The clear benefits of pulmonary rehabilitation for COPD patients have been demonstrated in multiple RCTs, meta-analyses, and ''real-life'' observational studies. Positive impacts have been reported for endpoints, such as functional capacity [7], muscle endurance and strength [8], cardiorespiratory fitness [9], breathlessness and hospital readmissions [10]. Although most of the large clinical studies have focused on COPD patients, individuals with other CRDs including those with interstitial lung disease [11], asthma [12], and pulmonary hypertension [13] have also benefited from PR.

PULMONARY REHABILITATION IN THE PRECORONAVIRUS DISEASE 2019 WORLD

Although pulmonary rehabilitation programs are heterogeneous in terms of their content and format, prior to the COVID-19 pandemic, the majority were hospital-based with multiple in-person visits. According to a global survey of pulmonary rehabilitation programs across 430 centres from 40 countries, less than 5% of pulmonary rehabilitation centres offered a home-based component and even fewer offered a standalone home-based program prior to the pandemic [14]. Most of these were maintenance extensions of initial hospital-based pulmonary rehabilitation in the form of tele-pulmonary rehabilitation, which utilizes communication and information technologies to provide rehabilitation [15]. A systematic review of home-based pulmonary rehabilitation for CRD found that tele-pulmonary rehabilitation – either as a primary or maintenance therapy – led to similar improvements in exercise capacity, HRQoL and dyspnoea scores compared with an in-person model [16]. Additionally, tele-pulmonary rehabilitation showed an overall higher completion rate (93%) compared with that of in-person rehabilitation (70%). Importantly, no harmful effects were noted with tele-pulmonary rehabilitation.

Table 1. Selected pulmonary rehabilitation studies during the coronavirus disease 2019 pandemic

Reference (year), country	Study design	Target patients	Number of participants	Description of intervention	Duration of intervention	Main findings
Lewis *et al.* (2021) [26], United Kingdom	Feasibility study	CRD	25	Delivery model: supervised home-based tele-PR via a learning management system 'eLearn'. Intervention: virtual assessment, livestreamed group exercise (3/week) and online education (2/week); clinician phone calls weeks 2 and 4	6 weeks	Significant improvements in clinical outcomes (exercise capacity, dyspnoea, psychological aspects); high patient 'inclusion', high acceptability to staff
Grosbois *et al.* (2021) [27▪], France	Feasibility study	CRD	83 (34 COPD, 49 other CRD)	Delivery model: hybrid of supervised home visits and telehealthcare. Intervention: home visit (provide equipment, supervise first exercise) plus 1 or 2/week interventions supervised via phone/video calls	8 weeks	79% completion rate; significant improvement in exercise tolerance, HRQoL, anxiety, depression, and fatigue score.
Liu *et al.* (2020) [30▪▪], China	Randomized controlled trial (RCT)	COVID-19 patients	72	Delivery model: hospital-based supervised PR with a home exercise component. Experimental group: supervised exercise plus unsupervised home activities (pursed-lip breathing, coughing training) 2/week. Control group: no intervention	6 weeks	Significant improvement in respiratory function, exercise capacity, HRQoL and anxiety, but no significant improvement in depression compared the control group
Wootton *et al.* (2020) [31], Australia	Case series	COVID-19 patients	3	Delivery model: unsupervised home-based tele-PR via videoconferencing. Intervention: aerobic and strengthening exercises, 4–6 days per week. Feedback regarding daily activity and education from multidisciplinary team (MDT)	6 weeks	Improved exercise capacity (5 and 1 min- sit-to-stand test) and breathlessness (mMRC) in all three patients. Fatigue (FAS) worsened in two patients. All patients highly positive about the program, increased confidence to return their normal life
Li *et al.* (2021) [32▪▪], China	Parallel-group RCT, block randomization	COVID-19 patients	120	Delivery model: unsupervised home-based tele-PR via smart phone application 'RehabApp', with heart rate/pulse oximetry. Experimental group: 40–60 min exercise in 3–4 sessions/week. Weekly consultation over phone. Control group: 10 min standardized education sessions	6 weeks	Superior outcome of tele-PR on primary outcome (6MWD), and physical HRQoL, compared with control group
Bhatt *et al.* (2021) [35], United Kingdom	Feasibility study	COPD-19	128	Delivery model: supervised home-based PR via smart phone application 'HIPAA'. Experimental group: 45–60 min exercise, three times/week in groups of four people; video-based education session. Control group: centre-based PR program.	12 weeks	Both groups showed clinically important improvements in 6MWD and SOBQ, but no between group difference

Table 1 (*Continued*)

Reference (year), country	Study design	Target patients	Number of participants	Description of intervention	Duration of intervention	Main findings
Hansen *et al.* (2020) [36] – initial report; Godtfredsen *et al.* (2020) [37] – 1-year follow-up report, Denmark	Single-blinded, multicentre, superiority RCT Data collected at the end of intervention, at 22 weeks and at 1-year follow-up	Severe to very severe COPD	134	Delivery model: supervised home-based group tele-PR Experimental group (10 weeks): 60 min exercise, 3/week via videoconferencing; 20 min education sessions Control group (12 weeks): hospital-based outpatient PR, 60-min exercise, 2/week. Education sessions 1/week. 1-year follow-up: exercise encouraged but not provided	10 weeks	End of intervention: significant change in 6MWD but no between group difference; higher completion rate in tele-PR. 22 weeks: 6MWD and anxiety improvements sustained only in tele-PR group. 1-year: no significant difference between or within groups in 6MWD
Alwakeel *et al.* (2021) [40▪▪], Canada	Multicentre prospective, nonrandomized controlled trial	COPD patients	6 centres, 177 individuals	Delivery model: supervised community-based tele-PR Experimental group: 1 h exercise and 1 h education, 3/week, via livestream. Healthcare professional present (setup, safety supervision) Control group: standard in-hospital PR (live-streamed to the tele-PR sites)	6 weeks per time, 5 times a year for 3 years	Significant improvement in exercise capacity (6MWD) and overall wellbeing (CAT). Improvements in CAT sustained at 12 months in tele-PR group but not in control group
Benzo *et al.* (2021) [42], USA	RCT Mixed-method feasibility study	Moderate-to-severe COPD	154	Delivery model: unsupervised home-based program. Experimental group: video-guided exercise 6/week with oximetry/activity monitoring; weekly health coaching via telephone. Control group: no intervention	8 weeks	86% adherence rate, and significant improvement in self-management, but no significant improvement in CRQ dyspnoea (as well as emotions-mastery-fatigue) compared with the control group
Jung *et al.* (2020) [53▪▪], United Kingdom	Pilot study	COPD patients with grade 3 or above on the MRC breathlessness scale	10	Delivery model: supervised VR-based PR Intervention: 20 min physical exercise and education (HD video), led by virtual instructor via a VR headset and probe, and data monitored remotely by clinical staff	8 weeks	Significant improvement in patients' compliance, physical ability, and psychological well being

6MWD, 6-min walk distance; CAT, COPD Assessment Test; COPD, chronic obstructive pulmonary disease; COVID-19, novel coronavirus disease 2019; CRD, chronic respiratory disease; CRQ, Chronic Respiratory Questionnaire; FAS, fatigue severity scale; HD, high definition; HIPAA, Health Insurance Portability and Accountability Act; HRQoL, health-related quality of life; MDT, multidisciplinary team; mMRC, modified Medical Research Council dyspnoea scale; PR, pulmonary rehabilitation; RCT, randomized controlled trial; SOBQ, San Diego shortness of breath questionnaire; STS, sit-to-stand test; Tele-PR, telehealth pulmonary rehabilitation; VR, virtual reality.

In the pre-COVID-19 world, remote pulmonary rehabilitation was seen as a means of overcoming many of the known barriers to successful pulmonary rehabilitation. Poor access to pulmonary rehabilitation remains a problem: a global survey from 2013 found that less than 1.2% of people with COPD had reasonable access to pulmonary rehabilitation programs in their residential communities [17]. Even in highly developed countries, access is poor in rural communities [18,19▪▪]. Low participation and completion rates are also issues, driven by factors, such as travel barriers, a perceived lack of benefit [20], and physical challenges of regular participation [21], all of which could potentially be addressed by delivering remote pulmonary rehabilitation. One of the biggest challenges for pulmonary rehabilitation is that there is a gradual decay of benefits after completing the program. This may be mitigated by implementing post-pulmonary rehabilitation follow-up at home or back in the hospital. However, currently, only 22% of pulmonary rehabilitation programs in Canada offer an institutionally based maintenance component [17]. It is important to remember that these challenges existed before, and will likely persist beyond, the COVID-19 pandemic.

PULMONARY REHABILITATION DURING CORONAVIRUS DISEASE 2019

During the COVID-19 pandemic, in-person pulmonary rehabilitation programs were mostly halted to reduce the spread of the virus [22]. This has subsequently led to an increase in demand for pulmonary rehabilitation during the pandemic [23]. Thoracic societies around the world have strongly recommended the implementation of remote pulmonary rehabilitation programs during the pandemic [24▪,25]. Although the published literature on pulmonary rehabilitation during the COVID-19 pandemic is relatively sparse, there are some examples of innovative responses to the crisis.

Alternative pulmonary rehabilitation delivery models for patients with chronic respiratory disease

Lewis *et al.* [26] undertook a rapid pulmonary rehabilitation remodelling using an online platform. Live-monitored home exercise sessions were accompanied by online educational sessions. The virtual pulmonary rehabilitation program improved patient outcomes including exercise capacity, psychological condition, and primary health, with high patient satisfaction. Similarly, Grosbois *et al.* [27▪] rapidly transitioned their Grosbois service to a program consisting of one supervised (via phone or video call) 90-min exercise session per week for 8 weeks. The completion rate was 79%, and there were significant improvements in both physical and psychological domains in the cohort as a whole. Interestingly, improvements in anxiety, depression, and fatigue were only observed in the subgroup of patients without COPD ($n = 34$), which led the authors to speculate that face-to-face visits might play a more important role in pulmonary rehabilitation of COPD patients than other CRDs.

Delivery of pulmonary rehabilitation for coronavirus disease 2019 survivors

With approximately one-third of COVID-19 survivors suffering from a post-COVID-19 syndrome (often referred to as 'long COVID'), many patients who recover from their acute COVID-19 illness may also require pulmonary rehabilitation. There is no clear consensus definition of long COVID but an increasing number of studies has shown that this syndrome may affect several organ systems [28] with the most common symptoms being physical and/or mental fatigue [29▪▪].

There have been some reports of pulmonary rehabilitation for COVID-19 survivors. A RCT from China [30▪▪] compared the benefits of respiratory rehabilitation, twice weekly for 6 weeks, to those of no intervention in older (aged ≥65 years) COVID-19 survivors. Patients in the pulmonary rehabilitation group demonstrated significant improvements in lung function, exercise capacity, HRQoL, and anxiety compared with the control group. Although this trial established the effectiveness of pulmonary rehabilitation following COVID-19, it involved a mixture of supervised exercise in hospital and unsupervised exercise at home. Wootton *et al.* [31] reported a single-centre case series of tele-pulmonary rehabilitation in three COVID-19 patients. In this 6-week program, all assessments were conducted remotely by video conferencing, and exercise was self-monitored using a pulse oximeter. The program led to improvements in exercise capacity and breathlessness in all three patients, as well as improvements in self-confidence and feelings of support during the recovery phase of COVID-19. Li *et al.* [32▪▪] performed a multicentre RCT of a 6-week unsupervised home-based pulmonary rehabilitation program, compared with a control group receiving educational sessions only, in previously hospitalized COVID-19 patients with residual dyspnoea. The investigators monitored the participants' heart rate and pulse oximetry remotely using a smartphone app. The intervention group demonstrated improvements in their functional exercise capacity, limb muscle strength, and

physical HRQoL that were sustained over 7 months of follow-up but improvements in dyspnoea were short lived.

On the basis of the available evidence, pulmonary rehabilitation appears to be effective for COVID-19 survivors. A scoping review based on 40 most recent studies of pulmonary rehabilitation in COVID-19 patients suggested that pulmonary rehabilitation program should begin during patient's inpatient-stay alongside other medical interventions, and continue in an outpatient setting, either at a community centre or at home [33▪]. Although the long-term consequences of COVID-19 in patients with and without COPD are unclear at this time, recent studies suggest that pulmonary rehabilitation could play a major role in restoring the functional status of these patients and improving their overall quality of life. Given that ''functional recovery and return to society are the ultimate medical outcomes instead of negative virology tests and the control of pulmonary inflammation'' [28], there is a pressing need to develop, coordinate, and enhance the healthcare framework and response, such as pulmonary rehabilitation, to support COPD patients during the pandemic.

PULMONARY REHABILITATION IN THE POST-CORONAVIRUS DISEASE 2019 WORLD

With the rapid advancement in science and technology, various remote rehabilitation approaches are quickly evolving, ushering in a new era of 'smart rehabilitation'. Figure 1 shows the transitions through the pulmonary rehabilitation program preceding, during, and succeeding COVID-19, as well as the advantages and disadvantages of different modalities. Rigorous evaluation and clinical studies will be required to determine which of these approaches are clinically feasible and most importantly improve the outcomes and care of patients with COPD. Promisingly, the data to date suggest that tele-pulmonary rehabilitation is noninferior to conventional pulmonary rehabilitation programs, though most of the studies have been small in size and scope [34].

The preferred model of delivery will be determined by infrastructure and expertise of individual centres and the needs of their patients. Programs may be supervised (i.e. an instructor guides the patient through the program) or unsupervised (i.e. self-guided, with the patient following a set routine

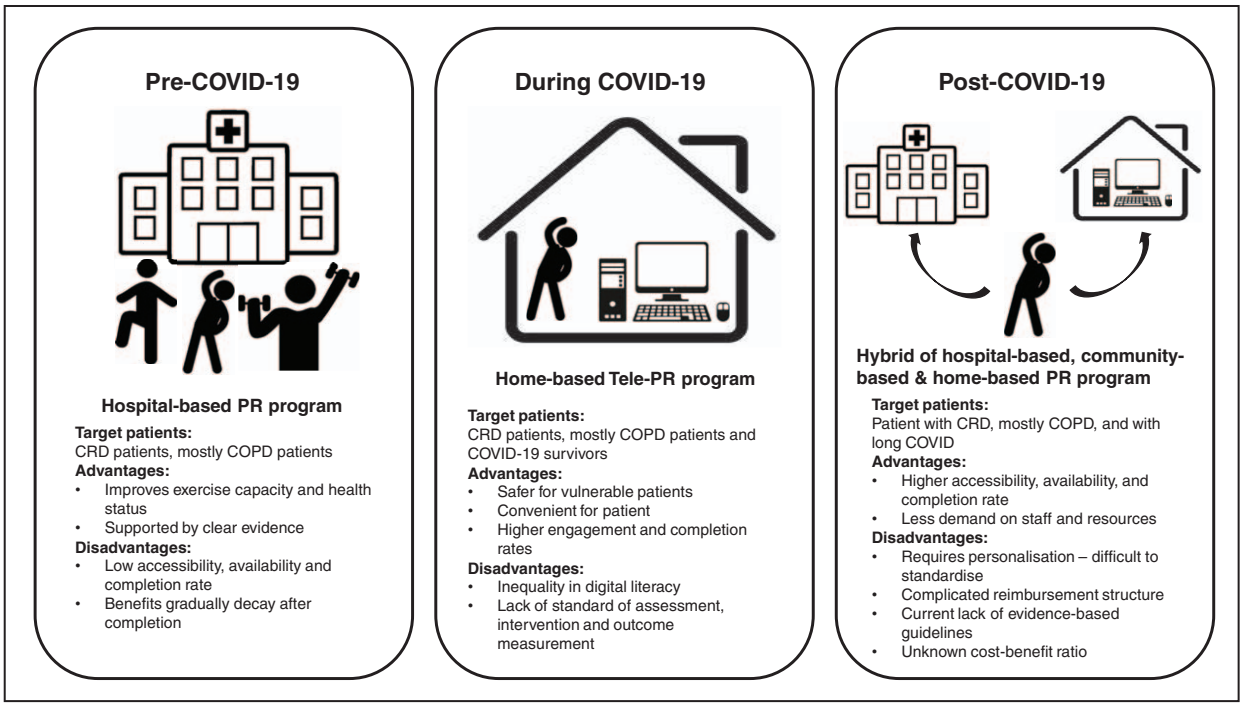

FIGURE 1. The evolving models of pulmonary rehabilitation because of the coronavirus disease 2019 pandemic. During the COVID-19 pandemic, pulmonary rehabilitation shifted from mostly hospital-based programs to mostly home-based telehealth pulmonary rehabilitation (tele-pulmonary rehabilitation) programs because of the requirements for social distancing and lockdown measures implemented in many countries. In the post-COVID-19 world, a 'hybrid' model combining traditional pulmonary rehabilitation with remote tele-pulmonary rehabilitation may be the most desirable. However, in order to achieve a patient-centred pulmonary rehabilitation program, there are challenges to overcome, such as optimization of patient selection, and lack of reimbursement, and evidence-based guideline support. COVID-19, coronavirus disease 2019.

or set of instructions), and the setting may be home-based or community-based. Given the success of its implementation during the COVD-19 pandemic period, a 'hybrid' model combining traditional pulmonary rehabilitation with remote tele-pulmonary rehabilitation may be the most desirable.

Supervised home-based tele-pulmonary rehabilitation

Bhatt *et al.* [35] recently reported outcomes from a live-monitored home-based pulmonary rehabilitation program offered to patients who were unable to attend a centre-based program. The investigators retrospectively matched participants to patients who had undergone conventional centre-based pulmonary rehabilitation; this allowed them to compare the two models, which had similar structures. They found that supervised tele-pulmonary rehabilitation produced similar clinical improvements to the centre-based program, suggesting that this is a viable alternative for patients who cannot participate in centre-based programs. Similarly, a recent multicentre RCT [36,37] compared a supervised tele-pulmonary rehabilitation program, delivered over 10 weeks via video conferencing using basic exercise equipment, to a conventional centre-based pulmonary rehabilitation program. The two groups showed similar improvements in exercise capacity (6MWD), but the supervised tele-pulmonary rehabilitation group showed better completion rates. This suggests that tele-pulmonary rehabilitation may improve adherence to, and accessibility of, pulmonary rehabilitation programs. However, in both the tele-pulmonary rehabilitation and conventional pulmonary rehabilitation groups, the exercise improvements were not sustained over time. Tele-pulmonary rehabilitation programs present an opportunity to engage and maintain contact with patients so that the benefits of pulmonary rehabilitation may persist after completion of the program, but they require optimization to achieve this goal [38].

Supervised community-based tele-pulmonary rehabilitation

Compared with a home-based model, community-based tele-pulmonary rehabilitation programs may provide participants an environment for social interaction and peer support, both of which are valued by COPD patients [39]. Other advantages, such as not needing to create a dedicated space at home, make community-based models particularly attractive.

Alwakeel *et al.* [40▪▪] implemented a province-wide community-based tele-rehab program in Quebec, Canada, at seven tele-sites (primary and secondary healthcare centres). All components of the 8-week program were standardized by concurrently video-conferencing the standard pulmonary rehabilitation program delivered at the hospital (which served as the control group) to all the tele-pulmonary rehabilitation sites. At each tele-pulmonary rehabilitation site, one healthcare professional was present to set up and coordinate the video conferencing, and to ensure participants' safety. Improvements in exercise capacity and overall wellbeing were comparable with the standard pulmonary rehabilitation program. However, the combined tele-pulmonary rehabilitation group showed a higher completion rate (83 vs. 72%) and more sustained improvements in 6MWD and COPD Assessment Test (CAT) scores over 12 months. The investigators hypothesized that stronger, ongoing community support and reinforcement improved patients' self-management skills, and in turn their overall health status.

Unsupervised tele-pulmonary rehabilitation

In an unsupervised tele-pulmonary rehabilitation model, patients undertake their own exercise training sessions and are followed-up with home visits or phone calls from health professionals to check on their progress and provide feedback [41]. Home-based unsupervised tele-rehab has been proposed as an alternative model that can increase access and lower the healthcare cost burden.

The outcomes from unsupervised home-based models appear to be mixed. For example, Benzo *et al.* [42] implemented a model of telephone health coaching along with unsupervised, video-guided exercise six times per week. This model showed a high degree of acceptability and adherence, as well as improvements in participants' self-management abilities, but no significant improvement in dyspnoea. Galdiz *et al.* [43] conducted a 12-month RCT comparing unsupervised tele-rehab program as a maintenance strategy to usual care (no intervention), and found that significant improvements were observed in psychological domains (SF-36, CRDQ-emotion score) but not exercise capacity.

The discrepancy in outcomes across different studies might be attributed to the contextual heterogeneity of these studies as there is no universally agreed upon standard for unsupervised pulmonary rehabilitation program. On top of that, there is a scarcity of literature comparing unsupervised tele-rehab to conventional pulmonary rehabilitation program. Therefore, more clinical studies are needed on this topic to fill this critical gap in knowledge and generate data to ensure the safety of participants in this setting.

Tele-pulmonary rehabilitation with virtual reality

Virtual reality allows users to experience an immersive, interactive, and multisensory computer-simulated 3D environment, which can reduce negative sensations [44] and make participants feel more engaged and motivated [45]. Virtual reality is, therefore, particularly attractive for rehabilitation programs, and has been successfully used for cognitive rehabilitation of poststroke patients [46], motor rehabilitation of frail elderly patients [47], gait training for individuals with Parkinson's disease [48], as well as physical and cognitive training for older adults with mild cognitive impairment [49]. In all these settings, virtual reality-incorporated rehabilitation achieved comparable or better results compared with traditional methods of rehabilitation delivery.

There are some recent trials using virtual reality as part of pulmonary rehabilitation programs for COPD patients. One RCT used immersive virtual reality therapy as a supporting method for COPD patients who were undergoing hospital-based pulmonary rehabilitation. This program showed benefits in reducing stress levels and improving symptoms of depression and anxiety compared with the control group, which received traditional therapeutic training [50]. The same research group also investigated and demonstrated that virtual reality training can improve exercise tolerance [51] and physical fitness [52▪] in COPD patients. A pilot study demonstrated that a remotely supervised virtual reality-based pulmonary rehabilitation program effectively improves participants' physical ability, psychological well being, and their HRQoL [53▪▪]. In this study, the virtual reality technology enabled health practitioners to track and monitor patients' physiological performance data, which increased patients' confidence and ensured their safety during exercise. A review on virtual reality application for COPD rehabilitation from a technological perspective has also shown that the use of virtual reality can be a promising solution to improve both at-home and in-hospital pulmonary rehabilitation [54] but there are still many aspects that have not been fully investigated. These include some side effects of virtual reality, such as dizziness that prohibit its application in some patients and reduce the long-term effectiveness of virtual reality in improving patient outcomes.

ONGOING CHALLENGES AND SOLUTIONS

Despite increasing evidence for the feasibility and safety of remote tele-pulmonary rehabilitation, a 'hybrid' pulmonary rehabilitation model may be more desirable as some in-person components may be indispensable. For example, initial assessment and exercise prescription have been performed in-person in most tele-pulmonary rehabilitation programs, either in-centre [35,40▪▪] or in the patient's home [27▪,32▪▪]. Many tele-pulmonary rehabilitation studies did not specify how the exercises were prescribed in the virtual setting, making it difficult to compare studies. In one small case series, initial assessment and exercise prescription were performed via video conferencing with the patient in full view [31]. Larger studies are required to determine whether the virtual exercise prescription is appropriate and can achieve maximal benefits.

More research is needed to ascertain the optimal methods for delivering telemedicine for patients with COPD in the community based on patients' needs and preferences, as echoed in a recent ATS Workshop report [19▪▪]. For example, a recent feasibility and acceptability trial [55] using a web-based pulmonary rehabilitation platform (SPACE) in patients who had experienced a recent acute exacerbation of COPD (AECOPD) reported technological barriers that led them to 'give up' on the program as they could not navigate the website. This, in turn, reduced their motivation to exercise. Guidelines and further clinical evidence are needed to optimize pulmonary rehabilitation programs suited for different patient populations.

Table 2. Recommended considerations for future studies on tele-pulmonary rehabilitation

Consideration	Unresolved questions
Cost-effectiveness	Which tele-PR model is the most cost-effective? How does this compare with traditional PR models?
Exercise prescription procedures	Are current procedures suitable for a tele-PR model? How can exercise prescription be standardized for tele-PR?
Maintenance of PR gains	What is the best way to follow patients after the initial tele-PR program? How durable are the benefits of tele-PR? Can tele-PR methods integrate exercise into participants' everyday life to maintain benefits?
Safety	Can the required exercise intensity be delivered in an unsupervised tele-PR program? What are the minimum monitoring requirements for supervised/unsupervised tele-PR programs?

PR, pulmonary rehabilitation; Tele-PR, telehealth pulmonary rehabilitation.

The cost-effectiveness of implementing tele-pulmonary rehabilitation remains unknown as there is scarcity of literature on the topic. Barbosa *et al*. [34] recommended that future clinical trials include a cost analysis, which can provide financial insights and be used for reimbursement and/or investment into these programs. It should be noted that telemedicine is heterogeneous in its infrastructure and delivery, which poses difficulties for quantitative analysis and generating standards/guidelines in the field. There are some recommendations in terms of the components, which should be incorporated in future studies (Table 2) to fill the gap in knowledge and to promote the creation of guidelines.

CONCLUSION

The COVID-19 pandemic has changed our lives drastically and forced the healthcare system to shift its focus to virtual care delivery. This shift has brought the tele-pulmonary rehabilitation to the centre stage and demonstrated its value as a viable alternative to face-to-face delivery of pulmonary rehabilitation. Greater-scale adoption of tele-pulmonary rehabilitation into the medical community will happen gradually, and multidisciplinary collaboration, along with high-quality clinical studies, and technology advancement are the keys in supporting and accelerating this process [56]. The most important reason for the lack of success in sustaining the benefits of pulmonary rehabilitation over time in patients is the failure to fully embed a regular exercise routine into patient's daily life and, as a result, patients returned to their sedentary lifestyle shortly after completion of the pulmonary rehabilitation program. Ultimately, the goal of achieving a tailored patient-centred pulmonary rehabilitation program is to understand individuals' daily life and to figure out the best exercise routine for each of them.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

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- ■■ of outstanding interest

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An in-depth summary of the latest evidence and challenges facing pulmonary rehabilitation from some of the world's leading experts in the field.

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26. Lewis A, Knight E, Bland M, *et al.* Feasibility of an online platform delivery of pulmonary rehabilitation for individuals with chronic respiratory disease. BMJ Open Respir Res 2021; 8:112.

27. ■ Grosbois JM, Gephine S, Le Rouzic O, Chenivesse C. Feasibility, safety and effectiveness of remote pulmonary rehabilitation during COVID-19 pandemic. Respir Med Res 2021; 80:100846.

This study is notable as it includes cohorts of COPD and non-COPD respiratory patients, and that improvements in anxiety and depression were not significant in the COPD cohort. This supports an individualized approach to pulmonary rehabilitation, where a hybrid model combining some in-person rehabilitaion may be more suitable for COPD patients.

28. Li J. Rehabilitation management of patients with COVID-19: lessons learned from the first experience in China. Eur J Phys Rehabil Med 2020; 56:335–338.

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This observational study is particularly important as it highlights the risk of developing 'long COVID' even in younger people with mild disease. The implications of these finding are that an age cohort not usually seen in pulmonary rehabilitation may require this service as the pandemic progresses.

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32. ■■ Li J, Xia W, Zhan C, *et al.* A telerehabilitation programme in postdischarge COVID-19 patients (TERECO): a randomised controlled trial. Thorax 2021. doi: 10.1136/thoraxjnl-2021-217382. [Epub ahead of print]

The most notable finding of this RCT of pulmonary rehabilitation in COVID-19 survivors was the durability of improvements in exercise capacity, which persisted over 7 months of follow-up.

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40. ■■ Alwakeel AJ, Sicondolfo A, Robitaille C, *et al.* The accessibility, feasibility, safety of a standardized community-based tele-pulmonary rehab program for COPD: a 3-year real-world prospective study. Ann Am Thorac Soc 2021. doi: 10.1513/AnnalsATS.202006-638OC. [Online ahead of print]

This study is impressive in its size and scope, being conducted province-wide and demonstrating how a tele-pulmonary rehabilitation model can be successfully implemented at a health system level.

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42. Benzo RP, Ridgeway J, Hoult JP, *et al.* Feasibility of a health coaching and home-based rehabilitation intervention with remote monitoring for COPD. Respir Care 2021; 66:960–971.

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