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Pulmonary Rehabilitation for Adults with Chronic Respiratory Disease

An Official American Thoracic Society Clinical Practice Guideline

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Abstract

Background: Despite the known benefits of pulmonary rehabilitation (PR) for patients with chronic respiratory disease, this treatment is underused. Evidence-based guidelines should lead to greater knowledge of the proven benefits of PR, highlight the role of PR in evidence-based health care, and in turn foster referrals to and more effective delivery of PR for people with chronic respiratory disease.

Methods: The multidisciplinary panel formulated six research questions addressing PR for specific patient groups (chronic obstructive pulmonary disease [COPD], interstitial lung disease, and pulmonary hypertension) and models for PR delivery (telerehabilitation, maintenance PR). Treatment effects were quantified using systematic reviews. The Grading of Recommendations, Assessment, Development and Evaluation approach was used to formulate clinical recommendations.

Recommendations: The panel made the following judgments: strong recommendations for PR for adults with stable COPD (moderate-quality evidence) and after hospitalization for COPD exacerbation (moderate-quality evidence), strong recommendation for PR for adults with interstitial lung disease (moderate-quality evidence), conditional recommendation for PR for adults with pulmonary hypertension (low-quality evidence), strong recommendation for offering the choice of center-based PR or telerehabilitation for patients with chronic respiratory disease (moderate-quality evidence), and conditional recommendation for offering either supervised maintenance PR or usual care after initial PR for adults with COPD (low-quality evidence).

Conclusions: These guidelines provide the basis for evidence-based delivery of PR for people with chronic respiratory disease.

Keywords: pulmonary rehabilitation; chronic obstructive pulmonary disease; interstitial lung disease; pulmonary hypertension; telerehabilitation

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Summary of Recommendations

1. For adults with stable chronic obstructive pulmonary disease (COPD), we recommend participation in pulmonary rehabilitation (strong recommendation, moderate-quality evidence).
2. For adults with COPD, we recommend participation in pulmonary rehabilitation after hospitalization for an exacerbation of COPD (strong recommendation, moderate-quality evidence).
3. For adults with interstitial lung disease, we recommend participation in pulmonary rehabilitation (strong recommendation, moderate-quality evidence).
4. For adults with pulmonary hypertension, we suggest participation in pulmonary rehabilitation (conditional recommendation, low-quality evidence).
5. For adults with stable chronic respiratory disease, we recommend offering the choice of center-based pulmonary rehabilitation or telerehabilitation (strong recommendation, moderate-quality evidence).
6. For adults with COPD, we suggest either supervised maintenance pulmonary rehabilitation or usual care after initial pulmonary rehabilitation (conditional recommendation, low-quality evidence).

Introduction

Chronic respiratory diseases (CRDs) pose a high burden of morbidity and mortality on patients and health systems globally. In 2017, an estimated 545 million people had a CRD, accounting for 3.9 million deaths (1). CRDs lead to disabling symptoms of dyspnea, fatigue, anxiety, depression, and fear; impair individuals' exercise tolerance and ability to undertake daily activities; reduce quality of life; and contribute to risk of hospitalization and increased mortality. Care for CRD incurs billions of dollars in healthcare costs annually (1, 2).

Pulmonary rehabilitation (PR) is "a comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies that include, but are not limited to, exercise training, education, and behavior change, designed to improve the physical and psychological condition of people with CRD and to promote the long-term adherence to health-enhancing behaviors" (3). PR is an essential component of the integrated care of people with CRD. Core components of PR include structured and progressive individually tailored exercise training, self-management education, patient assessment, and outcomes measurement (3–5) delivered by a multidisciplinary team of healthcare professionals (HCPs). Participation in PR reduces dyspnea; increases exercise capacity; improves health-related quality of life (HRQoL) and emotional function; confers social support; and, for those with chronic obstructive pulmonary disease (COPD), reduces hospital admissions and mortality risk after hospitalization (3, 6–9). The evidence base for PR was developed initially for COPD, with benefits now also recognized for other CRDs, including interstitial lung disease (ILD), pulmonary hypertension (PH), asthma, bronchiectasis (cystic fibrosis and non-cystic fibrosis), lung cancer, and those preparing for or recovering from lung transplant or from SARS-CoV-2 infection (COVID-19) (10–18).

Despite its proven benefits, PR remains underused (19–22) and underresourced (23–26). Less than 5% of people with COPD who may benefit from PR receive it (19–21). Barriers to patient access include the number and capacity (24, 26) of available programs, particularly in rural areas (25, 27, 28); the challenges of travel to a PR center; insufficient HCP and patient knowledge and awareness of the process and benefits of PR (22, 23); and competing health and time priorities (24–26). Inconsistent training curricula for HCP lead to a limited number of individuals trained in the discipline of PR (22). Moreover, HCPs' referral of patients to PR is suboptimal (22, 27, 28); racial and socioeconomic disparities also exist regarding patients' access to PR (29–31). Collectively, these issues contribute to significant healthcare inequalities for individuals with CRD.

Previous clinical practice guidelines (CPGs) providing recommendations for PR, published in 2007 (32) and 2011 (33), focused solely on COPD; the latter recommended PR for those with COPD and an FEV_1 <50% predicted. CPGs from other countries have expanded their recommendations to also include people with less severe COPD and other CRDs (34–36). The evidence base for PR has evolved substantially in recent years to include other CRDs and novel models for delivery such as telerehabilitation (PR delivered remotely using telehealth technologies).

These factors highlight the need for an updated CPG for PR to improve the clinical practice of PR as well as to guide healthcare policy worldwide. Greater knowledge of the proven benefits of PR should highlight the role of PR in evidence-based healthcare and

lead to more patient referrals for this important treatment. Although benefits of PR have been demonstrated for individuals with asthma, cystic fibrosis, bronchiectasis, lung cancer, lung transplant, and post–COVID-19 syndrome (12–19), inclusion of these was beyond the scope of the present document.

Methods

This CPG was developed in accordance with the policies and procedures of the American Thoracic Society (ATS). The guideline panel included 4 cochairs and 25 voting members: 10 pulmonary/critical care physicians, 1 advanced heart failure and transplant cardiologist, 1 internist, 8 physical therapists, 2 nurses, 1 respiratory therapist, 1 exercise physiologist, and 1 person with CRD who has undergone PR (Box 1). Potential conflicts of interest were disclosed and managed in accordance with the policies and procedures of the ATS (*see* Table E1 in the online supplement). This CPG reviews evidence pertaining to six PICO questions, wherein P = patient population, I = intervention, C = comparator, and O = outcomes (Table E2). We chose questions considered by our panel to highlight aspects and key outcomes of PR with the greatest potential to impact clinical practice, public policy, and reimbursement for PR. The methods by which the outcomes were chosen for analysis are detailed in the online supplement. We used the Grading of Recommendations Assessment Development and Evaluation approach (37) to appraise the quality of evidence and to formulate and grade recommendations (Tables 1 and 2). When possible, we used existing published systematic reviews. If a review was published more than 12 months prior or if our prespecified outcomes were not included in the existing systematic reviews, we updated the literature search accordingly (Table E3). The AMSTAR-2 (A MeaSurement Tool to Assess systematic Reviews) checklist (38) was used to appraise the quality of published systematic reviews (Table E4). For this CPG, we focused principally on established traditional models of PR delivered in inpatient or outpatient healthcare settings. In recognition of the important emergence of rehabilitation delivered remotely, we also evaluated the evidence regarding telerehabilitation. A detailed description of the methods is provided in the online supplement.

Results

Existing systematic reviews were available for all PICO questions (6, 8, 10, 11, 39–43). We updated existing systematic reviews for two PICO questions (8, 40) via comprehensive searches (*see* the METHODS section in the online supplement). The guideline panel used the Grading of Recommendations Assessment Development and Evaluation evidence-to-decision framework (44) to develop final recommendations. Voting was conducted online and was anonymous. Figure 1 summarizes the guideline recommendations, and Figure 2 summarizes research needs in PR.

Question 1: Should Adults with Stable COPD Undertake Pulmonary Rehabilitation?

Background. Approximately 11.7% of people worldwide have COPD (45). In the United States, approximately 16 million have diagnosed COPD; likely millions more have undiagnosed COPD (45–47). COPD results from the interaction of wide-ranging genetic and environmental factors (48–50). Dyspnea and reduced exercise capacity are cardinal features of COPD (45, 51). These symptoms relate to structural and functional changes in the respiratory system, as well as skeletal muscle dysfunction (52), deconditioning, cardiocirculatory limitations (53, 54), and other comorbid conditions (e.g., anxiety, fear, depression, osteoporosis, metabolic disorders, anemia, fatigue) (55, 56). Acute exacerbations of COPD (AECOPD) further worsen lung function, symptoms, and disability and increase patients' mortality risk (57). Collectively, these issues impair HRQoL (58). People with COPD typically remain symptomatic despite existing pharmacotherapies (45). Additional treatments are therefore needed to improve patients' outcomes.

Box 1. Patient Perspective

When I was diagnosed with chronic obstructive pulmonary disease (COPD) in 2001, I was in my early middle years. When I asked how long I might have to live, I was told to consider making end-of-life preparations in the next 3 to 5 years. That was 21 years ago. It has not been easy, but it's been vastly preferable to the alternative. A diagnosis of COPD is a slap to the soul. It shatters your persona. There are very few promising options. Pulmonary rehabilitation is, I believe, the best one. The very thought of exercising, though, of using a treadmill for even a few minutes a day is daunting to someone for whom breathing itself is a challenge. *But I am convinced that pulmonary rehabilitation saved my life.* At the beginning, I didn't know what to expect, but I knew it was my last best chance. I had the opportunity in classes to see the spectrum of the disease, from those who were moderately ill, to those who were getting ready for lung transplant, to those who could barely move, those who were already on supplemental oxygen. What pulmonary rehabilitation did for me was jump-start my desire to live. It has enabled me to live a good active life. I have been exercising 7 days a week for 21 years. Without pulmonary rehabilitation, I don't believe I would be alive today.

For someone who is considering participating in pulmonary rehabilitation for the first time, I would say that it's as important as any medicine that's going to be prescribed for you for COPD or for chronic lung disease. What all patients with lung disease need is an understanding of their disease and regular physical activity. Pulmonary rehabilitation imparts knowledge, guidance, empowerment, and is, in my view, your best chance of living the life you want to lead. Sadly, pulmonary rehabilitation is not available in many communities, but it should be. It is the standard of care in medicine. Everyone who has moderate, severe, or very severe disease needs the opportunity for pulmonary rehabilitation. Pulmonary rehabilitation can restore both body and soul. Thanks to pulmonary rehabilitation, I'm still working on those end-of-life preparations.

Table 1. Certainty of Evidence

Evidence Quality	Definition
High	High confidence that the estimated effect is close to the true effect
Moderate	Moderate confidence that the estimated effect is close to the true effect, but with a chance that the true effect is considerably different
Low	Low confidence in the estimated effect. Higher likelihood that the true effect is considerably different from the estimated effect
Very low	Very low confidence in the estimated effect. High likelihood that the true effect is considerably different from the estimated effect

The prespecified critical outcome for this question was exercise capacity. Important outcomes were dyspnea, HRQoL, adverse events (AEs), and healthcare use (HCU). Three systematic reviews were used for these analyses (6, 39, 40). An updated search was conducted for HCU to include recent data (40).

Description of the evidence and its quality. We found 82 randomized controlled trials (RCTs) (4,674 participants) reporting the effects of PR versus usual care for people with stable COPD (range of mean FEV_1, 26–75% predicted). Forty-seven studies involved outpatient programs, 10 of which included a home-based element; 29 studies were community (nonhospital) programs, of which 16 were entirely home based; 6 were inpatient programs, and of these, 3 were followed by a home-based program. Program duration ranged from 4 weeks to 1 year, with the majority being 8 to 12 weeks. Most programs used a combination of aerobic and resistance training; some included nonexercise components such as breathing retraining, education, and self-management.

Meta-analysis of 38 RCTs (6) showed that 6-minute-walk distance (6MWD) significantly increased after PR compared with control (mean difference [MD], 43.93 m; 95% confidence interval [CI], 32.64 to 55.21; 1,879 participants), with the lower end of the CI exceeding the minimally important difference (MID) of 30 m for COPD (59). The incremental shuttle walk distance (ISWD) also increased immediately after PR (MD, 39.77 m; 95% CI, 22.38 to 57.15; 8 RCTs; 694 participants), with the MD exceeding the MID of 35 m (60). Peak work capacity improved after PR compared with control (MD, 6.77 W; 95% CI, 1.89 to 11.65; 16 RCTs; 779 participants), with the MD exceeding the MID of 4 W (61).

Dyspnea measured by the Chronic Respiratory Disease Questionnaire (CRQ) improved after PR compared with control (MD, 0.72 points; 95% CI, 0.19 to 1.25; 13 RCTs; 836 participants), with the MD exceeding the MID of 0.5 units (62). Similar effects were seen for the Transitional Dyspnea Index (MD, 1.95 points; 95% CI, 1.09 to 2.81; 5 RCTs; 187 participants), with the MD and lower end of the CI exceeding the MID of 1 unit (63). Improvements for the Medical Research Council (MRC) or the modified MRC (mMRC) dyspnea scale score favored PR (standardized MD [SMD], −0.64 units; 95% CI, −0.99 to −0.30; 5 RCTs; 176 participants), but neither the MD nor the upper end of the CI exceeded a change in the score of 1 point (64).

HRQoL improved after PR compared with the control for the St. George's Respiratory Questionnaire (SGRQ) total score (MD, −6.8 points; 95% CI, −9.26 to −4.52; 29 RCTs; 1,146 participants) and all domain scores (symptoms, impact, and activities; Table E5). For the SGRQ total score, the lower end of the CI exceeded the MID of −4 points (65). Important improvements were also evident for the CRQ domains of fatigue (MD, 0.68 points; 95% CI, 0.45 to 0.92; 19 RCTs; 1,291 participants), emotional function (MD, 0.56; 95% CI, 0.34 to 0.78; 19 RCTs; 1,291 participants), and mastery (MD, 0.71; 95% CI, 0.47 to 0.95; 19 RCTs; 1,212 participants). The MD for each domain of the CRQ exceeded the MID of 0.5 units (62).

Table 2. Implications of Clinical Guideline Recommendations by Stakeholder

Stakeholder	Strong Recommendation	Conditional Recommendation
Patient	The majority of patients would want the recommended course of action in this situation, and only a small number would not.	Many patients in this situation would prefer the recommendation, but a substantial number may not. This is an opportunity for shared decision making between the clinician and patient.
Clinician	Most individuals should receive the course of action that is recommended. There is a low chance that additional formal decision aids are needed to help individuals make decisions consistent with their values and preferences, and adherence to this recommendation could be used as a performance indicator or quality criterion.	Different choices will be applicable to different patients, and additional factors will need to be considered in addition to the recommendation in order for a patient to make a decision according to their values and preferences. Decision aids may be needed to assist individuals in making their best choice. This is an opportunity for shared decision making between the clinician and patient.
Policy maker	The recommendation can be widely adapted as policy and can be used for performance indicators.	Policy making will require substantial additional debate and involvement of many and/or additional stakeholders. The likelihood of regional variance is also higher, and performance indicators would need to take into consideration any additional deliberation that has occurred.

Question	Recommendation	Strength of recommendation Quality of Evidence
1. Should adults with stable COPD undertake pulmonary rehabilitation?	For adults with stable COPD, we recommend participation in pulmonary rehabilitation	Strong Moderate
2. Should adults with COPD undertake pulmonary rehabilitation following hospitalization for an exacerbation?	For adults with COPD, we recommend participation in pulmonary rehabilitation following hospitalization for exacerbation of COPD	Strong Moderate
3. Should adults with ILD undertake pulmonary rehabilitation?	For adults with ILD, we recommend participation in pulmonary rehabilitation	Strong Moderate
4. Should adults with pulmonary hypertension undertake pulmonary rehabilitation?	For adults with pulmonary hypertension, we suggest participation in pulmonary rehabilitation	Conditional Low
5. Should adults with CRD undertake telerehabilitation?	For adults with stable CRD, we recommend offering the choice of center-based pulmonary rehabilitation or telerehabilitation	Strong Moderate
6. Should adults with CRD undertake maintenance pulmonary rehabilitation?	For adults with COPD, we suggest either supervised maintenance pulmonary rehabilitation or usual care after initial pulmonary rehabilitation	Conditional Low

Figure 1. Summary of recommendations. COPD = chronic obstructive pulmonary disease; CRD = chronic respiratory disease; ILD = interstitial lung disease.

In three RCTs (172 participants), there was no effect of PR on the rate ratio of respiratory-related hospitalizations during the 6 to 24 months of the studies (rate ratio, 0.76; 95% CI, 0.40 to 1.45) (Figure E3).

In 42 RCTs (2,150 participants), there were no serious AEs (adverse cardiovascular or musculoskeletal injuries) during training (39). No studies evaluated AEs formally as a study outcome. Mortality during the study period was low (total five deaths in PR group and seven deaths in control group, 42 RCTs, 2,720 participants) with no deaths related to PR (39). Mortality in the 3 to 24 months after PR was low (total five deaths in PR group

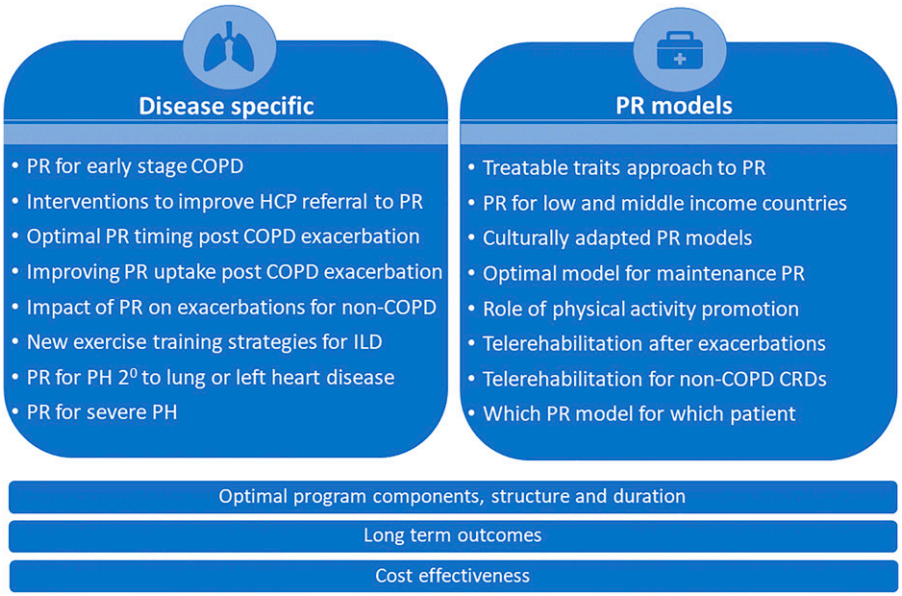

Figure 2. Research needs in pulmonary rehabilitation. COPD = chronic obstructive pulmonary disease; CRD = chronic respiratory disease; HCP = healthcare professional; ILD = interstitial lung disease; PH = pulmonary hypertension; PR = pulmonary rehabilitation.

and five deaths in control group, three RCTs, 172 participants) (66–68). Event rates in previous RCTs were too low to detect effects of PR on longer-term survival.

The certainty of evidence was low to moderate for the critical outcome of exercise capacity, low for the outcomes of dyspnea and HRQoL, and very low for the outcome of HCU. Certainty of evidence was affected by high risk of detection bias (no or unclear blinding of assessors) and substantial statistical heterogeneity for exercise capacity (I^2 = 32–74%), dyspnea (I^2 = 65–69%), HRQoL (I^2 = 58–64%), and hospitalization (I^2 = 62%), likely because of variations in PR setting, program components, and duration (6).

Panel judgments. **Desirable consequences and their magnitudes (benefits):** PR resulted in significant improvement in exercise capacity, reduction in dyspnea, and improvement in HRQoL compared with usual care of no PR, with MDs exceeding MIDs. Qualitative studies reveal that these and other benefits of PR, including improvements in physical functioning, sense of well-being, participants' knowledge of their lung condition, control of symptoms (e.g., less dyspnea), and social functioning (23, 69), are valued by patients.

Undesirable consequences and their magnitudes (harms): There were no serious AEs or deaths related to the intervention of PR among people with stable COPD.

ATS recommendation: For adults with stable COPD, we recommend participation in PR (strong recommendation, moderate-quality evidence).

Rationale for the recommendation: This recommendation places a high value on low- to moderate-quality evidence that PR for people with stable COPD improves exercise capacity, reduces dyspnea, and improves HRQoL (Table E13). These improvements, coupled with the high value that patients place on the benefits of PR (23, 69) and the fact that no significant AEs or deaths were related to PR, further support the recommendation. (Vote: 18 in favor, 0 against, 0 abstained.)

What others are saying: Our recommendation that patients with stable COPD should undergo PR, regardless of the degree of lung function impairment, is in keeping with other national and international guidelines (70, 71), statements (3, 22), and expert reports on COPD management (45, 72). Our recommendation differs from that of a previous international guideline which suggested that PR should be offered only to those with an FEV_1 below 50% predicted (33). Participants in the studies reported in PICO 1 had a range of disease severity (mean FEV_1 range, 26–75% predicted). A systematic review demonstrated that people with stable COPD and mild symptoms (mMRC dyspnea scale score, $\leq$1) benefit from PR (73), and a cluster analysis of $>$500 patients with COPD showed no relationship between severity of lung function impairment and response to PR (74).

Implementation considerations: Access to PR relies on patient referrals by HCPs. HCPs often lack sufficient knowledge of the benefits of and the referral process for PR (22, 26, 75–77). Patient factors, such as comorbid conditions, patient age, and socioeconomic factors, may impact HCPs' referrals for PR (78). Education of HCPs about the benefits of and the processes for referral for PR is a key component to help maximize patient referral. Medications should be optimized before commencing PR.

PR programs are often lacking in rural and remote communities (79). In addition, there is limited availability of staff adequately educated and trained to provide multidisciplinary evidence-based PR. Unequal access to and availability of PR programs widen health inequalities. Qualitative studies report patients' perspective that participation in PR can be challenging because of factors that include the costs of program and travel, competing demands on time (24), uncertainty of program benefit, or fear of exercising and dyspnea (80).

Values and preferences: This recommendation places a high value on the benefits of PR of improved exercise capacity, reduced symptoms of dyspnea, and improved HRQoL and a lower value on patient burden of travel, cost, and inconvenience.

Research needs: Despite the well-established benefits of PR for people with stable COPD, important questions remain. Further research is needed on the impact of PR at an early stage of disease (81), as well as on the optimal content and structure (including optimal program duration), benefits and costs of different models of PR for COPD, and the benefit of interventions targeted at HCPs to enhance referral and uptake. Although PR uses individualized exercise prescription (3), further focus on characterization and prioritization of an individual's treatable traits to determine the optimal format of PR (82) in conjunction with patient preferences is needed. Models of PR that are culturally adapted, appropriate, and feasible for diverse populations are also needed. The evaluation of whether PR reduces hospitalizations or mortality for people with stable COPD, although not easily addressed, is important (83). An overall evaluation of the costs relative to benefits of PR is important to healthcare providers and payers.

Question 2: Should Adults with COPD Undertake Pulmonary Rehabilitation after Hospitalization for an Exacerbation?

Background. Hospitalizations for AECOPD pose a significant social and economic burden for patients and healthcare systems (83–85). Patients hospitalized for an AECOPD are at a heightened risk of rehospitalization and mortality after hospital discharge (86–88). PR has been proposed as a potential adjunct therapy for people with COPD in the postexacerbation period because it encompasses several interventions known to improve health status and prognosis (3, 34). Previous reviews synthesizing evidence on PR after hospitalization for AECOPD have produced contrasting findings (8, 89–93). These reviews have included PR programs initiated during the hospital admission itself, up to the point of discharge, and/or after hospital discharge. Variations in the timing and model of delivery may explain some of the heterogeneity of outcomes. PICO 2 examined the efficacy of PR initiated within 3 weeks of hospital discharge after an AECOPD because most published trials use the criterion of $\geq$4 weeks postexacerbation as characteristic of stable COPD.

The prespecified critical outcome for this question was HCU. Important outcomes were exercise capacity, HRQoL, dyspnea, mortality, and AEs. We used data from a previously published Cochrane review (8) and updated the search to February 2022 (A. R. Jenkins and colleagues, unpublished results; this review will be published separately).

Description of the evidence and its quality. We found 17 RCTs (94–110) (1,724 participants) reporting the effects of usual care versus PR delivered after hospital discharge for an AECOPD. The mean FEV_1 of participants ranged from 31% to 57% predicted. Six studies commenced PR during the inpatient stay and continued after

discharge (94, 103, 106, 108–110), eight commenced outpatient PR within 2 weeks of discharge (95, 97, 99–101, 104, 105, 107), and three commenced PR between 2 and 4 weeks after discharge, with most participants in these studies starting by Week 3 (96, 98, 102). Program duration ranged from 2 weeks to 24 months. Most used a combination of aerobic and resistance training; some included nonexercise components such as education, self-management training, smoking cessation, lifestyle advice, and psychological support.

Meta-analysis of 12 RCTs showed that PR initiated within 3 weeks of hospital discharge reduced hospital readmissions compared with control (odds ratio [OR], 0.48; 95% CI, 0.30 to 0.77; 1,309 participants) (Table E6). PR also improved exercise capacity measured by 6MWD (MD, 57.5 m; 95% CI, 28.7 to 86.3; 12 RCTs; 943 participants) and ISWD (MD, 42.6 m; 95% CI, 6.3 to 78.8; 5 RCTs; 560 participants). Mean changes in exercise capacity exceeded the MIDs for each test (59, 60). There was no significant difference between PR and controls in endurance shuttle walk test time (MD, 91.4 s; 95% CI, −43.0 to 225.7; three RCTs; 500 participants), and the mean change was less than the MID (111). Improvements were evident in HRQoL measured with the SGRQ total score (MD, −8.7 points; 95% CI, −12.5 to −4.9; nine RCTs; 888 participants), with the upper end of the CI exceeding the MID of −4 points (65). Little to no difference was observed for the COPD Assessment Test (MD, −2.0 points; 95% CI, −4.7 to 0.8; five RCTs; 533 participants) and the EQ-5D-5 L health status measure (MD, 0.04 points; 95% CI, −0.15 to 0.24; two RCTs; 60 participants). Improvements in dyspnea were evident for the mMRC dyspnea scale score (MD, −0.31 points; 95% CI, −0.48 to −0.14; nine RCTs; 798 participants) and the CRQ dyspnea domain (MD, 1.0 point; 95% CI, 0.3 to 1.7; four RCTs; 205 participants). PR had no significant effect on all-cause mortality (OR, 0.75; 95% CI, 0.47 to 1.20; nine RCTs; 995 participants). There were no intervention-related AEs during PR after hospital discharge (four RCTs, 229 participants).

The certainty of the evidence was moderate for the critical outcome of HCU and very low to moderate for other outcomes. The certainty of the evidence was affected by marked statistical heterogeneity (I^2 = 67% for the critical outcome of hospital readmission; I^2 = 59–99% for other outcomes) that could not be fully explained by our prespecified subgroup analyses for program components, length of follow-up, or risk of bias (A. R. Jenkins and colleagues, unpublished results). Certainty was also limited by performance and detection bias as well as imprecision in effect estimates.

Panel judgments. **Desirable consequences and their magnitudes (benefits):** For people who have had a recent hospitalization for AECOPD, we found consistent evidence that PR reduced HCU as measured by hospital readmissions (critical outcome). There were large improvements in important patient outcomes, including exercise capacity, HRQoL, and dyspnea, which often exceeded MIDs. There was no evidence that PR affected mortality, but studies were likely underpowered for this outcome. The panel noted in a large retrospective study of 197,376 Medicare beneficiaries that participation in PR within 90 days after hospital discharge for an AECOPD was associated with a lower risk of mortality at 1 year (hazard ratio, 0.63; 95% CI, 0.57 to 0.69) (9).

Undesirable consequences and their magnitudes (harms): We did not find any evidence of AEs during PR implemented after hospitalization for an AECOPD. One trial reported higher mortality at 12 months in an unsupervised PR group (108), but this effect was not evident when data were synthesized across trials in a meta-analysis (A. R. Jenkins and colleagues, unpublished results). There are well-documented challenges with low uptake of PR after an AECOPD (112–114), suggesting that some patients may not find PR acceptable at this time. Barriers to participation after hospitalization may include increased symptoms, reduced physical capacity, high levels of anxiety, and substantial travel burden (115).

ATS recommendation. For adults with COPD, we recommend participation in PR after hospitalization for an AECOPD (strong recommendation, moderate-quality evidence).

Rationale for the recommendation: The panel concluded that the balance of desirable and undesirable effects supports the use of PR for people with COPD who have recently been discharged after hospitalization for an exacerbation (Table E14). There is moderate-quality evidence for a reduction in hospital readmissions, as well as very low– to moderate-quality evidence for improvements in exercise capacity, HRQoL, and dyspnea. These outcomes are likely important to patients. The likelihood of undesirable effects is low. (Vote: 18 in favor, 1 against, 1 abstained.).

What others are saying: In 2017, the European Respiratory Society (ERS)/ATS guideline for the management of AECOPD made a conditional recommendation for initiation of PR within 3 weeks of hospital discharge, based on very low–quality evidence (92). Our updated systematic review identified additional RCTs, and, as a result, the certainty of the evidence was increased. The present guideline did not address the efficacy of PR initiated or delivered during a hospitalization for an exacerbation (before discharge) (92); hence, comparisons with the ERS/ATS guideline cannot be made in this regard. A recent systematic review that examined the safety of PR during the hospital admission period for an AECOPD reported improvements in exercise endurance and HRQoL, albeit with an increase in AEs (93).

Implementation considerations: There is limited information on the costs of delivering PR after hospital discharge. However, established programs that accept patients with stable COPD are also suitable for patients recovering from an exacerbation, which may reduce costs related to setting up new programs. Recent modeling based on U.S. Medicare data showed that in the year after COPD hospitalization, PR resulted in substantial cost savings of $8,226 (95% prediction interval, $5,348–$10,873) (116). Increased uptake of PR after an exacerbation may be enhanced by increasing HCPs' knowledge of its benefits and increasing access to programs, particularly in underserved areas (112, 113). Achieving patients' uptake of early posthospitalization PR is challenging. Patients who decline PR in the immediate postdischarge period should be offered PR again once their condition is stable, in keeping with PICO 1.

Values and preferences: This recommendation places a high value on reducing hospital admissions and improving exercise capacity, dyspnea, and HRQoL and a lower value on the burden of program attendance.

Research needs: Future research is needed to determine the optimal timing for initiation of PR after an AECOPD, as well as the impact of postexacerbation PR on other aspects of HCU and costs. Investigation into the role and safety of alternative models of PR (e.g., telerehabilitation) after hospitalization should be undertaken. Finally, the impact of PR after hospitalization

for other disease states (e.g., ILD and PH) warrants investigation.

Question 3: Should Adults with Interstitial Lung Disease Undertake Pulmonary Rehabilitation?

Background. ILDs are a diverse group of conditions with varying degrees of lung inflammation and/or fibrosis. ILDs, especially idiopathic pulmonary fibrosis (IPF), are characterized by a progressive decline in lung function, hypoxemia, and high mortality. Reduction in exercise capacity is a cardinal feature of ILDs and is frequently associated with exertional dyspnea, which may be profound. Those with the greatest reductions in exercise capacity have the worst HRQoL (117). Poor exercise capacity is also associated with worse survival (118, 119). Despite pharmacotherapies that may reduce disease progression in ILDs, few treatments improve symptoms, HRQoL, or physical function.

The prespecified critical outcome for this question was exercise capacity. Important outcomes were HRQoL, dyspnea, HCU, mortality, and AEs. When possible, we used data from a recently published Cochrane review to quantify treatment effects (10). We conducted a preplanned subgroup analysis including patients with IPF only.

Description of the evidence and its quality. We found 21 RCTs (909 participants) reporting the effects of PR versus usual care in people with a wide variety of ILDs, with mean FVC ranging from 55% to 86% predicted (10). The majority (18 studies) were outpatient programs, and 15 (83%) of 18 had a duration of 8–12 weeks. Most used a combination of aerobic and resistance training; some included nonexercise components such as education, nutritional advice, and psychological support.

Meta-analysis of 13 RCTs (10) showed that 6MWD increased after PR compared with control (MD, 40.07 m; 95% CI, 32.70 to 47.44; 585 participants), with the lower end of the CI exceeding the MID (59). Improvements in 6MWD were maintained at 6–12-month follow-up in comparison with the control group, but the CI was wider (MD, 32.43 m; 95% CI, 15.58 to 49.28; five RCTs, 297 participants). Between-group improvement in 6MWD was also evident in the subgroup with IPF at the end of rehabilitation (37.25 m; 95% CI, 26.16 to 48.33; eight RCTs, 278 participants); however, this was not maintained at 6–12 months (1.64 m; 95% CI, −24.89 to 28.17; three RCTs; 123 participants). Improvements were evident for other exercise capacity outcomes at the end of rehabilitation (peak work, peak $\dot{V}O_2$ [$\dot{V}O_2$peak]); however, fewer studies were available (Tables E7 and E8) (10).

HRQoL improved after PR compared with control regarding both SGRQ total score (SGRQ and IPF-specific SGRQ combined) (MD, −9.29; 95% CI, −11.06 to −7.52; 11 RCTs; 478 participants) and the CRQ dyspnea domain (MD, 0.68; 95% CI, 0.42 to 0.93; 5 RCTs; 321 participants), with the MD between groups exceeding the MID for both measures. Improvements in HRQoL were sustained at 6–12-month follow-up, but the magnitude was smaller (SGRQ total score MD, −4.93; 95% CI, −7.81 to −2.06; four RCTs; 240 participants). A similar between-group difference in HRQoL at the end of rehabilitation was seen in the IPF subgroup (SGRQ MD, −7.91; 95% CI, −10.55 to −5.26; six RCTs; 194 participants); however, this was not maintained at 6–12 months (MD, −3.45; 95% CI, −7.43 to 0.52; two RCTs; 89 participants).

Dyspnea (mMRC scale) improved in those who undertook PR in comparison with the control group, both at the end of rehabilitation (SMD, −0.36; 95% CI, −0.58 to −0.14; seven RCTs; 348 participants) and at 6–12-month follow-up (SMD, −0.29; 95% CI, −0.49 to −0.10; six RCTs; 335 participants). This represents a small to moderate effect size, with an SMD of −0.36 corresponding to −0.32 points on the mMRC scale. Similar effects were seen in the subgroup with IPF at the end of rehabilitation (SMD, −0.41; 95% CI, −0.74 to −0.09; four RCTs; 155 participants) and at 6–12-month follow-up (SMD, −0.38; 95% CI, −0.72 to −0.05; three RCTs; 123 participants).

In one RCT, there was no effect of PR on hospitalization for cardiorespiratory reasons over 30 months of follow-up (OR, 0.99; 95% CI, 0.29 to 3.39; 32 participants) (120). No effect of PR on mortality was evident during 6–12 months of follow-up (OR, 0.40; 95% CI, 0.14 to 1.12; four RCTs; 291 participants) (10). Limited data were available for these outcomes.

No AEs were noted in the 10 RCTs that reported AEs during training (adverse cardiovascular events, musculoskeletal injuries, and deaths). There was no between-group difference for deaths during the intervention period (OR, 0.51; 95% CI, 0.16 to 1.59; six RCTs, 376 participants).

The certainty of the evidence was moderate for the critical outcome of exercise capacity and low to moderate for other outcomes. The certainty of the evidence was affected by detection bias and small numbers of studies for some outcomes. For the subgroup with IPF, the certainty of the evidence was moderate for the critical outcome of exercise capacity at the end of rehabilitation and very low to moderate for other outcomes. The smaller number of studies available in IPF, particularly at long-term follow-up, affected the certainty of the evidence.

Panel judgments. **Desirable consequences and their magnitudes (benefits):** For people with ILD, we found consistent evidence that PR resulted in clinically important improvements in the critical outcome of exercise capacity at the end of rehabilitation, sustained for 6–12 months. Similar improvements were evident for patients with IPF but were not maintained at follow-up. Improvements in HRQoL and dyspnea were also clinically meaningful, both in all participants and in the subgroup with IPF. Few data were available to assess the effects on HCU or mortality. People with ILD reported that they valued the individualized program and expert monitoring and peer support and that their symptoms, establishment of and confidence in new exercise routines, self-management skills, and disease knowledge were improved after PR (121).

Undesirable consequences and their magnitudes (harms): We did not find any evidence of important AEs related to participation in PR for people with ILD. In a small qualitative study among people with ILD, those who chose not to attend PR did not believe it would help them or had fear of exercising; others reported that center-based PR was not accessible because of difficulties with travel and transport, scheduling, caring responsibilities, or being unwell (121).

ATS recommendation: For adults with ILD, we recommend participation in PR (strong recommendation, moderate-quality evidence).

Rationale for the recommendation: The panel concluded that the balance of desirable and undesirable effects support the use of PR in patients with ILD (Table E15). There is moderate-quality evidence supporting improvements in exercise capacity and low- to moderate-quality evidence for improvements in HRQoL and

dyspnea. These outcomes are likely important to patients. In the context of IPF and other fibrotic ILDs in which disease is progressive and 5-year mortality is high, these improvements may be particularly meaningful even if not sustained in the long term. The likelihood of undesirable effects is very low. (Vote: 19 in favor, 0 against, 0 abstained.).

What others are saying: In 2011, the ATS/ERS/Japanese Respiratory Society/Latin American Thoracic Society guideline for the diagnosis and management of IPF made a weak recommendation in favor of PR, with uncertainty regarding the duration of benefit (122). More recent updates to the Cochrane review (10) have demonstrated sustained benefits of PR at 6–12 months. Many other guidelines for IPF management also recommend PR (123–126). The Australian and New Zealand PR guidelines made a weak recommendation for this treatment in ILD, based on low-quality evidence (36). The certainty of evidence has increased since then, with a doubling of the number of RCTs of PR in ILD.

Implementation considerations: People with ILD often experience profound exertional oxygen desaturation. Consideration should be given to delivering PR in a setting in which supplemental oxygen can be administered during training. There is limited information on the costs of delivering PR for people with ILD. The costs will vary according to the PR model employed. For instance, costs are likely lower for outpatient PR (the most common model in the United States) than for inpatient rehabilitation. On the basis of data from two RCTs of outpatient PR conducted in Australia and Japan (127, 128), the National Institute for Health and Care Excellence clinical guideline for IPF (123) concluded that PR repeated every 6 to 12 months was cost-effective when compared with no PR.

Values and preferences: This recommendation places a high value on improving exercise capacity, dyspnea, and HRQoL and a lower value on burden of travel, cost, and inconvenience.

Research needs: The optimal delivery model of PR for patients with ILD has not been determined. Future research should examine whether exercise training strategies that reduce dyspnea and/or exertional oxygen desaturation (e.g., the use of high-intensity interval training or high-flow oxygen therapy) can achieve better outcomes. Moreover, further work is needed to determine whether there may be differential responses to PR among people with different types of ILD or those with different stages of disease. The impact of PR on ILD exacerbations and associated costs and survival should be evaluated. The role of alternative PR models (e.g., home-based or telerehabilitation models) for ILDs remains to be established.

Question 4: Should Adults with Pulmonary Hypertension Undertake Pulmonary Rehabilitation?

Background. Despite advances in medical therapies, many patients with PH, including those with pulmonary arterial hypertension (PAH; group 1 PH), continue to experience significant morbidity, including reduced exercise capacity with exertional dyspnea and poor HRQoL (129). Nonpharmacologic treatments such as PR are needed to reduce symptoms and improve HRQoL.

The prespecified critical outcome for this question was exercise capacity; important outcomes were HRQoL, dyspnea, New York Heart Association (NYHA)/World Health Organization (WHO) functional class, mortality, and AEs. When possible, we used data from a recently updated Cochrane review to quantify treatment effects (11). We conducted a preplanned subgroup analysis including patients with PAH only.

Description of the evidence and its quality. We found 14 RCTs (571 participants) reporting the effects of PR versus usual care in people with PH. Most participants had PAH or chronic thromboembolic PH (the vast majority were in functional class II or III; when reported, mean pulmonary artery pressure was 36 to 59 mm Hg). Five RCTs included an inpatient rehabilitation phase of 2–4 weeks, with most programs lasting 8–15 weeks. Most used a combination of aerobic and resistance training; some included respiratory muscle training, breathing techniques, and mind-body modalities such as yoga.

Meta-analysis of 11 RCTs showed that 6MWD increased after PR compared with control (MD, 48.52 m; 95% CI, 33.52 to 63.62; 394 participants; Table E9), with the lower end of the CI exceeding the MID (59). Improvement in 6MWD was also evident in the subgroup with PAH (63.97 m; 95% CI, 8.74 to 119.21; three RCTs; 71 participants; Table E10). Peak power increased in those undertaking rehabilitation compared with control (MD, 12.12 W; 95% CI, 3.70 to 20.55; five RCTs; 226 participants), with similar findings in the subgroup with PAH. $\dot{V}O_2$peak was also increased (MD, 2.06 ml/kg/min; 95% CI, 1.19 to 2.93; seven RCTs; 314 participants). No studies reported long-term effects on exercise capacity beyond the PR period.

HRQoL improved after PR compared with control on both the 36-item Short Form Health Survey (SF-36) Physical Component Score (MD, 4.20; 95% CI, 1.43 to 6.98; five RCTs; 187 participants) and the SF-36 Mental Component Score (MD, 3.71; 95% CI, 1.34 to 6.08; five RCTs; 186 participants). These changes exceed the MID proposed for patients with ILD (130); an MID for these HRQoL outcomes is not available for PH. Similar between-group differences in HRQoL after PR were seen in the subgroup with PAH (SF-36 Physical Component Score MD, 4.63; 95% CI, 0.80 to 8.47; two RCTs; 33 participants; SF-36 Mental Component Score MD, 4.17; 95% CI, 0.01 to 8.34; two RCTs; 33 participants). There were no studies reporting long-term effects on HRQoL beyond the PR period.

No studies reported the effect of PR on dyspnea. An improvement in NYHA/WHO functional class was evident in those who undertook PR in comparison with the control group (MD, −0.60; 95% CI, −0.85 to −0.35; two RCTs; 40 participants). No data were available for the subgroup with PAH.

Ten RCTs reported AEs during the intervention period (including mortality, disease progression and symptoms precluding training [illness, dizziness, syncope, or presyncope], with no difference between groups [risk difference, 0.01; −0.02 to 0.04; 391 participants]); AEs were often not clearly or systematically reported. No studies reported deaths in the exercise training group during the intervention or beyond the PR period.

The certainty of the evidence was low for the critical outcome of exercise capacity and moderate for other outcomes. The certainty of the evidence was affected by risk of bias (lack of allocation concealment, missing data) and substantial heterogeneity (⩾70%) for the critical outcome of exercise capacity. Subgroup analysis showed that heterogeneity was lower for outpatient programs than inpatient programs (53% vs. 81%), but the effect size was smaller for outpatient programs (change in 6MWD mean, 35 m vs. 69 m). For the subgroup with PAH, the certainty of the evidence was low to

moderate for the critical outcome of exercise capacity and moderate for other outcomes. The smaller number of studies available in PAH affected the certainty of the evidence.

Panel judgments. **Desirable consequences and their magnitudes (benefits):** For people with PH, including those with PAH, we found consistent evidence that PR delivered clinically important improvements in the critical outcome of exercise capacity at the end of rehabilitation. Mean improvements in HRQoL were clinically meaningful for the total group of participants and for the PAH subgroup. There were few data assessing effects on dyspnea, functional class, or mortality. People with PH report that they value components of PR (e.g., education about exercise and PH, undertaking supervised exercise sessions, psychological support) (131).

Undesirable consequences and their magnitudes (harms): In the context of clinical trials, we did not find any evidence that AEs occurred more frequently in participants with PH undergoing PR than in those in the control group. However, in a survey of 187 people with PH from 19 countries, 63% reported an AE during exercise, including chest pain, arrhythmias, dizziness, or hypotension (131). An uncontrolled study of inpatient rehabilitation reported that AEs occurred in 13.6% of 183 patients, with most being mild and not directly attributable to exercise training (132). These included syncope after training ($n = 2$), presyncope immediately after cycle training ($n = 1$), presyncope not associated with training ($n = 5$), supraventricular tachycardia during training that was self-limiting ($n = 2$), respiratory infection ($n = 14$), and minor hemoptysis ($n = 1$). It is likely that AEs may occur in some patients during PR, but these can be managed safely in the context of an appropriately supervised PR program.

ATS recommendation: For adults with PH, we suggest participation in PR (conditional recommendation, low-quality evidence).

Rationale for the recommendation: The panel concluded that the balance of desirable and undesirable effects supports the use of PR for patients with PH (Table E16). There is low-quality evidence supporting improvements in exercise capacity and low- to moderate-quality evidence for improvements in HRQoL. These outcomes are likely important to patients. The likelihood of undesirable effects is low in the context of a supervised PR program in which staff have expertise in PH. (Vote: 19 in favor, 0 against, 0 abstained.).

What others are saying: The 2019 ERS statement on exercise training and rehabilitation in patients with severe chronic PH reported that exercise training improves exercise capacity, muscle function, HRQoL, and possibly right ventricular function and pulmonary hemodynamics (133). The statement concluded that there was a strong need to establish specialized PR programs for people with PH to enhance access. The 2022 European Society of Cardiology and ERS guidelines for the diagnosis and treatment of PH (134) recommend supervised exercise training for patients with PAH who are stable clinically and receiving optimized pharmacological treatment.

Implementation considerations: Patients with PH should be stable while receiving optimized medical therapy before commencing exercise training in PR. People with WHO/NYHA class IV PH and those with severe hemodynamic impairment have infrequently been included in clinical trials; thus, the efficacy and safety of PR remain uncertain in these subgroups. Close monitoring during exercise is encouraged for patients with a history of arrhythmia, syncope or presyncope during exercise, including during the performance of exercise assessments such as the 6-minute-walk test (135). Telemetry should be considered for those with a history of arrhythmia. Supplemental oxygen should be provided as needed to maintain patients' oxygen saturation greater than 90% during exercise.

The components of PR for people with PH are similar to those used for other chronic lung and heart diseases (3, 136); thus, patients with PH could enroll in either pulmonary or cardiac rehabilitation programs. Inpatient rehabilitation programs may allow more intensive monitoring and supervision than outpatient programs; however, inpatient programs are not available in many countries, and patient preferences should be taken into account. It is likely that costs would be lower for outpatient PR (the most common model in the United States) than for inpatient rehabilitation.

Values and preferences: This recommendation places a high value on improving exercise capacity and HRQoL and a lower value on minor AEs, burden of travel, cost, and inconvenience for patients.

Research needs: Clinical trials examining the benefits of PR for people with PH associated with lung disease and/or hypoxemia or left heart disease are needed. Future trials should examine the safety and efficacy of PR for people with severe (WHO class IV) PH. Although dyspnea and fatigue are commonly reported symptoms in PH (131), existing RCTs have not examined these outcomes; this should be addressed in future trials. The impact of nonexercise PR components for individuals with PH is not yet known. Longer-term follow-up is required to assess the longevity of benefits and any impact of rehabilitation on time to clinical worsening or survival. The potential role of telerehabilitation to support remote delivery of supervised PR in people with PH remains to be explored.

Question 5: Should Adults with Chronic Respiratory Disease Undertake Telerehabilitation?

Background. Access to and uptake of center-based PR programs are limited globally because of an insufficient number of programs and staff (137), poor referral rates (26, 78), and patient-related barriers to attendance, including issues associated with travel and transport, poor understanding of what PR entails, comorbidities, and caring responsibilities (24, 26). COVID-19–related social distancing requirements have placed further limitations on the delivery of center-based PR (138).

In recent years, alternative models of PR delivery have emerged, particularly those making use of information and communication technologies to deliver PR remotely (telerehabilitation). Telerehabilitation may provide a PR option for patients who cannot otherwise attend a center-based program. A key challenge for using telerehabilitation is the ability of such programs to deliver the essential components of PR (82), including a comprehensive, face-to-face assessment and aerobic/resistance exercise training that is individually prescribed and progressed. Although telerehabilitation interventions for PR have been described in the literature (139–146), the clinical efficacy of such programs is not well understood. The prespecified critical outcome for this question was exercise capacity. Important outcomes were HRQoL, dyspnea, program completion, AEs, and HCU.

Description of the evidence and its quality. A recent Cochrane review (41) included five RCTs (139–143) and two controlled clinical trials (CCTs) (144, 145) comparing telerehabilitation with center-based PR in people with stable CRD (total 1,199 participants), 99% of whom had COPD. Participants in the included studies had a mean age ranging from 66 to 71 years and a mean FEV_1 ranging from 33% to 61% predicted.

The technological modalities employed to deliver telerehabilitation differed widely between studies and encompassed telephone calls (two RCTs; 418 participants) (142, 143), a purpose-designed website with (140) or without (139) telephone support (two RCTs; 193 participants), and videoconferencing (three studies [one RCT]; 588 participants) (141, 144, 145). In the two CCTs of telerehabilitation delivered via video conferencing, the intervention was delivered from a PR center to one or more remote healthcare sites using a "hub-and-spoke" model (144, 145); because of the CCT design, these studies could not be included in the meta-analysis. The degree of supervision of exercise training also varied between studies (in person, in real time, or minimal), as did the format (group vs. individual) and the location to which telerehabilitation was delivered (patient's home vs. healthcare facility). There was a lack of consistency in intervention duration and the duration of follow-up.

For the critical outcome of exercise capacity, a meta-analysis of four RCTs (556 participants) showed no difference between telerehabilitation and center-based PR in the magnitude of gains in 6MWD (MD, 0.06 m; 95% CI, −11 to 11) at the end of the intervention. At 12-month follow-up, there was no difference between intervention modalities for the 6MWD (MD, 1.40 m; 95% CI, −12.62 to 15.43; two RCTs, 308 participants).

There was no difference between telerehabilitation and center-based PR at the end of the rehabilitation intervention for improvements in the important outcomes of HRQoL (SGRQ total score MD, −1.26; 95% CI, −3.97 to 1.45; two RCTs; 274 participants) and dyspnea (CRQ dyspnea domain MD, 0.13; 95% CI, −0.13 to 0.40; three RCTs; 426 participants). There was also no difference between telerehabilitation and center-based PR for measures of HRQoL or dyspnea at 12 months of follow-up (Table E11). Participants were more likely to complete telerehabilitation than center-based PR (93% vs. 70%; OR, 5.36; 95% CI, 2.12 to 9.21; three RCTs; 516 participants). Clinically meaningful improvements in exercise capacity (endurance cycle test, endurance shuttle walk test, incremental shuttle walk test), dyspnea, and HRQoL were demonstrated for both telerehabilitation and center-based rehabilitation at the end of rehabilitation (within-group changes).

Six (85%) of the seven studies of telerehabilitation compared with center-based PR, including four RCTs, reported data on AEs (Table E11). AEs were similar for telerehabilitation and center-based PR. Reported AEs tended to be unrelated to rehabilitation and included hospitalizations and unrelated musculoskeletal injuries.

There was limited and inconsistent reporting of HCU. The likelihood of being hospitalized during the entire study period (from enrollment to completion of follow-up) was lower for telerehabilitation than for center-based PR (OR, 0.65; 95% CI, 0.43 to 0.99; three RCTs; 516 participants).

The certainty of the evidence was moderate for the critical outcome of exercise capacity, low for the outcomes of HRQoL and dyspnea, and not graded for the outcome of HCU (hospitalization). There was no important statistical heterogeneity (exercise capacity $I^2 = 0$–22% and HRQoL $I^2 = 0$–31%). The certainty of the effects was limited by the small number of studies and participants, as well as by the heterogeneity of telerehabilitation models.

Panel judgments. **Desirable consequences and their magnitudes (benefits):** For people with stable CRD, we found consistent evidence that improvements in the critical outcome of exercise capacity and the important outcomes of HRQoL and dyspnea were similar for telerehabilitation and traditional center-based PR (*see* PICO 1). Qualitative evidence suggests that patients value the benefits achieved with telerehabilitation, as well as the convenience and flexibility of being able to undertake rehabilitation in their own home (147, 148). People with COPD who have undertaken telerehabilitation describe feeling supported by staff and their peers, despite the remote and/or virtual nature of the interactions (147, 148). A high degree of satisfaction is reported with the technological components for those telerehabilitation models making use of more sophisticated equipment (149).

Undesirable consequences and their magnitudes (harms): There is no direct reported evidence of undesirable effects for patients undertaking telerehabilitation; available qualitative evidence suggests that patients view telerehabilitation favorably (147–149).

ATS recommendation: For adults with stable CRD, we recommend offering the choice of center-based PR or telerehabilitation (strong recommendation, moderate-quality evidence).

Rationale for the recommendation: The panel concluded that for individuals with stable CRD (the majority with COPD), the balance of desirable and undesirable effects does not favor one intervention (telerehabilitation or center-based PR) over the other for specific patient populations and outcomes tested to date (Table E17). There is moderate-quality evidence supporting similar improvements in exercise capacity (6MWD) and low-quality evidence supporting similar improvements in HRQoL and dyspnea. These outcomes are likely important to patients. Importantly, the current body of published evidence supporting the use of center-based PR for people with stable COPD is much larger (RCTs and other trials; *see* PICO 1) than that for telerehabilitation. We, therefore, suggest that telerehabilitation be considered as an alternate PR option and not as a replacement for center-based PR. Because of the heterogeneity of remote rehabilitation interventions studied, there is currently insufficient evidence to determine if one model of telerehabilitation is better than another. (Vote: 12 in favor, 2 against, 4 abstained.)

What others are saying: Because telerehabilitation has only recently emerged as a treatment intervention, no recommendations regarding its use for patients with CRD are available in other guidelines.

Implementation considerations: Reports of real-world application of telerehabilitation are emerging (144, 145, 150); however, these have primarily described low-cost programs requiring few resources. The feasibility of implementation of more resource-intensive programs, such as those requiring specialist equipment or infrastructure, web support, or smartphone application development, have not been widely described (151). Telerehabilitation programs implemented in clinical practice should follow well-defined PR intervention procedures that adhere to the essential components of PR, including center-based

patient assessments, before program commencement (82). Because some models of remotely supported telerehabilitation programs may result in lower-intensity supervision and exercise training, robust service audit and benchmarking processes for telerehabilitation are needed to ensure program efficacy.

Although telerehabilitation may improve access to PR services for some people, accessing healthcare delivered remotely might not be suitable for some people because of the need for equipment (phone, tablet, or computer), reliable internet access, costs, and the skills required to operate equipment and technology. A study in the United Kingdom found that 31% of people with COPD had never accessed the internet (152); this may vary geographically and over time. For some patient demographic groups, accessing health care delivered remotely may also be challenging, especially where telehealth is their only service option. In a large U.S. cohort study (148,042 participants), factors associated with lower use of video technology for health care included older age, lower household income, Black race, Latinx ethnicity, or being female (153). Moreover, special consideration may be required for individuals with vision or hearing impairment or balance issues or who require close physiological monitoring and/or lack home caregiver support.

There is very limited evidence on resource requirements (costs) of providing telerehabilitation or expenses that may be incurred by PR participants undertaking telerehabilitation. In one study of a low-cost telerehabilitation program delivered by telephone in Australia, the cost of program delivery was not different from that of center-based PR ($AUD298 [Australian dollars] vs. $AUD312) (142). There are no studies of resource requirements (costs) for telerehabilitation specific to the U.S. healthcare context. No data are available regarding costs for establishing and sustaining remote PR program models that require higher resources, such as those that use more advanced technology (e.g., videoconferencing).

Values and preferences: This recommendation places a high value on improving exercise capacity and HRQoL and a lower value on the burden of travel and inconvenience for attending center-based programs, acquisition of digital skills, and cost of participating in telerehabilitation.

Research needs: Telerehabilitation for PR is rapidly evolving. There is an urgent need for future research to establish optimal models of telerehabilitation and which patient characteristics (including living circumstances and familiarity with technology) are best suited to each delivery modality. The majority of studies of telerehabilitation compared with center-based PR have, to date, been undertaken in people with stable COPD. The effectiveness, safety, and acceptability of telerehabilitation after AECOPD and in CRD other than COPD remain to be determined. Trial designs may need to accommodate patient preference for the PR model, such as through cluster randomization at a program level. Most studies of telerehabilitation compared with center-based PR have had limited follow-up beyond the immediate rehabilitation period. Understanding the duration of benefits and factors contributing to benefits will be important to support the implementation of such models. The impact of telerehabilitation on other outcomes, including HCU, hospital readmissions, anxiety, depression, fatigue, self-efficacy, disease knowledge, and physical activity, merits study. There is currently limited evidence for the cost-effectiveness of low-technology models of telerehabilitation, and there are no studies of cost-effectiveness for higher-resource telerehabilitation models. Implementation of delivery models, long-term sustainability, and the associated economic impact of telerehabilitation need further investigation.

Question 6: Should Adults with Chronic Respiratory Disease Undertake Maintenance Pulmonary Rehabilitation?

Background. The benefits of PR for exercise capacity and HRQoL often diminish within 12 months of completing PR (154, 155). Maintenance programs, defined as ongoing supervised exercise at a lower frequency than that delivered in the PR program itself (36), have been proposed as a method of sustaining the benefits. There would be value in identifying acceptable, feasible, accessible, and cost-effective approaches to maintain the benefits of PR for people with CRD. However, there is currently no consensus on the optimal approach to sustain the gains made in PR in the long term. The evidence base supporting maintenance PR programs is growing, but heterogeneity of trial and intervention designs currently poses challenges for interpretation. There is therefore a need to clarify the effects of maintenance programs after PR.

The prespecified critical outcome for this question was exercise capacity; important outcomes were dyspnea, HRQoL, HCU, and AEs. We used two recently published systematic reviews to quantify treatment effects (42, 43).

Description of the evidence and its quality. In total, 21 RCTs comparing maintenance with usual care after initial PR were included in this evidence synthesis, with data also extracted from an additional report (156) of an included study (157). Of these, 15 RCTs (1,398 participants) were included in meta-analyses (67, 154, 155, 157–168), and 6 RCTs (401 participants) were narratively reported (169–174). Studies included stable patients with mild to very severe COPD; no studies including participants with other CRDs were included. The duration of interventions ranged from 4 weeks to 36 months. Because maintenance PR is a long-term intervention, data were included in meta-analyses for outcomes at 6–12 months. In-person supervision was provided in 11 studies, remote supervision in 6 studies, and a combination of in-person and remote supervision in 4 studies. Frequency of supervised exercise sessions varied from weekly to once every 3 months, with most studies ($n = 14$) offering supervision more frequently than once per month.

Meta-analysis showed that although 6MWD improved with maintenance PR compared with usual care, this did not reach statistical or clinical significance (MD, 25.9 m; 95% CI, −1.0 to 52.8; 10 RCTs; 639 participants). There were no effects of maintenance PR on ISWD (MD, 4.2 m; 95% CI, −44.9 to 53.2; two RCTs; 111 participants) or endurance shuttle walk test time (MD, 26.9 s; 95% CI, −60.6 to 114.3; five RCTs; 369 participants). Likewise, no significant effects were seen for peak work or $\dot{V}O_2$peak (Table E12).

CRQ dyspnea did not improve after supervised maintenance PR (MD, 0.3 points; 95% CI, −0.5 to 1.1; four RCTs, 210 participants). No other measures of dyspnea were evaluated in the analyzed studies.

HRQoL improved after supervised maintenance PR compared with usual care for CRQ total score (MD, 0.5 points; 95% CI, 0.0 to 1.0; four RCTs; 258 participants) as well as the domains of CRQ fatigue (MD, 0.4 points; 95% CI, 0.0 to 0.7; four RCTs; 210 participants), CRQ emotional

function (MD, 0.6 points; 95% CI, 0.2 to 1.0; four RCTs; 210 participants), and CRQ mastery (MD, 0.5 points; 95% CI, 0.1 to 1.0; four RCTs; 210 participants). The MD between maintenance PR and control met or exceeded the MID of 0.5 units for CRQ total score and the domains of emotional function and mastery (62). Maintenance PR had no effect on SGRQ total score (MD, −1.6 points; 95% CI, −4.9 to 1.8; five RCTs; 276 participants), or the domains of SGRQ symptoms (MD, −0.3 points; 95% CI, −6.3 to 5.7; four RCTs; 234 participants), SGRQ activity (MD, −2.6 points; 95% CI, −8.1 to 2.9; four RCTs; 234 participants), or SGRQ impact (MD, −2.1 points; 95% CI, −7.4 to 3.2; four RCTs; 234 participants).

Maintenance PR did not reduce the risk of respiratory-cause hospital admissions (risk ratio, 0.74; 95% CI, 0.41 to 1.37; four RCTs; 279 participants). No significant effects were reported for other aspects of HCU, including all-cause admissions or hospital length of stay. No AEs were noted in six RCTs (599 participants) that reported AEs during maintenance PR.

The certainty of the evidence was very low to low for the critical outcome of exercise capacity, very low for dyspnea, low to moderate for HRQoL, low for the outcome of HCU, and moderate for AEs. The certainty of the evidence was affected by risk of bias (performance, detection, and attrition bias), heterogeneity (exercise capacity I^2 = 0–67%; dyspnea I^2 = 82%; HRQoL I^2 = 0–68%), and imprecision (small numbers of studies and wide CIs).

Panel judgments. **Desirable consequences and their magnitudes (benefits):** For people with COPD, we found inconsistent evidence that maintenance PR improved exercise capacity and HRQoL at 6–12 months. The balance of effects tended to favor maintenance PR, but the number of studies was small. No AEs were evident. People with COPD report that they value the opportunity for ongoing, structured exercise after PR completion, with peer and professional support (175).

Undesirable consequences and their magnitudes (harms): Despite no evidence of AEs, the cost or burden of maintenance PR programs for patients (e.g., transport or time) should not be underestimated as potential undesirable consequences. Likewise, the cost of provision of maintenance programs could potentially reduce already limited available resources (financial and workforce) for providing primary/initial PR programs.

ATS recommendation: For adults with COPD, we suggest either supervised maintenance PR or usual care *after initial PR* (conditional recommendation, low-quality evidence).

Rationale for the recommendation: The panel concluded that the balance of desirable and undesirable effects may support the use of maintenance PR for people with COPD, but certainty is low (Table E18). There is low-quality evidence suggesting possible improvements in exercise capacity and low- to moderate-quality evidence supporting improvements in HRQoL. These outcomes are likely important to patients. The likelihood of undesirable effects is low. (Vote: 18 in favor, 0 against, 0 abstained.)

What others are saying: Our recommendation is consistent with the Australian and New Zealand PR guidelines (36), which reported insufficient evidence of a homogeneous nature to draw meaningful conclusions on the efficacy of maintenance PR. However, a previous British Thoracic Society guideline (34) made strong recommendations based on expert opinion for continuing exercise after PR, but the optimal approach was not detailed. The 2013 ATS/ERS statement on PR highlighted that developing ways to extend the effects of PR is an important goal (3).

Implementation considerations: After PR, all patients should be encouraged to participate in ongoing regular exercise, regardless of whether supervised maintenance PR is provided. The choice of maintenance PR or unsupervised exercise should be guided by patients' needs, capabilities, preferences, and local access to maintenance PR. There is a lack of information and understanding of optimal maintenance program content (e.g., including frequency of supervision and mode of delivery) as well as the associated costs. Expansion of currently established PR programs to include maintenance programs will require an increase in resources to enable expanded capacity. Access to primary/initial PR in the United States remains poor, with maintenance programs sparsely available and accessible only to those who have completed an initial PR program. The delivery mode and components of maintenance PR are likely to impact the acceptability and feasibility for patients.

Values and preferences: This recommendation places a high value on improving and maintaining exercise capacity and HRQoL as well as reducing dyspnea, but uncertainties exist regarding whether these will be consistently better achieved with structured maintenance PR.

Research needs: Existing data suggest that more than one supervised session each month is required (42); future research should determine the optimal frequency of supervised maintenance PR. There is a need to determine the optimal content of maintenance PR and the efficacy of alternate approaches to its provision, such as telerehabilitation. The role of repeat PR programs warrants further investigation (176). There is also a need to determine the effects of maintenance PR for individuals with CRDs other than COPD.

Discussion

In this CPG, we provide recommendations for PR for people with COPD that have been updated with current evidence (for patients who are clinically stable and in the postexacerbation period) and new recommendations for people with ILD and PH. We also provide recommendations regarding the use of telerehabilitation and maintenance PR. This CPG included six PICO questions that the panel considered critical to guide clinical practice.

Other important issues of great importance to patients, such as anxiety, depression, and fatigue have also been shown to improve after participation in PR (6, 10, 177–179) but were not addressed in this CPG. The reported impact of PR on individuals' daily physical activity levels (180) is an important area for continued study. Novel models of PR other than telerehabilitation were not specifically addressed. Moreover, although many of the published RCTs regarding PR focus on exercise training, PR is much more than exercise training alone. Although less easily proved, patient education (181) and health-enhancing behavior change are considered by PR experts to be essential components of PR to optimize patients' outcomes (3).

In 2015, the ATS/ERS policy statement proposed recommendations and actionable items to advance the implementation, use, and delivery of PR (22). A subsequent ATS workshop on defining modern PR (82)

elucidated the essential components of PR and the potential roles of different PR program models. A "one size fits all" approach to PR is not optimal, given that people with CRDs have widely varying symptoms; disease severity; comorbidities; and physical, functional, psychological, and social impacts of their disease. Further work is required to understand how precision medicine using a "treatable traits" approach in PR could optimize patient outcomes (182–184), including which type of PR program model is optimal for individual patients. Shared decision making between patients and HCPs will remain key to optimizing PR uptake and helping to solve barriers to patients' participation. The availability of a choice of PR model will depend on the widespread implementation and resourcing of a spectrum of models and on furthering advocacy and health system policy related to PR.

Funding for PR varies across health systems. In the United States, extremely low reimbursement rates are provided by the Centers for Medicare and Medicaid Services and other third-party payers (185). This poses an existential threat to many center-based PR programs and does not allow program expansion to help accommodate those in need of PR services (including those with post–COVID-19 syndrome). Despite widespread use of telehealth during the SARS-CoV-2 pandemic, there is still no set infrastructure in the United States for implementation of novel models of PR such as telerehabilitation that could help to improve patient access.

Conclusions

The evidence presented in this CPG highlights the important role of PR in evidence-based health care for patients with COPD, ILD, and PH. Given the proven benefits of PR as articulated in this CPG and elsewhere, and to improve the development of an appropriate widespread infrastructure of varying models of PR, we believe that continued dialogue between HCPs, patients, third-party payers, health system administrators, and other policy makers regarding healthcare funding is a priority. We seek to foster PR program access, encourage enhancement of HCPs trained in the discipline of PR, and implement newer models of PR beyond the research setting while maintaining essential components and optimal standards of care for PR programs (82) to further improve the care of patients with CRD. HCPs, patients with CRDs, and the general public are encouraged to collaborate in ongoing advocacy efforts to meet these goals.

Authors' Note

The ATS Quality Improvement and Implementation Committee reviewed the guideline and determined that recommendations 1 through 3 are potentially suitable for performance measure development. A performance measure relating to HCPs' referrals of appropriate patients with stable COPD to PR (as addressed in PICO 1) is already under development by the Quality Improvement and Implementation Committee in collaboration with the ATS Assembly on Pulmonary Rehabilitation. ■

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