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Defining Modern Pulmonary Rehabilitation

An Official American Thoracic Society Workshop Report

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Abstract

Pulmonary rehabilitation is a highly effective treatment for people with chronic lung disease but remains underused across the world. Recent years have seen the emergence of new program models that aim to improve access and uptake, including telerehabilitation and low-cost, home-based models. This workshop was convened to achieve consensus on the essential components of pulmonary rehabilitation and to identify requirements for successful implementation of emerging program models. A Delphi process involving experts from across the world identified 13 essential components of pulmonary rehabilitation that must be delivered in any program model, encompassing patient assessment, program content, method of delivery, and quality assurance, as well as 27 desirable components. Only those models of pulmonary rehabilitation that have been tested in clinical trials are currently considered as ready for implementation. The characteristics of patients most likely to succeed in each program model are not yet known, and research is needed in this area. Health professionals should use clinical judgment to determine those patients who are best served by a center-based, multidisciplinary rehabilitation program. A comprehensive patient assessment is critical for personalization of pulmonary rehabilitation and for effectively addressing individual patient goals. Robust quality-assurance processes are important to ensure that any pulmonary rehabilitation service delivers optimal outcomes for patients and health services. Workforce capacity-building and training should consider the skills necessary for emerging models, many of which are delivered remotely. The success of all pulmonary rehabilitation models will be judged on whether the essential components are delivered and on whether the expected patient outcomes, including improved exercise capacity, reduced dyspnea, enhanced health-related quality of life, and reduced hospital admissions, are achieved.

Keywords: lung diseases/rehabilitation; pulmonary disease; chronic obstructive/rehabilitation; healthcare quality; access and evaluation

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Overview

The American Thoracic Society (ATS) Workshop on Defining Modern Pulmonary Rehabilitation was held at the ATS International Conference on May 17, 2019. The workshop addressed the emergence of new pulmonary rehabilitation models that aim to enhance access and uptake, including telerehabilitation and home-based models. The objectives of the ATS workshop were to *1*) achieve consensus on the essential components and outcomes of pulmonary rehabilitation, *2*) provide a framework to support adoption of evidence-based emerging pulmonary rehabilitation models by policy-makers and payers, and *3*) identify practical requirements for successful implementation of emerging pulmonary rehabilitation models. Before the workshop, experts in pulmonary rehabilitation from around the world were invited to contribute to a Delphi process to achieve consensus on essential program components. Key findings of the Delphi process and workshop were as follows:

- The current definition of pulmonary rehabilitation from the 2013 ATS/European Respiratory Society (ERS) statement remains relevant, providing flexibility to deliver programs across a variety of settings.
- Only those emerging pulmonary rehabilitation models that have been tested in clinical trials should currently be considered for implementation.
- There are 13 essential components of pulmonary rehabilitation that should be delivered in any program model, encompassing patient assessment, program content, method of delivery, and quality assurance.
- Desirable components of pulmonary rehabilitation were also identified, the delivery of which may depend on local resources, health-system organization, and individual patient needs, goals, and preferences.
- The future of pulmonary rehabilitation will involve more choices for patients and greater personalization of programs.
- Personalization is guided by a comprehensive patient assessment, a key element of all pulmonary rehabilitation programs.
- Regular clinical audits of pulmonary rehabilitation processes and outcomes are important for documenting clinical effectiveness and efficiency.
- Accreditation and certification programs should ensure that the outcomes of alternative models are assessed using the same standards as conventional center-based pulmonary rehabilitation programs.
- There are insufficient data to determine the characteristics of patients most likely to succeed in different models of pulmonary rehabilitation; clinical judgment should be used to identify those patients who remain best served by a center-based, multidisciplinary approach.
- Successful implementation will be judged by whether the essential components of pulmonary rehabilitation are delivered and by whether the expected outcomes are achieved.

Background

Pulmonary rehabilitation is a cornerstone of treatment for people with chronic respiratory diseases (1–5). The pulmonary rehabilitation model has conventionally consisted of supervised exercise training, education, self-management strategies, and support delivered to groups of patients at least twice a week for 8 weeks or longer in either an inpatient or outpatient setting by a multidisciplinary team. There is level 1 evidence supporting the benefits of pulmonary rehabilitation for chronic obstructive pulmonary disease (COPD), including improved exercise capacity, reduced dyspnea, enhanced health-related quality of life, and reduced hospital admissions (6, 7). There is also growing evidence for the efficacy of pulmonary rehabilitation to improve similar outcomes in other conditions, including interstitial lung disease (3), bronchiectasis (4), and pulmonary hypertension (5). Pulmonary rehabilitation is particularly effective in patients with COPD who suffer from severe exacerbations, in whom the benefits of this therapy include significant reductions in hospital admission and likely include improved survival (7, 8). Despite these important benefits, pulmonary rehabilitation is grossly underused worldwide, with data from the United States and Canada demonstrating that less than 5% of eligible individuals ever undertake a program (9, 10). To address this implementation failure, the ATS and ERS published a policy statement in 2015 on "Enhancing Implementation, Use and Delivery of Pulmonary Rehabilitation" (11). Among its recommendations, the ATS/ERS policy statement calls for "novel pulmonary rehabilitation program models that will make evidence-based pulmonary rehabilitation more accessible and acceptable to patients and payers."

The challenge of developing and testing novel program models has been taken up by the pulmonary rehabilitation research community. Recent publications have provided new evidence on the effects of new pulmonary rehabilitation models, such as telerehabilitation (12); low-cost, home-based models (13, 14); and Web-enabled pulmonary rehabilitation (15). Some of these trials, powered for noninferiority and using robust methods, have demonstrated outcomes that are similar to those of traditional center-based pulmonary rehabilitation (13, 15). As a result, there is increasing clinical interest and implementation around the world. Although increasing the capacity of traditional center-based programs is surely an avenue forward, there is value in new models that widen access and increase participation in pulmonary rehabilitation. This became acutely apparent during the beginning of the coronavirus disease (COVID-19) pandemic, when center-based programs worldwide were rapidly closed down to reduce the risk of viral spread among participants, and many programs attempted a rapid transition to home-based or telehealth models. However, there is little information about how best to deliver these models in a clinical setting. To support the rollout of emerging models of pulmonary rehabilitation in routine service provision, it is important to define the key characteristics required for a program to be considered "pulmonary rehabilitation", in order to understand its evidence base, and to increase the confidence of a successful outcome for the individuals who participate. Expected outcomes of pulmonary rehabilitation are improvements in dyspnea, quality of life and exercise tolerance, and, for patients with COPD, a reduction in hospital admissions (16).

Although the potential of emerging pulmonary rehabilitation models to improve access and enhance health equality is substantial, it must be acknowledged that the adoption of new pulmonary rehabilitation models comes with some risk for patients, providers, and payers in relation to maintenance of high-quality outcomes. The process and outcomes of traditional center-based rehabilitation have been carefully defined in international statements and guidelines (16, 17). As a result, the standard of care is relatively consistent across programs, and the outcomes of pulmonary rehabilitation are meaningful for patients and the health system (18). There will be no value in diluting such an effective intervention to improve access. Currently, there is no agreement regarding the role of emerging pulmonary rehabilitation models, the training and implementation requirements for healthcare providers, or the quality-assurance requirements to ensure that implementation is successful. A new approach to the future of pulmonary rehabilitation is needed, which acknowledges the development and adoption of emerging models, defines essential and desirable components, and ensures that the quality of outcomes is maintained.

The overall objectives of this ATS workshop were to *1*) achieve consensus on the essential components and outcomes of pulmonary rehabilitation, *2*) provide a framework to support adoption of evidence-based emerging pulmonary rehabilitation models by policy-makers and payers, and *3*) identify practical requirements for successful implementation of emerging pulmonary rehabilitation models.

Methods

The workshop proposal was approved and funded by the ATS Board of Directors. The 17-member workshop committee comprised a patient representative and an interdisciplinary group of clinicians and researchers from the United States, Australia, Canada, and Western Europe. Disciplines represented on the committee were pulmonary medicine, primary care medicine, nursing, physical therapy, and respiratory therapy. Participants were selected on the basis of academic work in the area of pulmonary rehabilitation, clinical or research experience with a variety of pulmonary rehabilitation models across different healthcare systems, or international leadership in pulmonary rehabilitation in professional societies. Our patient representative provided input through all stages of the process, including design of the workshop proposal, review of the Delphi findings, provision of content for the workshop meeting focused on the valued components of pulmonary rehabilitation from the perspective of participants, and review of the workshop report. Potential conflicts of interest were disclosed and managed in accordance with the policies and procedures of the ATS.

Before the workshop and to inform the workshop discussions, we invited 100 pulmonary rehabilitation experts from across the world to take part in an online Delphi process. Experts were identified through scientific publications and leadership roles in international societies, ensuring a variety of disciplines, geographical locations, and perspectives on the new models. The areas of expertise of invitees included pulmonary medicine, gerontology, palliative care, primary care, exercise physiology, physical therapy, respiratory therapy, nursing, occupational therapy, dietetics, educational delivery, and psychology. Respondents were from a wide range of geographical areas, with the majority being from North America and Europe (*see* Table E1 in the online supplement), including 54 respondents in round 1 and 47 respondents in round 2. Respondents were asked to rate the importance of a wide range of aspects of pulmonary rehabilitation, including program components, assessments, supervision and support, program location, and quality assurance (*see* online supplement for survey). The items for round 1 were generated on the basis of the description of pulmonary rehabilitation components in the ATS/ERS Pulmonary Rehabilitation Statement (16), together with additional items to reflect newer program models and quality-assurance requirements derived from recent publications (12–15) and established quality-assurance processes (18). Participants were asked to rate their agreement about whether each aspect is an essential feature of pulmonary rehabilitation on a 5-point Likert scale (1–5), using "strongly agree" = 1, "agree" = 2, "neutral" = 3, "disagree" = 4, and "strongly disagree" = 5 as anchors. Items with a median score of $\leqslant 2$ and high consensus (interquartile range [IQR], 0) were considered as essential components of the pulmonary rehabilitation model. Items with a median score of $\geqslant 4$ and high consensus (IQR, 0) were eliminated. Items without consensus were included in the second round, in which respondents were presented with the first-round scores and invited to rescore the items. Participants in round 1 were also asked to nominate any additional items that they considered to be critical elements of pulmonary rehabilitation by answering the question "Are there any other

critical features of pulmonary rehabilitation that have not been specified here?" Respondents were invited to rate these additional items in a second round of the Delphi process.

The workshop was convened in Dallas, Texas, on May 17, 2019. Speakers (A.E.H., S.J.S., R.Z., N.S.C., L.H.-W., C.G., C.L.R.) outlined the challenges for access and uptake of pulmonary rehabilitation across the world; patient perspectives on current and emerging pulmonary rehabilitation models; results of the Delphi process, highlighting areas of consensus and areas in which consensus was not reached; quality-assurance requirements for pulmonary rehabilitation; and how the current definition of pulmonary rehabilitation might apply to emerging models. Each talk was followed by discussion among the entire panel of participants. The purpose of this workshop was not to perform a literature review regarding the efficacy of individual models, which is available elsewhere (19), but rather to achieve consensus on essential components and outcomes that could be applied to any pulmonary rehabilitation model, either existing or emerging in the future.

The initial draft of the workshop report was authored by the co-chairs and speakers. The other workshop members then reviewed and edited the draft report. The workshop report underwent several cycles of external peer review and revisions, followed by review and approval by the ATS Board of Directors.

The Definition of Pulmonary Rehabilitation

The ATS/ERS Pulmonary Rehabilitation Statement (2013) defines pulmonary rehabilitation as "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 chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors" (16). This definition has been very useful for highlighting the aims of pulmonary rehabilitation, some of its important components, and the central role of behavior change. It is a conceptual definition and thus does not identify the specific structure, setting, and supports that are required for pulmonary rehabilitation models to succeed. The definition was developed at a time when pulmonary rehabilitation programs in North America and Europe were almost entirely center based, with less than 4% of programs delivered in other settings (20). The workshop committee was invited to consider this definition in light of more recent developments in the science and practice of pulmonary rehabilitation.

The workshop committee agreed that the 2013 definition of pulmonary rehabilitation was still relevant (16), providing the flexibility to deliver programs across a variety of settings. There was consensus among the committee members that the definition should be complemented by clearer guidance on the essential features that must be included in a pulmonary rehabilitation program. Consistent with the recommendations of the Pulmonary Rehabilitation Policy Statement (11), the committee emphasized the need for clear metrics to demonstrate the quality of a pulmonary rehabilitation program, as demonstrated by success in improving patient outcomes. The committee used data from the Delphi process to inform development of these metrics.

The Problem: Poor Access and Uptake of Pulmonary Rehabilitation across the World

The concepts of "access," "uptake," and "completion" are key to the challenges facing pulmonary rehabilitation programs around the world. Although these terms are often used interchangeably, they highlight different obstacles to delivery of pulmonary rehabilitation. Table 1 provides definitions and suggests potential metrics that could be used by individual programs and jurisdictions to measure these important concepts.

Table 1. Key concepts and definitions for pulmonary rehabilitation: access, uptake, and completion

	Definition	Potential Metrics
Access	Are eligible patients offered a pulmonary rehabilitation program?	Number of programs available per geographical area/population. Percentage of eligible patients who are referred
Uptake	Do patients take up the offer of rehabilitation?	Percentage of referred patients who attend a pulmonary rehabilitation assessment. Percentage of referred patients who attend at least one session
Completion	Do patients finish the rehabilitation program?	Percentage of patients attending 70% of sessions. Percentage of patients attending a discharge assessment

Access refers to the availability of pulmonary rehabilitation to patients who would benefit, encompassing the existence and accessibility of programs, inclusion and exclusion criteria, and referral practices. Most of the data on access to pulmonary rehabilitation focus on patients with COPD. In the United States, it has been found that less than 4% of Medicare beneficiaries with COPD have access to pulmonary rehabilitation (9) and that only 1.9% of those recently hospitalized for an exacerbation of COPD attend rehabilitation within 6 months of discharge (21), despite the recommendation to do so (22). In Canada, less than 1% of those with COPD have access to a program (10). There are also geographical disparities in access to programs in the United States and Canada, with fewer available in rural areas (10, 23).

Since 2015, there have been a series of audits to examine the provision of rehabilitation against the British Thoracic Society (BTS) guidelines (17) and associated quality standards (24). The first organizational audit report (25) found that 68,000 patients were referred for pulmonary rehabilitation in the audit time period, 15% of those eligible. The most recent audit report (18) highlights that, contrary to current evidence (22), 29% of programs do not offer postexacerbation rehabilitation,

5% exclude smokers, and 5% exclude patients with diagnoses other than COPD.

Poor awareness and knowledge of pulmonary rehabilitation by healthcare professionals is a major barrier to patient referral (11). A primary care physician survey in the United States in 2016 found that 12% of physicians did not know if pulmonary rehabilitation was available in their area and that 33% rarely or never referred to the service (26). Data from the United Kingdom indicate that after a COPD exacerbation, suitability for rehabilitation is assessed in 44% of patients at hospital discharge, and only 15% of patients are referred to a program (27). Referral is also influenced by the perceptions of the health professional regarding likely benefit or harm, inadequate information about how to make a referral, perceived waiting-list time, and the administrative burden of referral (28).

Uptake is whether an eligible patient accepts the offer of pulmonary rehabilitation. This is usually assessed as the percentage of those referred who attend an initial assessment at the pulmonary rehabilitation center. In the United Kingdom, 31 of every 100 patients referred do not ever attend an assessment (29). Similarly, after an exacerbation of COPD, 33% of patients referred to pulmonary rehabilitation never commence the program (27). Uptake is heavily influenced by patient perspectives, including beliefs and expectations regarding pulmonary rehabilitation and physical challenges of program attendance (28). Cultural background may also have an important influence on beliefs and expectations regarding pulmonary rehabilitation, and a lack of culturally responsive rehabilitation models may adversely affect uptake (30). Patient perspectives that may influence uptake of pulmonary rehabilitation are discussed in more detail in a following section.

Completion is whether a patient finishes a pulmonary rehabilitation program. It is usually defined as either attendance at a predefined number of sessions or attending a discharge assessment. The BTS audit indicates that of those patients who attend an initial assessment, 62% complete the program (18). After a COPD exacerbation, a similar proportion complete pulmonary rehabilitation (63%) (27). Survey data show that health professionals estimate median completion rates of 75–90% (20). Although this may overestimate completion rates (31), these data suggest that once patients commence a program, the majority will be retained to the end. The BTS currently tasks pulmonary rehabilitation providers with achieving completion rates of at least 70% (18), indicating that there is still room for improvement. Completion is influenced by practical factors such as travel, transport, car parking, and cost of attendance as well as by patient-related factors such as physical disability, illness, depression, and smoking status (28).

There remain gaps in our knowledge of these important issues. Access, uptake, and completion of pulmonary rehabilitation in most low- and middle-income countries are largely unknown but are likely to be low, as programs are less frequently available (32). Although the problem of underuse of pulmonary rehabilitation has been better documented in high-income countries, interventions to improve the situation are only starting to be developed. A systematic review of interventions to improve uptake and completion of pulmonary rehabilitation, published in 2017, found only one randomized study that was eligible for inclusion (33). A subsequent systematic review included 14 studies with a wider range of designs, most of which evaluated referral or uptake of pulmonary rehabilitation in the context of broader programs aimed at improving evidence-based management of COPD (34). Although some improvements were demonstrated, particularly for referral, the variety of interventions and high risk of bias prevented the authors from making recommendations for clinical practice. There remains a dearth of high-quality evidence regarding strategies to improve awareness and knowledge among health professionals, which are key contributors to poor access.

Why Do We Need Innovation in Pulmonary Rehabilitation?

Novel models of pulmonary rehabilitation could address many of the patient-related and system-related barriers to participating in pulmonary rehabilitation, including improvements to access (e.g., reducing geographical restrictions to eligibility for center-based programs using remotely delivered models), uptake (allowing patient preference for home-based care, reducing barriers related to travel and disability) and completion (decreasing the cost and burden of attendance, enabling continuing participation despite fluctuations in symptoms and functional status). However, the potential benefits go beyond access, uptake, and completion. The development of a range of new models is well aligned with contemporary principles of person-centered care and personalized medicine, in which treatment choices are made on the basis of an individual's characteristics and preferences. The availability of multiple effective models may allow patients to be offered the program in which they are most likely to succeed, which could vary according to factors such as disease stage, comorbidities, psychosocial features, digital literacy, and patient choice. Novel forms of pulmonary rehabilitation may also facilitate inclusion of newer technologies. In addition to the delivery of rehabilitation via teleconferencing and apps, there is now the opportunity to incorporate wearables (e.g., for physical activity) and remote monitoring. Novel models also offer the opportunity to embed innovations in education delivery and behavioral change in pulmonary rehabilitation.

Traditional and Emerging Models of Pulmonary Rehabilitation

In 2015, the ATS/ERS policy statement challenged the pulmonary rehabilitation community to conduct research that tested alternative models of providing pulmonary rehabilitation (11). It states that "adoption of alternative models for pulmonary rehabilitation will require demonstration of comparable or greater clinical outcomes to those of traditional pulmonary rehabilitation programs, as well as evaluation of safety and cost-effectiveness, staff training and guideline development." Since then, a number of clinical trials have provided data on the safety and clinical outcomes of program models, including home-based rehabilitation; telerehabilitation; interactive, Web-based models; combined heart failure/pulmonary rehabilitation models; and programs requiring minimal resources (Table 2). These programs have all included the key components of exercise training, education, and behavior change (16), and the committee thus considered that they met the

Table 2. New models of PR that have been tested in clinical trials: definitions and descriptions

Model	Definition	Description of Studies						
		Number of RCTs	Location of Studies	Key Components	Comparison	Total Participants	Intervention Group Participants	Comparison Group Participants
Home-based PR	Majority/all of PR program undertaken in patient's own home. May or may not include home visits from healthcare professional and/or telephone support. May or may not require specific equipment (e.g., cycle ergometer)	*N* = 13	Including Australia, Spain, Canada, Brazil, the Netherlands, Egypt	Duration range, 4 wk to 18 mo. May or may not include in-person supervision at home or telephone support	No rehab control: *n* = 7 studies (61–67). Center-based PR: *n* = 4 studies (13, 35, 68, 69). *n* = 2 studies had 2 comparison groups (no rehab control and center-based PR) (70, 71)	*N* = 961	*n* = 463	*n* = 498
Telerehabilitation	The use of information and communications technology, including text messaging and video communication, to provide rehab at a distance. Contains some degree of two-way interaction between patient and healthcare professional. May be delivered to the patient's home, to a healthcare facility, or in the community	*N* = 4	Canada, Australia, Italy, Greece	Duration range, 8 wk to 12 mo. Two studies of maintenance rehab. *n* = 3 delivered into home; *n* = 1 delivered to community center	No rehab control: *n* = 2 studies (12, 72). Center-based PR: *n* = 2 studies (73, 74). *n* = 1 study had 2 comparison groups (no rehab control and center-based PR) (75)	*N* = 704	*n* = 269	*n* = 435
Web-based rehabilitation	Computer tailored intervention offering a "menu" or "suite" of modules for participants to work through, usually independently. Access to advanced modules may be predicated by completion of earlier/preparatory tasks	*N* = 4	UK, the Netherlands	Duration range, 6 wk to 12 mo. Web-based application for access on computer or tablet	No rehab control: *n* = 1 study (76). Center-based PR: *n* = 2 studies (15, 77). Equivalent intervention provided on paper material *n* = 1 study (78)	*N* = 383	*n* = 237	*n* = 146

(Continued)

Table 2. (*Continued*)

Model	Definition	Description of Studies						
		Number of RCTs	Location of Studies	Key Components	Comparison	Total Participants	Intervention Group Participants	Comparison Group Participants
Community PR	Supervised group exercise and/or education undertaken in a community-based location—often in a nonhealthcare facility (neither in a hospital nor at the patient's home)	*N* = 8	UK, the Netherlands, Denmark, Australia, Ireland, U.S.	Duration range, 6 wk to 20 mo. Exercise and education rehab delivered within community-based setting near patient's home	No rehab control: *n* = 6 (79–84). Center-based PR: *n* = 2 studies (85, 86). Other community intervention *n* = 1 study (86)*	*N* = 1,008	*n* = 503	*n* = 505
Primary care PR	Program of education and/or exercise delivered by staff within the primary care setting	*N* = 3	Ireland, Hong Kong, Australia	Duration range, 6 to 8 wk. Interventions included home-based rehab accessed from primary care; standard education PR delivered at GP clinic or local center; PR plus Tai Chi	No rehab control: *n* = 2 studies (87, 88). Center-based PR: *n* = 1 study (89)	*N* = 758	*n* = 373	*n* = 385
PR using minimal equipment	Use of practical, everyday objects rather than exercise/gym equipment, with referral and delivery processes tailored to local cultural requirements. May or may not include routine supervision	*N* = 5	Spain, Australia, Austria, Sweden	Duration range, 8 wk to 12 mo. Included community walking; use of a pedometer; ground-based walking; Nordic walking; resistance bands	No rehab control: *n* = 5 studies (36, 90–93)	*N* = 687	*n* = 366	*n* = 321
Breathlessness rehabilitation	Addresses the symptom-based needs of people with CHF and/or COPD in the same program. Comprises both exercise and nonexercise interventions	*N* = 2	UK, Italy	Duration range, 8 wk to 4 mo	No rehab control: *n* = 2 studies (72, 94)†	*N* = 224	*n* = 93	*n* = 131

Definition of abbreviations: CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; GP = general practitioner; PR = pulmonary rehabilitation; RCT = randomized controlled trial; rehab = rehabilitation; UK = United Kingdom; U.S. = United States.

Data represent an overview of models sourced from published systematic reviews and clinical guidelines (16, 17, 50, 95–97) and do not represent a comprehensive review of current literature.

*Study had a center and alternate community comparisons.

†One study had additional rehab comparator group with COPD.

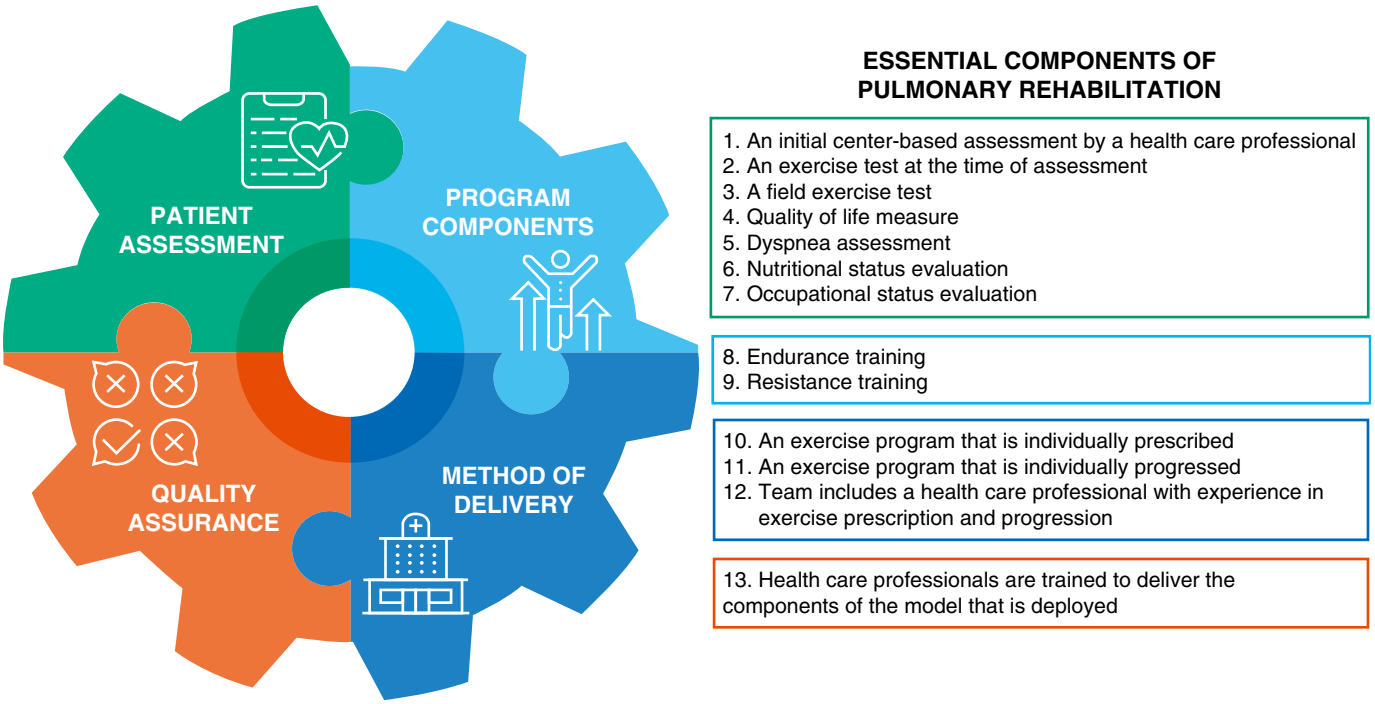

Figure 1. Essential components of pulmonary rehabilitation. Essential components of the pulmonary rehabilitation model were identified through a Delphi process. An essential component was defined as having a median score ⩽2 (strongly agree or agree it is essential) and high consensus (interquartile range, 0).

definition of pulmonary rehabilitation. The committee considers that it is only those models that have been tested in clinical trials that should currently be considered for implementation, and the recent acceleration of clinical trial publications related to new pulmonary rehabilitation models confirms that such an approach is feasible (Table 2). However, these models vary enormously with regard to features often considered important in pulmonary rehabilitation, including content and mode of delivery, exercise modality, exercise dose, degree of supervision, group versus individual delivery, access to a multidisciplinary team, provision of formal/structured education, self-management training, and psychosocial support offered. Some new program models are more "comprehensive" than others; those that require internet access and specialist equipment (e.g., pulse oximeters, exercise bikes) may be better suited to well-resourced healthcare settings (12, 35), whereas simpler, low-cost models such as those using minimal equipment and relying only on a telephone may be more feasible to implement in low-resource settings (13, 36). As new models are adopted into practice, they will inevitably be adapted to local contexts, potentially giving rise to even greater variation. As a result, there is a need for clear guidance regarding which programs do, or do not, constitute pulmonary rehabilitation to ensure that patients, health professionals, payers, and policy-makers can make informed decisions. The Delphi process was specifically designed to achieve consensus on this topic.

The committee agreed that interventions that are solely focused on physical activity promotion (for instance those focused on increasing daily steps, often including a wearable device for motivation and feedback) are valuable but do not meet the definition of pulmonary rehabilitation. The committee acknowledged that improving physical activity and reducing sedentary behavior are very important for people with chronic respiratory conditions and that physical activity interventions may achieve positive outcomes (37, 38). However, these interventions do not include the key components of pulmonary rehabilitation (endurance and resistance exercise training, education, and comprehensive support for behavior change) or address its goals (improving both physical and psychological health, enhancing adherence to a range of health behaviors). Although physical activity reflects any movement performed in daily life that requires energy expenditure, exercise training is planned, structured, and repetitive and has the aim of improving or maintaining physical fitness; this is a key component of the pulmonary rehabilitation model and underpins many of its benefits (16). Physical activity interventions have an important role for some patients but are not considered a substitute for a comprehensive pulmonary rehabilitation program, which more thoroughly addresses the needs and goals of individuals living with moderate-to-severe chronic respiratory disease. The committee acknowledged that pulmonary rehabilitation programs have often had only a modest effect on physical activity in daily life (39), and a combination of strategies may be needed.

Patient Perspectives on Traditional and Emerging Models of Pulmonary Rehabilitation

There is a complex interaction between patient and healthcare system factors that influence the feelings, attitudes, and behaviors of patients regarding center-based pulmonary rehabilitation. For people who have successfully completed a center-based

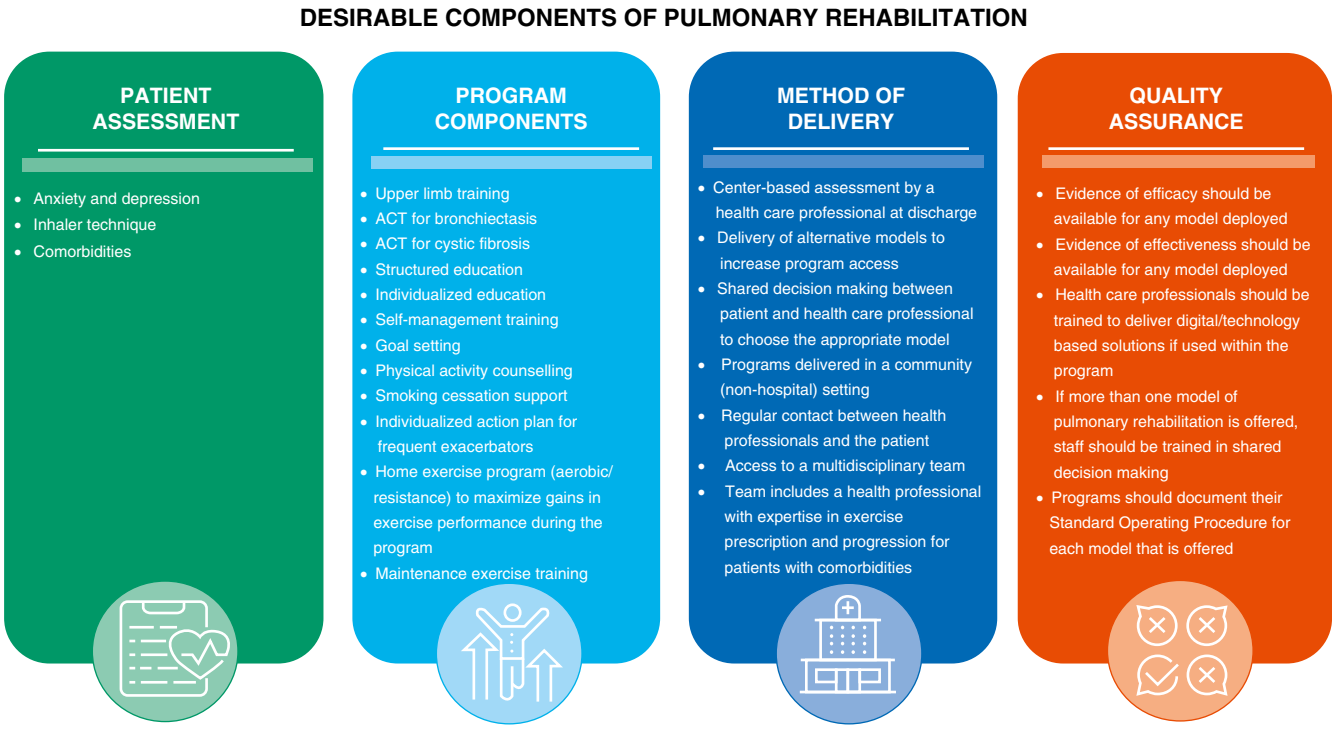

Figure 2. Desirable components of pulmonary rehabilitation. Desirable components of the pulmonary rehabilitation model were identified through a Delphi process. A desirable component was defined as having a median score ⩽2 (strongly agree or agree) but as having some variation in scores (interquartile range, 1). ACT = airway clearance techniques.

program, the experience is frequently very positive. In an online survey of people with chronic respiratory disease with over 1,600 responses, only half of the participants had ever undertaken pulmonary rehabilitation, but among those who did, their descriptions included "*a must*" and "*the best thing I ever did*," with perceived benefits including improved physical, emotional, and social functioning (40). Barriers to attendance at center-based pulmonary rehabilitation commonly include issues associated with travel and transport, poor timing of programs, and competing demands on time (e.g., caring for others, work responsibilities, and social commitments), as well as cost, illness, and the impact of comorbidities (41, 42). A systematic review using the Theoretical Domains Framework identified knowledge of pulmonary rehabilitation, expectations and beliefs about anticipated program outcomes, and environmental factors (including geography, transport logistics, group dynamics, and social support) as factors that influence uptake of center-based pulmonary rehabilitation (28).

The patient experience of emerging pulmonary rehabilitation models is increasingly being explored. Many individuals with COPD who participated in home-based pulmonary rehabilitation valued the flexibility of the home-based program for the ease with which they could fit it in with their life and also valued how such programs reduced their travel burden (43). In this model, which employed weekly telephone contact with a physiotherapist, participants identified the physiotherapist as a source of social support, in addition to their family and friends, that encouraged their ongoing commitment to the program (43). The SPACE for COPD (Self-management Programme of Activity, Coping and Education) program, delivered using a manual, was also positively received; regular contact with health professionals and support from family during the program were highly valued (44). The challenges of longer-term adherence to exercise were also highlighted, with competing demands (often unrelated to their illness) perceived as affecting their ongoing exercise participation (44). In home-based pulmonary rehabilitation, participants identified a lack of variety in exercise training as a challenge to their ongoing engagement and commitment (43).

People with chronic respiratory disease eligible to attend pulmonary rehabilitation have indicated a willingness to use information technology associated with telerehabilitation services (45) and a desire to self-monitor with biosensors (46). Patients have identified that social contact through a virtual group, as well as easy communication with healthcare professionals for education and support, are key requirements for a successful telerehabilitation program (46). In these preliminary reports, telerehabilitation participants reported that the virtual social interaction was positive, the technology requirements were easy to learn, and the equipment was acceptable to have in their home (47, 48). These reports suggest that patients are satisfied with their experience of emerging models of pulmonary rehabilitation. However, not all patients have access to these technologies, and some patients may prefer not to use them, may be unable to acquire the necessary skills, or may require family support to use technology effectively. Patients who choose to participate in telerehabilitation trials may differ from those included in conventional programs. Ensuring that emerging models deliver the essential requirements of a pulmonary rehabilitation program, while

also meeting the needs of patients, is critical if we are to maintain the quality and effectiveness of pulmonary rehabilitation.

Essential Components of Pulmonary Rehabilitation

The first round of the Delphi process achieved consensus on 11 essential components of pulmonary rehabilitation, with 2 additional items achieving consensus in the second round. The 13 essential components of pulmonary rehabilitation are shown in Figure 1. These items address patient assessment, program content, method of delivery, and quality assurance. The Delphi results also highlighted items for which our definition of consensus (median, $\leq$2; IQR, 0) was not met but that were considered important by the respondents (median, 1; IQR, 1). The committee made a *post hoc* decision to report these items as desirable features of pulmonary rehabilitation (Figure 2).

The committee agreed that the essential components of pulmonary rehabilitation are well-established practices that are generally underpinned by strong evidence (Figure 1). For instance, the Cochrane review that underpins evidence for pulmonary rehabilitation in people with stable COPD includes 65 randomized controlled trials of pulmonary rehabilitation, of which 65 (100%) include the essential component of endurance training and 50 (77%) include resistance training; 62 trials (95%) report using an exercise test, of which 55 (85%) are field exercise tests; 50 trials (77%) report measuring health-related quality of life; and 37 (57%) report measurement of dyspnea (6). This Cochrane review demonstrates clinically important improvements in exercise capacity and health-related quality of life in people with stable COPD after pulmonary rehabilitation (6), with similar findings being shown in high-quality systematic reviews of pulmonary rehabilitation after an exacerbation of COPD (7), bronchiectasis (4), interstitial lung disease (3), or pulmonary hypertension (5). These essential components of pulmonary rehabilitation identified in the Delphi process are therefore well aligned with the evidence supporting this intervention and are consistent with results from a global survey of pulmonary rehabilitation professionals representing 430 programs, who identified quality-of-life assessment (82.1% of the respondents), the 6-minute walk test (45.8%), and dyspnea assessment (41.4%) as the three most important assessments in pulmonary rehabilitation (20). Most of the emerging pulmonary rehabilitation models (Table 2) also include these components. Many of the essential components relate to assessment, highlighting the importance of thorough patient evaluation for directing clinical care to ensure that the expected outcomes of pulmonary rehabilitation are achieved. Several of these assessments (exercise capacity, dyspnea, and quality of life) may also play an important role at the program level for quality assurance and benchmarking (18). Operationalization of these essential assessment components may vary according to the setting and resources; for instance, a comprehensive assessment of nutritional status and occupational status could be provided in programs that are sufficiently well resourced (e.g., thorough assessments by a dietician and occupational therapist) but may be more limited in other settings (screening questions at the time of initial assessment, followed by referral when required). Essential components related to exercise training highlighted the importance of individualized prescription and progression by an experienced healthcare professional. The committee agreed that this is a key feature of pulmonary rehabilitation, regardless of the model. Similarly, health-professional training in all components of pulmonary rehabilitation is essential and should relate directly to the model being delivered. Limited training opportunities for pulmonary rehabilitation professionals was highlighted as a key challenge in the ATS/ERS policy statement (11). The committee agreed that future training initiatives should encompass the knowledge and skills necessary to deliver emerging program models. This includes skills for assessment of safety, as exercise training in older patients is not without risk, and monitoring and evaluation strategies will vary with different program models.

The committee agreed that the desirable components of pulmonary rehabilitation programs (Figure 2) were useful and important, but strong evidence of their individual impacts was not yet available. An example of this is the delivery of education, a key component of the current pulmonary rehabilitation definition (16). Although the committee agreed that education is central to pulmonary rehabilitation because it provides the knowledge necessary to underpin behavior change, its impact and ideal format are unclear. Historically, many pulmonary rehabilitation programs have provided structured group education programs, often delivered by members of a multidisciplinary team. In COPD, clinical trials have not yet demonstrated a benefit of structured education over and above exercise training alone (6, 49). In the Australia/New Zealand pulmonary rehabilitation guideline, this has given rise to a recommendation that pulmonary rehabilitation can be delivered irrespective of whether a structured education program is available, acknowledging that there are many alternative formats for providing education and support to program participants (50). The impact of individualized education, with content targeted to an individual's needs and goals, has not yet been tested in a clinical trial. In emerging pulmonary rehabilitation models, education has been delivered in a variety of formats, including via videoconferencing (51) and via an online platform (15), with positive overall program outcomes, but the specific effects of the education component have not been isolated. The inclusion of structured and individualized education as a "desirable" component reflects ongoing uncertainty around the optimal methods of delivery and should not be seen as diminishing the importance of education in pulmonary rehabilitation. Self-management training, which improves health-related quality of life and reduces hospital readmission for people with COPD outside of pulmonary rehabilitation (52), was also identified as a desirable component, but the optimal delivery of such training within pulmonary rehabilitation programs is not yet certain. These challenges have been comprehensively discussed in a previous ATS workshop report (53).

Other desirable program components were interventions for which evidence of benefit was available from clinical trials, but some uncertainties remain. Examples of this are upper limb training, airway clearance techniques, physical activity counseling, and maintenance exercise. Upper limb training in COPD improves dyspnea in people with COPD but may not impact health-related quality of life (54). Airway clearance techniques have been included in some pulmonary rehabilitation trials for patients with bronchiectasis but has also been

Table 3. Suggested model for a comprehensive assessment in pulmonary rehabilitation

Essential Components of Assessment	Also Consider
Exercise capacity	Activities of daily living
Quality of life	Advance care planning needs
Dyspnea	Airway clearance requirements
Nutritional status	Anxiety and panic
Occupational status	Cognitive status
	Comorbidities: impact and management
	Coping skills
	Depression
	Educational needs
	Exacerbation management skills
	Falls history
	Fatigue
	Financial needs
	Frailty
	Goals and priorities
	Housing needs
	Inhaled medication device technique
	Inspiratory muscle strength and endurance
	Medication adherence and side effects
	Mobility
	Musculoskeletal limitations
	Oxygen needs, use of oxygen devices
	Palliative care needs
	Peripheral muscle strength and endurance
	Physical activity in daily life
	Safety of home environment
	Safety of specific exercise modalities
	Self-efficacy
	Sleep disturbance
	Social support
	Speech and swallowing
	Smoking status

included in "usual care" control groups, so its routine role in pulmonary rehabilitation is not clear (4). A small number of studies suggest that addition of physical activity counseling to pulmonary rehabilitation can improve daily steps in people with COPD (mean improvement, 1,452 steps; 4 studies), but the methodological quality was poor (39). Outcomes of maintenance exercise training after pulmonary rehabilitation are variable, with little benefit for programs delivered monthly or less frequently (50). Benefits of maintenance exercise training are evident with more intensive models, but the dropout rate is high (55). It is likely that these program components will be useful for some patients in pulmonary rehabilitation, which is consistent with their identification as desirable rather than essential.

Desirable components of pulmonary rehabilitation included seven items related to the method of delivery and five items related to quality assurance (Figure 2). These represent components of program structure and principles of program delivery that are infrequently tested in clinical trials but provide an optimal environment in which evidence-based care can be delivered. For example, the Delphi results indicated that access to a multidisciplinary team was a desirable, but not essential, feature of pulmonary rehabilitation (Figure 2). A global survey of pulmonary rehabilitation programs ($n = 430$) found wide variation in the composition of the pulmonary rehabilitation team in both the number and disciplines of healthcare professionals included (20). Geographical variation was also evident, with dietitians, exercise physiologists and respiratory therapists more common in North America, and occupational therapists, social workers, and psychologists more common in Europe. A small number of programs were run by a single health professional (4%), which may reflect local resources, particularly for programs located in more remote settings. Comments from Delphi respondents and committee members highlighted the importance of a thorough assessment of individual needs and access to targeted, comprehensive care. Ideally, this comes from within the pulmonary rehabilitation team, but in some settings, it could be sourced elsewhere. This is reflected in the Delphi responses; for instance, nutritional assessment was considered an essential component of pulmonary rehabilitation to ensure that poor nutritional status was identified; however, delivery of nutritional interventions was not included in the essential features, as in some settings, this may be more accessible outside the team. Similarly, the assessment of anxiety and depression was a desirable feature of pulmonary rehabilitation, but the committee acknowledged that diagnosis and treatment of mood disorders may or may not be available within the pulmonary rehabilitation program. This reinforces the importance of multidimensional assessment in pulmonary rehabilitation for identifying important problems and the necessary referral pathways.

Regular contact between health professionals and patients was identified as a desirable feature of delivery for pulmonary rehabilitation programs (Figure 2). Qualitative data confirm that regular contact with health professionals is of great importance to pulmonary rehabilitation participants for timely, personalized advice and support (43, 44). The lack of consensus on this item being "essential" may reflect uncertainties around what constitutes "regular" contact or how a health professional is defined. In traditional pulmonary rehabilitation programs, participants have extensive contact with health professionals, usually twice each week or more frequently (16). Emerging program models may provide contact of a similar frequency (51) but have also reported contact involving once-weekly telephone calls (13) or less frequent contact (14). The nature of the contact is also likely to be important. Some patients may be best suited to the traditional model in which health professionals provide direct supervision of exercise training, whereas others may respond well to telephone calls or videoconferences involving structured goal-setting (13). Future trials of new pulmonary rehabilitation models should clearly specify the nature, frequency, and duration of contact with health professionals so that clearer guidance can be provided in this area. Until more specific evidence is available to inform decisions about the optimal model for individual patients, contact with health professionals should

remain a key component of patient-centered pulmonary rehabilitation delivery.

The committee considered that all pulmonary rehabilitation programs should have the capacity to deliver the essential components effectively to all patients, both in research and clinical practice, regardless of whether the program is center based or delivered elsewhere. The patient-tailored nature of pulmonary rehabilitation, as specified in the ATS/ERS definition (16), means that the desirable components of pulmonary rehabilitation should vary across individuals according to their needs. This principle is relevant regardless of how the program is delivered. The committee considered that many of the desirable components are not unique to pulmonary rehabilitation and should be considered core elements of comprehensive care of the patient with chronic respiratory disease. For instance, addressing mood disorders, inhaler technique, influenza vaccination, and smoking cessation are critical to patient well-being and outcomes and could be addressed in a number of settings by skilled health professionals. There may be additional components (e.g., assessment of pain) that are clinically important but were not identified by the Delphi participants; this is a limitation of the process. A thorough patient assessment, conducted in every patient at the start of pulmonary rehabilitation, is a key opportunity to individualize care and referral pathways.

Comprehensive Assessment: A Critical Element of Modern Pulmonary Rehabilitation

Advances in science, technology, and clinical practice offer a unique opportunity to positively evolve the pulmonary rehabilitation model to include greater personalization of program components. Delivery of personalized pulmonary rehabilitation requires a comprehensive assessment of each individual's needs, goals, and preferences. It is desirable that patients arrive in pulmonary rehabilitation with an established diagnosis confirmed by pulmonary function testing, so this is not considered a component of pulmonary rehabilitation assessment. Cardiopulmonary exercise testing may also be necessary in some patients before pulmonary rehabilitation to provide detailed information on exercise responses and thus formulate a safe and effective exercise prescription. Essential components of pulmonary rehabilitation assessment determined by the Delphi process include evaluation of exercise performance, quality of life, dyspnea, nutritional status, and occupational status (Figure 1 and Table 3). However, these five domains will be insufficient to guide individualization of program components, particularly in patients with more complex needs. Some additional factors that may require consideration and assessment are shown in Table 3. Although not all pulmonary rehabilitation settings will have the capacity to perform comprehensive assessment across all these domains (e.g., diagnosis of mood disturbance, objective measures of physical activity), a screening process may facilitate identification of problems and goals that require specialized assessment by other health professionals and/or referral for ongoing management. Some assessment items may inform the decision to provide training in specific skills for individual patients, such as, for example, training in the use of respiratory devices such as inhalers, oxygen, and home ventilators. A menu-based approach to pulmonary rehabilitation assessment, in which health professionals start with a broad "menu" of relevant assessment domains and identify those domains relevant to each individual patient, followed by detailed assessment using robust tools that are specific to the relevant domain, may prove useful in the future.

Which Pulmonary Rehabilitation Model for Which Patient?

Consistent with the principle of personalized rehabilitation, it should be expected that not all models of pulmonary rehabilitation will be equally suitable for all patients with chronic respiratory disease. The committee considered that research identifying the characteristics of patients most likely to succeed in each type of pulmonary rehabilitation program should be a high priority. However, the number of existing clinical trials of alternative rehabilitation models is small (Table 2), and there is currently no standardized way to assess which model would best suit which patient (and *vice versa*). It has been suggested that home-based programs are unsuitable for complex patients or for those with hypercapnia, hypoxemia, very severe dyspnea, recent hospitalization, or frailty (56). Although there are some patients whom the committee considered would clearly be better served in a multidisciplinary, center-based program (e.g., those with pulmonary hypertension and a history of syncope; those with movement disorders and/or a history of falls), it was acknowledged that recent trials of home-based interventions have successfully included participants with substantial multimorbidity (13, 14). Other factors that are likely to influence the choice of the "best" program model for an individual patient include social circumstances (e.g., work and caring responsibilities, access to transport, support at home), access to and attitudes regarding technology, and personal preferences related to location and supervision. Such factors may be difficult to quantify in clinical trials but reinforce the importance of shared decision-making to facilitate optimal treatment choices.

Looking to the future, providers might offer a "suite" of evidence-based pulmonary rehabilitation models, which all offer the essential components (Figure 1) but vary in complexity and mode of delivery. Selection of models will be guided by the maturing evidence base as well as by the local context (for instance, telerehabilitation models may be particularly relevant for rural and regional areas where travel distance is prohibitive). Center-based, multidisciplinary rehabilitation programs will remain critical for ensuring that patients who require a comprehensive, supervised pulmonary rehabilitation program can receive it efficiently and effectively. However, providers of pulmonary rehabilitation in settings where such comprehensive resources are not available may consider referral pathways that "extend" the pulmonary rehabilitation team. A menu-based approach may prove useful for assessing clinical needs, treatment goals, the availability of additional clinical services and referral pathways, and personal preferences. Hybrid or stepped models, in which patients move from one program to another (e.g., commence in a center-based program with supervision and transition to a minimally supervised model at home), may be useful. Successful implementation will be judged by whether the essential components of pulmonary rehabilitation are delivered and by whether the expected outcomes are achieved. A rigorous approach to quality

assurance, applied consistently across programs, will therefore be required.

Quality Assurance for Pulmonary Rehabilitation

Any pulmonary rehabilitation provider should systematically ensure that the service is clinically impactful, and the processes are efficient and effective. Novel and existing programs can be evaluated through audits of outcomes and processes. Outcomes need to be measured against peer performance or expected increments in performance on the basis of clinical trials. Processes are measured against accepted standards. A robust process of quality assurance is not widely implemented in pulmonary rehabilitation, although the United Kingdom has made significant advances in recent years. The BTS identified quality standards for pulmonary rehabilitation (24) on the basis of previously published, evidence-based guidelines (17). This has facilitated two national audits of pulmonary rehabilitation processes and outcomes (18, 29) and has developed into a program of continuous clinical auditing.

Clinical audits are an important component of quality assurance. A clinical audit first allows a comparison of service data against the known minimum clinically important differences for an outcome measure and, second, allows benchmarking. This benchmarking can be either an internal comparison of discrete services provided by one organization (e.g., community vs. hospital) or can be a comparison with other services if data are collected regionally or nationally. With respect to emerging models, this framework can be used to evaluate the implementation and effectiveness of these novel interventions, which have so far only been described in research papers. The Delphi process identified the assessment of exercise capacity, health-related quality of life, and dyspnea as essential components of pulmonary rehabilitation, and the impact of all programs on these outcomes should be assessed. This process allows services to observe variations in the clinical effectiveness and efficiency of the process. The latter might, for example, include waiting times to access rehabilitation programs from the point of referral. In the United Kingdom, a quality standard includes targets for enrollment and completion, against which audit data are evaluated. Currently, UK rehabilitation providers are tasked with enrolling 85% of patients within 90 days of receiving a referral and achieving completion rates of 70% (defined as attendance at a discharge appointment) (18). Such metrics may vary across jurisdictions but should be clearly defined. Once identified, there should be a process of quality improvement for any deficits identified. This can be a complex process and may require institutional support and training.

Pulmonary Rehabilitation Accreditation, Certification, and Supporting Processes

The purpose of these programs is to recognize and potentially reward high-quality care. It helps patients recognize services that are deemed to meet the quality standards and helps funders to commission effective services.

In the United States, there is a certification scheme led by the American Association of Cardiovascular and Pulmonary Rehabilitation (57). There are two components: certification of the program and certification of the rehabilitation professional. Being a certificated program requires a comprehensive review that covers organizational issues, quality of care, and outcomes. Certification of the rehabilitation professional acknowledges the specialist skills required to deliver effective, patient-centered pulmonary rehabilitation and is awarded in partnership with the American Association of Respiratory Care. The certificate can be accessed by the multidisciplinary team (nurses, therapists, physiologists). There is a requirement that the individuals complete an educational program, which currently comprises 12 modules describing the fundamentals of pulmonary rehabilitation.

The Pulmonary Rehabilitation Services Accreditation Scheme in the United Kingdom was launched in 2018 and is supported by the Royal College of Physicians Accreditation Unit. There is guidance in the United Kingdom that supports the commissioning of programs that are accredited or are working toward accreditation. The process of accreditation for healthcare services is a professionally led, supportive process involving self-assessment and external peer review to assess the quality of clinical services in relation to established standards and promote continuous quality improvement. A core component of a formal accreditation process is reviewing audit/clinical-effectiveness data and process data (e.g., waiting times) alongside less obvious clinical standards that support high-quality, timely, and clinically effective service delivery that is patient focused. These additional aspects might include leadership and organization, person-centered care, patient education and information, facilities and equipment, and workforce.

The Swiss Society for Pulmonology specifies a range of accreditation requirements for pulmonary rehabilitation programs in Switzerland, including staff training, program leadership and oversight, pre- and post-program assessments, pulmonary rehabilitation program content, and quality-control metrics (58). Accredited pulmonary rehabilitation programs are reimbursed by health insurers.

For emerging models of pulmonary rehabilitation, accreditation and certification should ensure that programs achieve their expected outcomes and also have the necessary leadership, organization, and staff development in place. Workforce capacity and training for emerging models may be particularly important, as these may require a unique set of skills, including health coaching, remote monitoring, and the use of technology. Health professionals have expressed concerns about adoption of telerehabilitation models, including a change in work role, invisible work practices such as delivering and installing equipment, and fears of insufficient support with technology; however, they also identify exciting opportunities to reach underserved patients (59, 60). Successful implementation of emerging models will require that the workforce is well supported and adequately trained.

Putting Emerging Models of Pulmonary Rehabilitation into Practice

There is a pressing need to increase the scope of, and access to, rehabilitation. However, increasing the number of individuals participating in rehabilitation programs should not compromise the quality of the service and the outcomes for the individual. There is a justifiable concern from providers that the desire to increase

capacity may manifest with an expectation from payers/commissioners to adopt untested models or, even worse, models in which testing has not provided evidence of efficacy. It is of course important to increase capacity, but expansion should be controlled and reflect the evidence. Pulmonary rehabilitation is a high-value intervention for the individual and the healthcare system, and the integrity of the service and its outcomes should not be conceded. In fact, novel forms of pulmonary rehabilitation should contribute to an overall greater effectiveness at the population level. This must be demonstrated by achievement of the expected outcomes of pulmonary rehabilitation, including improved exercise capacity, reduced dyspnea, enhanced health-related quality of life, and reduced hospital admissions.

Putting new models into practice requires negotiation with health-system payers to agree to growth in capacity and, importantly, to also agree to benchmarking criteria to evaluate the newly introduced intervention. The committee considered that it is crucial to the integrity of pulmonary rehabilitation programs that any new models implemented are supported by evidence of efficacy and effectiveness. Although these features were considered only a desirable component of pulmonary rehabilitation by the Delphi respondents (Figure 2), this may reflect historical challenges in our field, given the modest numbers of clinical trials and inconsistent approaches to benchmarking and auditing. However, this workshop report has documented the recent evolution of pulmonary rehabilitation, with increased numbers of high-quality trials and established national audit processes now in place. These features significantly increase the feasibility of implementing effective and efficacious models.

Staff engagement and training are critical to effective delivery of emerging pulmonary rehabilitation models. Indeed, there may be institutional barriers to adopting novel methodologies; this may be particularly apparent where the use of technology by both staff and participants is required. In addition, technology evolves more quickly than standard rehabilitation, requiring constant adaptation and upgrading of hardware, software, and interfaces. It is important to recognize these obstacles and provide the necessary training for all parties. It is imperative that services adopt new ways of working in collaboration with all stakeholders and ensure that implementation follows the best available evidence. It is a limitation to this workshop report that the committee did not include hospital administrators, insurance payers, and policy-makers.

Future Research Directions

The emergence of new models of care presents new and exciting opportunities. Until recently, there has been very little "choice" for pulmonary rehabilitation patients; the delivery model has largely been "one size fits all," which is arguably inconsistent with the personalized approach of modern medicine. For example, although patients with COPD are consistently prescribed inhaled therapy (monotherapy, dual therapy, or triple therapy), there is always a choice among devices that best suits the patient. This emerging choice of pulmonary rehabilitation models presents many challenges that are best addressed with prospective, clinical-implementation trials. Important areas of focus for future research include the following:

- Development of valid behavioral and physiological biomarkers that identify the suitability of a patient for a particular type of pulmonary rehabilitation model. What factors determine which model best suits which type of patient? More evidence is urgently needed to help health professionals and patients make informed decisions on the basis of patient characteristics. This aligns with the emergence of personalized medicine.
- How do we titrate the level of care required in a pulmonary rehabilitation program for each individual, and is this personalization better than the one-size-fits-all approach?
- Do hybrid or stepped models have a role for patients who decline rehabilitation or who may drop out of a conventional program?
- Uptake of postexacerbation pulmonary rehabilitation is very low; would an alternative model support transition into conventional supervised pulmonary rehabilitation? Or would it facilitate recovery as a standalone package in these more complex patients?
- How might these emerging models be deployed as a maintenance strategy, given that many are delivered at a lower cost than center-based pulmonary rehabilitation?
- Does use of emerging pulmonary rehabilitation models in clinical practice genuinely increase access and widen participation in hard-to-reach groups?
- To date, the evidence has been largely accumulated for COPD; do these alternative models offer an effective solution for other chronic respiratory diseases?
- What are the optimal methods to assess the safety of undertaking different pulmonary rehabilitation models?
- What is the cost and effectiveness or utility gain of emerging pulmonary rehabilitation models compared with other models in the short and longer term?
- Can emerging models enhance participation in pulmonary rehabilitation in low- and middle-income countries?
- What are the training needs of participants and service providers for optimizing delivery and outcomes?
- To what extent is the rapid and constant evolution of technology a barrier to the implementation of pulmonary rehabilitation models that rely on digital platforms (i.e., rapidly evolving software and hardware)?

Conclusions

This is an exciting time for pulmonary rehabilitation, with emerging models bringing new opportunities to improve patient access and outcomes. The future of pulmonary rehabilitation will include more choices for patients and opportunities for greater personalization of programs. In this workshop report, we have defined the essential components of pulmonary rehabilitation for all program models. The delivery of desirable components of pulmonary rehabilitation depends on local resources, health-system organization, and individual patient needs. Individualization of pulmonary rehabilitation is facilitated by a comprehensive patient assessment, which should be a feature of all programs. Only those models of pulmonary rehabilitation that are underpinned by evidence from clinical trials should be considered for implementation. Robust quality-assurance processes are necessary for all programs to ensure that the substantial benefits of pulmonary

rehabilitation are consistently attained by people with chronic lung disease across the world. ■

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