

# British Thoracic Society Clinical Statement on pulmonary rehabilitation

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## INTRODUCTION

The evidence-based British Thoracic Society (BTS) Guideline for pulmonary rehabilitation (PR) in adults was published in 2013.<sup>1</sup> There is a strong evidence base for the benefits of PR,<sup>2</sup> and it is one of the most cost-effective interventions for adults with chronic obstructive pulmonary disease (COPD).<sup>3</sup> Furthermore, PR improves exercise capacity and health-related quality of life (HRQOL) in COPD to a much greater magnitude than observed with bronchodilator therapy.<sup>4</sup>

Since the Guideline, there is deeper understanding of referral characteristics, outcome measures, patient selection, programme delivery, potential adjuncts and the role of maintenance following PR. The BTS Clinical Statement on PR is a narrative review which provides a snapshot of current knowledge and best practice in topical areas by providing a series of clinical practice points that are informed by evidence where this exists, or based on expert opinion and collective clinical experience where evidence is limited.

The Clinical Statement is not intended to be a comprehensive review as much of the BTS Guideline remains relevant today and does not need revisiting.<sup>1</sup> Furthermore, BTS, alongside other respiratory societies, reviewed the current state of education in PR.<sup>5</sup> The intended audience are PR clinicians working within health settings in the UK and beyond. The Clinical Statement will provide a framework to inform future BTS Quality Standards for PR. We have also highlighted areas of research priority, which will be of interest to clinical researchers.

In this Statement, we highlight the growing interest in alternative models of delivering PR (eg, home based, remote supervision, use of technology), accelerated by the restrictions placed on face-to-face PR delivery during the global COVID-19 pandemic. These PR models, typically delivered remotely, might potentially increase provision of, and accessibility to PR. However, research gaps remain and it is crucial these models are optimised and carefully evaluated before widespread adoption.<sup>2</sup>

A recent international workshop report, using a Delphi process, defined essential and desirable components of PR.<sup>6</sup> We have adapted this to define the core components of PR (box 1), which will help health payers decide if they are commissioning an intervention that is likely to produce good outcomes.

## Box 1 Core components of a pulmonary rehabilitation (PR) programme

- ⇒ An initial face-to-face assessment by a suitably trained healthcare professional.
- ⇒ Initial assessment must include a validated exercise test from which an individualised exercise prescription can be obtained.
- ⇒ Endurance and resistance training, which is individually prescribed and progressed with regular supervision from suitably trained healthcare professionals.
- ⇒ A structured education programme.
- ⇒ Delivered by a dedicated team of healthcare professionals trained in exercise assessment, prescription and progression, with experience of delivering patient-focused education on chronic respiratory disease management.
- ⇒ The programme model, including assessment and delivery components, must have been independently reported to be safe and effective.
- ⇒ Measurement of core outcomes before and after PR. These should include a validated exercise test, measures of breathlessness and health-related quality of life, and other outcomes that evaluate core components of the intervention, such as lower limb muscle strength and disease knowledge.
- ⇒ Participation in regular audit of organisational and clinical outcomes; for example, engagement with a recognised national audit programme where available.
- ⇒ External peer review to monitor safe and effective practice; for example, engagement with a recognised national accreditation programme where available.

## METHODOLOGY

The Clinical Statement group (CSG) was chaired by SJS and WM and included experts in a range of disciplines including respiratory medicine, rehabilitation, physiotherapy and lay/patient input. The CSG identified key areas requiring clinical practice points and the overall content was developed to reflect the scope approved by the BTS Standards of Care Committee (SOCC). Following discussions of broad statement content, individual sections were drafted by group members. A final edited draft was reviewed by the BTS SOCC before posting for public



consultation and peer review on the BTS website November 2022 to January 2023. The revised document was reapproved by the BTS SOCC in April 2023 before final publication.

## SUMMARY OF CLINICAL PRACTICE POINTS

### Access, referrals and uptake

- ▶ PR provider leads should have designated sessional time to coordinate management and delivery of the service. This should include: regular education of potential referrers about PR and referral pathways; working closely with commissioners to understand the demographics of the local population; the expansion, training and skills maintenance of a specialist workforce to deliver PR; the collation of key organisational metrics.
- ▶ PR providers should demonstrate the offer of timely, accessible and high-quality services by the regular monitoring and publication of key organisational metrics. This includes waiting time from referral receipt to assessment and enrolment, percentage of referred patients who attend an assessment, percentage of patients who are assessed that attend at least one planned supervised session, percentage of the number of attended to planned sessions, percentage of patients attending a discharge assessment.
- ▶ PR providers should work closely with relevant national professional societies and other stakeholders to develop competency documents and training programmes to maintain, upskill and expand the skilled workforce needed to deliver increased PR.

### Assessment and outcomes

- ▶ A high-quality PR assessment should include a multisystem approach that helps identify individuals who might benefit from other cost-effective interventions (such as vaccination and smoking cessation) or onward referral to multidisciplinary specialists. This information should be communicated to other relevant healthcare professionals involved in the individual's care.
- ▶ Assessment of patient safety for exercise training and exercise capacity to facilitate exercise prescription should be conducted in-person using a validated field walking test (incremental shuttle walk (ISWT), 6 min walk tests (6MWT)) or laboratory cardiopulmonary exercise test.
- ▶ There is no evidence to support the safety or validity of field walking tests or simple functional tests that are supervised remotely.
- ▶ When routine face-to-face assessments are restricted, hybrid assessments can be considered with questionnaire-based assessments conducted over the telephone and a directly supervised, face-to-face assessment of exercise capacity.
- ▶ Functional tests are complementary to, but not a replacement for, validated exercise walking tests. There is no evidence to support aerobic or strength exercise prescription from simple functional tests.

### Extending the scope of PR

- ▶ PR should be offered to symptomatic individuals with chronic respiratory disease including COPD, asthma, bronchiectasis and interstitial lung disease (ILD).
- ▶ PR may be helpful in the recovery of subgroups of patients with post-COVID-19 syndrome where they are functionally and symptom limited.
- ▶ The assessment, exercise and education components of PR should be adapted for relevant cardiorespiratory diseases, taking into account disease-specific issues.

- ▶ The workforce should receive training and be competent to deliver high-quality PR for relevant cardiorespiratory diseases.
- ▶ PR practitioners should have the skillset to support prehabilitation interventions for patients awaiting lung cancer and lung transplant surgery, but the current delivery model of PR needs to be adapted in order to be appropriately time sensitive.
- ▶ PR practitioners have a role in identifying potential candidates for lung volume reduction (LVR) procedures at the post-PR assessment.
- ▶ Patients with stable chronic heart failure (CHF), pulmonary arterial hypertension (PAH) or chronic thromboembolic pulmonary hypertension (CTEPH) can be incorporated safely within directly supervised outpatient PR programmes.
- ▶ Outpatient supervised PR, incorporating both exercise training and education should be offered to all appropriate patients discharged from hospital, including hospital-at-home and early supported discharge schemes after exacerbation of COPD.
- ▶ Members of the integrated care team should reoffer 'delayed' PR in individuals who decline an initial offer of posthospitalisation PR.

### Alternatives models of PR

- ▶ Every eligible individual referred for PR should have the opportunity to access directly supervised, centre-based PR in a timely way as this model is supported by a convincing evidence base.
- ▶ In patients who decline or drop out from supervised centre-based PR, providers should offer an alternative model of delivery. Any alternative model should have a supporting evidence base (ideally within the National Health Service (NHS) setting), and incorporate a directly supervised, validated exercise test from which individualised exercise can be prescribed, and validated outcome measures to evaluate efficacy.
- ▶ Both staff and patients require training to support alternative PR models, particularly those involving digital technology, in order to promote digital inclusion.

### Adjuncts to and maintenance of PR

- ▶ Oxygen supplementation should not be routinely used as an adjunct to PR except in individuals already established on long-term or ambulatory oxygen therapy.

**Table 1** Effect of referrer education on pulmonary rehabilitation referrals

Action	Effect on referrals
Delivering education to primary care referrers <sup>19-21</sup>	3%–5% increase
Patient education as part of a 'patient held score card' with advice to discuss referral at their next COPD review <sup>22</sup>	6% increase
Integrated approach to COPD care <sup>23</sup>	25% increase over 3 years
Delivering education to secondary care referrers <sup>41 42</sup>	6% increase RR: 2.78 (95% CI 2.65 to 2.90)
Delivering COPD discharge bundles by pulmonary rehabilitation practitioners versus non-pulmonary rehabilitation practitioners <sup>38</sup>	60% vs 12% OR: 14.46 (95% CI 5.28 to 39.57)
COPD, chronic obstructive pulmonary disease; RR, risk ratio.	

- ▶ Non-invasive ventilation (NIV) should not be routinely used as an adjunct to PR in those naïve to domiciliary NIV, but could be offered to those already established on domiciliary NIV.
- ▶ Inspiratory muscle training (IMT), as an adjunct to PR, is associated with improvements in respiratory muscle function, but this has not translated to improvements in core outcomes.
- ▶ Physical activity (PA) counselling should be a core component of the PR educational component. The use of pedometers or/and additional PA counselling as adjuncts to PR require further evaluation.
- ▶ PR programmes should deliver self-management education and advice around the importance of regular exercise after the PR programme has been completed. There is insufficient evidence to support the routine formal delivery of maintenance programmes.

## PR: ACCESS, REFERRALS AND UPTAKE

### Access and referrals

There is a large disparity between the number who are eligible and the number receiving PR.<sup>7</sup> Reasons for this are complex, but barriers may exist at several points of the pathway. Referral from primary care appear to be influenced negatively by increasing age, gender (women less likely), deprivation, comorbidities, respiratory disability and smoking status.<sup>8</sup> The PR outcomes from individuals with lower socioeconomic status are not compromised, but they are less likely to be referred or to complete PR.<sup>9</sup> Over 10% of services in England and Wales did not offer PR to those with greatest respiratory disability (Medical Research Council Dyspnoea Scale 5). Equity of access is rarely addressed within UK services, but modification of PR to suit the needs of a diverse population has been proposed in other countries.<sup>10</sup> Health and digital literacy require attention, particularly with ever diversifying modes of PR delivery, including the use of technology.<sup>11 12</sup>

Although there is a dearth of randomised controlled trial (RCT) data to support specific interventions designed to improve referral for PR,<sup>13 14</sup> identified referrer barriers include a lack of referrer knowledge around eligibility criteria or how to refer for PR.<sup>15</sup> Several observational studies have provided indirect evidence that improving education can increase referral rates (summarised in [table 1](#)).

The most recent (prepandemic) national audit data identified that the median waiting time from receipt of referral to PR enrolment was 84 days, with only 54% receiving PR within 90 days of referral receipt.<sup>16</sup> A similar waiting time from prescription to receipt of an inhaler would be unacceptable, despite bronchodilators being a less cost-effective intervention to PR.<sup>3</sup> Commissioners need to ensure that accessibility to PR has at least the same priority as access to pharmacological therapy. This would require investment in workforce and training, with the BTS report 'A workforce for the future' highlighting the substantial shortage of skilled healthcare professionals and support staff for PR.

### Uptake and completion

Barriers to uptake and completion of PR are complex,<sup>17 18</sup> but factors relating to the quality of a PR service, such as lack of patient-centredness and coordination within PR team, inadequate professional competence of staff, lack of a holistic approach and limited accessibility, are relevant.<sup>17</sup>

There are few interventional studies targeting uptake and completion. Observational studies have explored interventions

such as group opt-in sessions (which led to a smaller proportion of those referred attending assessment),<sup>19</sup> patient-held manuals with research evidence summaries (which improved attendance in the most socioeconomic disadvantaged patients),<sup>20</sup> and a nurse-general practitioner partnership care plan which increased attendance at PR by 21.5% compared with usual care.<sup>21</sup> In the acute setting, a patient codedigned education video did not improve posthospitalisation PR uptake.<sup>22</sup> Other interventions currently being tested include the use of lay health workers to support patients.<sup>23</sup>

### Clinical practice points

- ▶ PR provider leads should have designated sessional time to coordinate management and delivery of the service. This should include: regular education of potential referrers about PR and referral pathways; working closely with commissioners to understand the demographics of the local population; the expansion, training and skills maintenance of a specialist workforce to deliver PR; the collation of key organisational metrics.
- ▶ PR providers should demonstrate the offer of timely, accessible and high-quality services by the regular monitoring and publication of key organisational metrics. This includes waiting time from referral receipt to assessment and enrolment, percentage of referred patients who attend an assessment, percentage of patients who are assessed that attend at least one planned supervised session, percentage of the number of attended to planned sessions, percentage of patients attending a discharge assessment.
- ▶ PR providers should work closely with relevant national professional societies and other stakeholders to develop competency documents and training programmes to maintain upskill and expand the skilled workforce needed to deliver increased PR.

### Research gaps

- ▶ Development of interventions to improve referrals to, uptake and completion of PR.
- ▶ Exploring adaptations to PR services and their evaluation to ensure programmes meet the needs of a diverse population, including equity of access.

## ASSESSMENT AND OUTCOMES

### Core outcomes

Core outcomes were documented in the previous BTS guideline and include measures of breathlessness, exercise capacity and HRQOL, which improve with aerobic training.<sup>1</sup> Other key assessment measures document the efficacy of the other components of PR (resistance training and education). Lower limb muscle strength is most reliably measured using isometric or isotonic techniques.<sup>24</sup> Assessing the effects of the education component is challenging, with limited availability of validated questionnaires, particularly for non-COPD conditions.<sup>25</sup> Validated COPD knowledge questionnaires are generally used in PR settings.<sup>26 27</sup> A list of suggested educational topics were published in the BTS Guideline,<sup>1</sup> and the current state of education in PR was reviewed in 2019.<sup>5</sup> Further research is needed to determine the impact of the educational component beyond knowledge acquisition.

### The wider PR assessment

Although the initial assessment for PR is primarily performed to assess suitability and safety for PR and to facilitate exercise

prescription, it also presents an opportunity to review general health, and the wider management of the respiratory condition. This may result in recommendations to the referrer to either optimise treatment, conduct further investigations or refer to a more appropriate service.

For example, the assessment for PR should identify individuals who might benefit from cost-effective interventions such as vaccination and smoking cessation,<sup>3</sup> or those with treatable traits associated with poor prognosis that might prompt onward referral to multidisciplinary specialists or more flexible personalised approaches to support PR completion.<sup>28 29</sup> Examples are summarised below.

There is a significantly increased risk of several cardiovascular diseases in COPD<sup>30</sup> so unexplained symptoms (such as chest pain or intermittent claudication), or identification of elevated blood pressure or arrhythmias should prompt referral for further evaluation. Long-term oxygen therapy for severe hypoxaemia remains one of the few interventions that influence prognosis in adults with COPD.<sup>31 32</sup> Both low body mass index (specifically unintentional weight loss) and extreme obesity are factors for poor prognosis.<sup>33–35</sup> Frailty is associated with adverse prognosis in adults with COPD,<sup>36–39</sup> including increased likelihood of PR non-completion,<sup>29 40</sup> but frail completers have favourable outcomes from PR.<sup>40</sup> Anxiety and depression are common in patients referred for PR<sup>16 41</sup> and are associated with reduced adherence to interventions, increased dyspnoea and lower levels of patient activation.<sup>42–45</sup> Impairments in activities of daily living, assessed through a comprehensive history or a structured questionnaire, may identify those who require occupational therapy input.

The initial assessment should also provide the PR provider with information about literacy, language, cultural and social needs to help plan flexible and personalised approaches to PR delivery.

### Home-based or remote assessment of core outcomes

Since the COVID-19 pandemic, there has been increasing interest in home-based or remote assessment options. Many non-exercise outcomes, such as HRQOL, are assessed through questionnaires. The COPD Assessment Test, Saint Georges Respiratory Questionnaire and Hospital Anxiety and Depression Scale have comparable validity and reliability when delivered over the phone compared with face-to-face delivery.<sup>46 47</sup>

However, evidence is lacking to support remote delivery of functional or field walking tests as a reliable alternative to face-to-face testing. Although sit to stand, step and timed up and go tests are feasible in the home-setting, they do not accurately reflect oxygen desaturation with walking or allow exercise prescription.<sup>48</sup> The 6MWT supported by mobile phone application algorithms offers a potentially attractive approach but has not been validated in chronic respiratory disease populations.<sup>49</sup> There are some data to suggest that there is no significant difference in 6 min walk distance when performed indoors or outdoors,<sup>50</sup> although further corroboration is required in variable environmental conditions. Current assessment of patient safety for exercise-training and exercise capacity to facilitate exercise prescription should be conducted in-person, irrespective of the PR delivery model (see the 'Alternatives models of delivering PR' section).

### Functional assessments

Simple functional assessments are attractive as they do not require as much space as field walking tests<sup>51</sup> and can be

performed in most healthcare settings. These include four metre gait speed,<sup>52–54</sup> sit to stand tests (five repetition, 30s, 1 min),<sup>55–58</sup> step tests,<sup>59–61</sup> timed up and go,<sup>62</sup> and composite measures combining several functional tests. These have been reviewed in detail elsewhere.<sup>48 63–65</sup> These functional tests have a moderate relationship with field walking test performance or muscle strength and are responsive to exercise-based interventions or PR.

However, there are several caveats. Most validation studies have taken place in clinical settings where the tests were directly supervised and therefore the safety and validity of remotely supervised functional tests in patients with chronic respiratory disease have not been established. Some functional tests have floor or ceiling effects that might limit their application in PR. For example, 15% of those referred for PR were not able to complete the five repetition sit to stand,<sup>55</sup> while the 4 m gait speed is less responsive to PR in higher functioning individuals with COPD.<sup>52</sup> Functional tests are also typically submaximal, and therefore, not able to support individualised exercise prescription.<sup>52</sup> Others have used functional tests as surrogate markers of muscle strength. However, the relationship between five repetition sit-to-stand test and quadriceps strength is only moderate.<sup>55</sup>

### Physical activity

Reduced PA is associated with poor prognosis in COPD.<sup>66</sup> Although PA can be measured subjectively using questionnaires, there are limitations to this method including recall bias.<sup>67</sup> There is a growing literature on measuring PA using wearable devices, including pedometers and accelerometers, but considerable variability has been reported in clinical trials.<sup>68</sup> An International Taskforce on PA has recommended implementation of standard operating procedures for PA data collection and reporting.<sup>66</sup> Although PA has been identified as an important outcome that may be potentially amenable to PR, further research is required before implementation into routine clinical practice.

### Clinical practice points

- ▶ A high-quality PR assessment should include a multisystem approach that helps identify individuals who might benefit from other cost-effective interventions (such as vaccination and smoking cessation) or onward referral to multidisciplinary specialists. This information should be communicated to other relevant healthcare professionals involved in the individual's care.
- ▶ Assessment of patient safety for exercise-training and exercise capacity to facilitate exercise prescription should be conducted in-person using a validated field walking test (incremental shuttle walk (ISWT), 6 min walk tests (6MWT)) or laboratory cardiopulmonary exercise test.
- ▶ There is no evidence to support the safety or validity of field walking tests or simple functional tests that are supervised remotely.
- ▶ When routine face-to-face assessments are restricted, hybrid assessments can be considered with questionnaire-based assessments conducted over the telephone and a directly supervised, face-to-face assessment of exercise capacity.
- ▶ Functional tests are complementary to, but not a replacement for, validated exercise walking tests. There is no evidence to support aerobic or strength exercise prescription from simple functional tests.

**Table 2** Extending the scope for pulmonary rehabilitation

Condition	Adaptation
Asthma	▶ To minimise risk of adverse events, patients should be medically optimised prior to PR referral. <sup>75</sup>
Bronchiectasis	▶ Optimisation of airway clearance technique is recommended before and during PR. <sup>76</sup> ▶ No data on risk of cross-infection of multiresistant organisms during PR, <sup>77</sup> but local infection control policies should be followed.
Interstitial lung disease	▶ Compared with COPD, profound exercise-induced desaturation is more common in idiopathic pulmonary fibrosis (IPF) and some subtypes of interstitial lung disease. <sup>78</sup>
Post-COVID-19	▶ Caution with unexplained chest pain. ▶ Consider patients with functional limitation and ongoing symptoms for post-COVID-19 rehabilitation. ▶ Individuals with postintensive care syndrome have multisystemic symptoms and deficits, which may require individualisation of exercise and education components. ▶ Fatigue and postexertional symptom exacerbation should be closely monitored through symptom, exertion, activity scores and diaries.
Lung cancer	▶ Due to time sensitivity for curative surgery, conventional PR programmes would require adaptation to be suitable for prehabilitation. ▶ Optimal timing, setting, nature and duration of PR for postlung cancer surgery or advanced lung cancer remains unknown. ▶ Advanced lung cancer not a contraindication to PR but flexibility required for pragmatic reasons (eg, timing of chemotherapy session).
Lung volume reduction	▶ All individuals should have completed PR prior to their assessment for lung volume reduction procedures. ▶ PR practitioners may have a role in identifying potential candidates at the post-PR assessment.
Lung transplantation	▶ All individuals should have completed PR prior to their assessment for lung transplantation.
Chronic heart failure	▶ Programme adaptations/considerations might include <sup>107</sup> : – Provision of disease-specific education. – Workforce training to understand signs of decompensated heart failure. – Inclusion of a heart failure nurse in the multi-disciplinary team.
Pulmonary hypertension	To be eligible for PR, people with pulmonary arterial hypertension (PAH) and chronic thromboembolic pulmonary hypertension (CTEPH) should have stable disease <sup>109 112</sup> : ▶ No change in drug therapy or dose in previous 2 months. ▶ No syncope or symptomatic arrhythmia in previous 2 months. ▶ International guidelines recommend that exercise is supervised by specialist exercise professionals. <sup>112</sup> ▶ Remote supervision of exercise training is not recommended in people with PAH or CTEPH.
Perihospitalised exacerbation of COPD	▶ PR should be outpatient, started after hospital admission and incorporate comprehensive exercise and education components. ▶ Reoffer PR to people who initially decline in the immediate posthospitalisation period.

COPD, chronic obstructive pulmonary disease; PR, pulmonary rehabilitation.

### Research gaps

- ▶ Development of outcomes that assess the effectiveness of the education component of the PR programme.
- ▶ Studies to assess the safety and validity of remotely supervised exercise and functional outcomes through videoconferencing or mobile applications.
- ▶ Alternative strategies to prescribe exercise and deliver effective PR in the absence of a directly supervised validated exercise test.
- ▶ Clarify the value of measuring PA and other physiological data obtainable from wearables as part of routine clinical practice in PR.

## EXTENDING THE SCOPE OF PR

### Chronic respiratory disease other than COPD

There is a growing evidence-base and real-world experience of delivering PR to people with chronic respiratory disease including asthma, bronchiectasis and ILD. Systematic reviews have demonstrated that exercise training, compared with control interventions, significantly improves exercise capacity and HRQOL.<sup>69–72</sup> Furthermore, real-world data suggest that these improvements are of similar magnitude to those observed in matched patients with COPD.<sup>41 73 74</sup>

Although the core components of PR (outlined in [box 1](#)) continue to apply, potential adaptations needed to deliver PR to people with non-COPD chronic respiratory disease are outlined in [table 2](#). For asthma, to minimise risk of adverse events, patients should be medically optimised prior to referral for PR.<sup>75</sup> Similarly, as bronchiectasis is characterised by excessive sputum production, a review and optimisation of airway clearance

technique should be initiated before and during PR.<sup>76</sup> There are no data to support increased risk of cross-infection of multiresistant organisms,<sup>77</sup> but local infection control policies should be followed. Compared with COPD, profound exercise-induced oxygen desaturation is more common in IPF and some subtypes of ILD.<sup>78</sup> Although most standard PR education is relevant to people with non-COPD respiratory disease, some adaptations are needed (eg, medications) or particular components prioritised (eg, airway clearance in bronchiectasis).

### Post-COVID-19

Guidance from the BTS regarding the role of adapted PR to meet the recovery needs in post-COVID-19 syndrome has been previously published.<sup>79</sup> Several observational studies have demonstrated that PR following hospitalised COVID-19 is associated with significant improvements in exercise capacity, breathlessness and HRQOL.<sup>80–85</sup> Without a control group, natural recovery cannot be dismissed as the main driver of improvements.<sup>61</sup> However, symptom burden, reduced exercise tolerance and sequelae of hospitalisation for COVID-19 remain substantial at 5 months postdischarge,<sup>86</sup> with negligible improvement 1 year after discharge.<sup>87</sup> Initial trial data suggest a role for PR in the recovery of individuals with post-COVID-19 syndrome,<sup>88</sup> and the results of further trials are awaited.<sup>89 90</sup>

Several factors need to be considered when providing PR to individuals with post-COVID-19 syndrome ([table 2](#)). A proportion will have postintensive care syndrome with multi-organ impairment, and there should be a wider assessment for symptoms such as fatigue, muscle weakness, breathing pattern disorder, post-traumatic stress, swallow/speech difficulties

and peripheral neuropathy. These should be considered when individualising the exercise and education components of the programme. Unidentified (and therefore untreated) pulmonary thromboembolic disease<sup>91</sup> and myocarditis<sup>92</sup> have been reported in the post-COVID-19 syndrome, which are relative contraindications to PR. Furthermore, postexertional symptom exacerbation (PESE) is a widely reported symptom in post-COVID-19 syndrome.<sup>93</sup> Given the potential for deterioration following overexertion, fatigue and PESE should be closely monitored during PR through symptom, exertion and activity scores and diaries during and after PR sessions.

### Lung cancer

Prehabilitation is the focus on modifiable risk factors in individuals preparing for lung cancer treatment, typically commencing at the point of diagnosis and is multimodal in approach.<sup>94</sup> A systematic review suggested that exercise pre surgery improves physical and pulmonary function, although the interventions were very heterogeneous in nature and duration.<sup>95</sup> While PR addresses some modifiable factors, the time-sensitivity of lung cancer resection means that the traditional outpatient PR model would need significant adaptations to be suitable for prehabilitation (table 1).

A Cochrane review identified eight RCTs of exercise training following surgical resection of non-small cell lung cancer.<sup>96</sup> Compared with usual care, improvement in exercise capacity was greater in the intervention group, but trial populations were small and there was lower certainty for other outcomes. Due to the significant heterogeneity of the interventions, the optimal timing, setting, nature or duration of exercise training for post lung cancer surgery patients remains unclear. Few patients are currently referred for PR after lung cancer surgery.<sup>97</sup>

A Cochrane review identified 6 RCTs (total 221 patients) of exercise training for advanced lung cancer.<sup>98</sup> Compared with usual care, exercise training may improve or avoid decline in exercise capacity and HRQOL, but the small sample sizes and heterogeneity between studies limit interpretation. Advanced lung cancer is not a contraindication to PR per se, but adjustments and flexibility of the PR delivery may be needed for pragmatic reasons (eg, timing of chemotherapy sessions).

### Lung volume reduction

LVR procedures are recommended by the National Institute for Health and Care Excellence (NICE) for the treatment of selected individuals with emphysema and hyperinflation.<sup>99</sup> As part of the workup for LVR, all individuals should receive PR, a prerequisite to randomisation in landmark trials of LVR.<sup>100</sup> Furthermore, it plays an important role in selecting individuals for LVR with up to 20% improving their exercise tolerance to such an extent that they change LVR risk stratification groups.<sup>101</sup>

In the UK, only a small minority of eligible patients undergo LVR due to the absence of standardised referral pathways.<sup>102</sup> However, PR practitioners may have a role in identifying potential candidates as the post-PR assessment represents the point at which the patient's functional capacity and management of breathlessness should be optimised. Recent analysis of data from the National Asthma and COPD Audit suggested that up to 18.1% of PR completers met the NICE criteria for an LVR-focused respiratory review (forced expiratory volume in 1 s <50% predicted, non-smoker, MRC $\geq$ 3, 6MWT>140 m or ISWT>80 m).<sup>103</sup>

### Lung transplantation

Before referral for lung transplantation, individuals with advanced lung disease should have been optimised, including completion of PR. Unlike for lung cancer, waiting time for lung transplantation is unpredictable, and there is little guidance on the ideal content or duration of a prehabilitation programme for lung transplantation, and consequently few published data.

Exercise training following lung transplantation has been studied in more detail. A Cochrane review to determine the benefits and safety of exercise training in adult lung transplant recipients included 8 RCTs involving 438 participants.<sup>104</sup> However, results could not be aggregated due to the small number of underpowered trials and the heterogeneity of the interventions. The authors concluded that the effects of exercise-based rehabilitation following lung transplantation were uncertain due to imprecise estimates of effects and high risk of bias.<sup>104</sup>

### Cardiac disease and pulmonary hypertension

Cardiac comorbidity is highly prevalent in patients attending PR.<sup>16</sup> There are no convincing data to suggest that stable cardiac comorbidity is associated with worse outcomes to PR.<sup>105</sup> Exercise-based cardiac rehabilitation is safe in individuals with CHF and improves exercise capacity and HRQOL.<sup>106</sup> Integrating individuals with CHF and those with chronic respiratory disease into breathlessness rehabilitation programmes is feasible with minor adaptations (table 2).<sup>107</sup> These improve exercise capacity in CHF, with a magnitude similar to that observed in COPD.<sup>108</sup> Only 18% of PR services in the UK currently accept patients with CHF.<sup>16</sup>

In a systematic review of seven trials in patients with primarily pulmonary arterial hypertension (PAH) including some with CTEPH, exercise-based rehabilitation improved 6MWT distance and peak oxygen consumption compared with usual care.<sup>109</sup> A multicentre trial of exercise training in PAH and CTEPH, conducted after the systematic review, showed that exercise training is feasible, safe and well tolerated, and may improve quality of life and peak oxygen consumption.<sup>110</sup> However, the exercise training was inpatient based, individually supervised and atypical of PR practice in the NHS. Collective experience is that supervised exercise training is safe and effective in PAH and CTEPH,<sup>111</sup> and in those with pulmonary hypertension secondary to chronic lung disease. Expert consensus is that patient selection is key (stable disease with no change in drug therapy or dose, and no syncope or symptomatic arrhythmia in previous 2 months).<sup>109 112</sup> In PAH and CTEPH, exercise-based rehabilitation should be directly supervised in person by specialist exercise healthcare professionals such as PR practitioners.<sup>112</sup> Remotely supervised exercise training is not recommended in those with PAH and CTEPH.

### PR around the time of a hospitalised exacerbation of COPD

Extrapulmonary manifestations of hospitalised exacerbations include reduced walking performance,<sup>113 114</sup> HRQOL,<sup>115 116</sup> low PA levels<sup>117</sup> and muscle dysfunction<sup>118</sup>—all of which are associated with poor prognosis,<sup>37 113 119</sup> but also potentially responsive to PR.

The BTS Guideline on PR recommended that individuals hospitalised for acute exacerbation of COPD should be offered PR at hospital discharge to commence within 1 month of discharge.<sup>1</sup> The Cochrane systematic review included 20 trials and 1477 participants and demonstrated moderate to large effects of rehabilitation on HRQOL and exercise capacity in patients with COPD after an exacerbation.<sup>120</sup> Additionally, there

is evidence that PR after a hospitalised exacerbation may reduce the risk of readmission<sup>121 122</sup> and improve survival with a dose-response effect.<sup>123</sup> However, the content, setting and duration of rehabilitation interventions were heterogeneous.

In the UK setting, inpatient rehabilitation may not be feasible given the short duration of hospital stays. Two trials conducted in the NHS setting evaluated PR initiated during the inpatient stay and progressing to a more ‘light touch’ approach to post discharge outpatient treatment with the aim of addressing both the initial insult of the hospitalisation as well promoting recovery.<sup>124 125</sup> However, benefits were less impressive than observed in post exacerbation outpatient PR trials.<sup>121 124-126</sup> Rehabilitation started 1 month after hospitalisation yielded better overall results than rehabilitation started during the hospital admission.<sup>127</sup> A systematic review, including 30 studies, identified that longer programmes, starting after hospital discharge and including an educational component (as well as exercise), were most effective at reducing hospital readmissions.<sup>128</sup>

Implementation of PR following an exacerbation remains a challenge. Real-world data suggest that uptake is between 1.5% and 9%.<sup>123 129</sup> Strategies to improve referral, uptake and completion have been limited.<sup>22</sup> ‘Delayed’ PR following a hospital admission is still associated with benefits,<sup>130</sup> and therefore, it is important to reoffer PR to people who initially decline in the immediate posthospitalisation period.

#### Clinical practice points

- ▶ PR should be offered to symptomatic individuals with chronic respiratory disease including COPD, asthma, bronchiectasis and ILD.
- ▶ PR may be helpful in the recovery of subgroups of patients with post-COVID-19 syndrome where they are functionally and symptom limited.
- ▶ The assessment, exercise and education components of PR should be adapted for relevant cardiorespiratory diseases, taking into account disease-specific issues.
- ▶ The workforce should receive training and be competent to deliver high-quality PR for relevant cardiorespiratory diseases.
- ▶ PR practitioners should have the skill set to support prehabilitation interventions for patients awaiting lung cancer and lung transplant surgery, but the current delivery model of PR needs to be adapted in order to be appropriately time sensitive.
- ▶ PR practitioners have a role in identifying potential candidates for LVR procedures at the post-PR assessment.
- ▶ Patients with stable CHF, PAH or CTEPH can be incorporated safely within directly supervised outpatient PR programmes.
- ▶ Outpatient supervised PR, incorporating both exercise training and education, should be offered to all appropriate patients discharged from hospital, including hospital-at-home and early supported discharge schemes after exacerbation of COPD.
- ▶ Members of the integrated care team should reoffer ‘delayed’ PR in individuals who decline an initial offer of posthospitalisation PR.

#### Research gaps

- ▶ Trials to understand the role of PR in the recovery of post-COVID-19 syndrome.
- ▶ Trials to determine the optimal timing, setting, nature or duration of exercise training for postlung cancer, advanced lung cancer and post lung transplant surgery.

- ▶ Trials to evaluate the effects of PR in hospitalised exacerbations of chronic respiratory disease other than COPD.
- ▶ Interventional trials designed to increase referral to and uptake of post exacerbation PR.
- ▶ The role of alternative remote PR models in the post exacerbation setting.
- ▶ The role of PR in non-hospitalised exacerbations.

#### ALTERNATIVES MODELS OF DELIVERING PR

Barriers to traditional hospital-based PR have been well documented.<sup>18 131</sup> This has highlighted the need for alternative models of delivering PR, as these may potentially increase uptake and accessibility.

National audit data show that non-medical, community-based settings are increasingly used to deliver supervised PR in the UK.<sup>7</sup> PR delivered in a community setting has similar efficacy to that produced in a hospital-based setting.<sup>132</sup> Supervised PR using minimal resources have similar efficacy to programmes using specialist exercise equipment.<sup>133</sup>

Home-based rehabilitation spans a range of delivery options ranging from standardised manuals, web-based applications, telerehabilitation and face-to-face supervision. Across all these modes, the level and frequency of supervision and contact with a healthcare professional may vary dramatically. Commissioners need to consider carefully whether alternative models delivered by providers include the core components detailed in **box 1**. Although some PR models might involve remote supervision, published trials have all incorporated a directly supervised face-to-face, validated exercise test prior to the intervention to evaluate safety and facilitate exercise prescription. Furthermore, baseline exercise capacity is required to quantify effectiveness.

#### Home based, non-digital

In this model, individual patients are provided with a manual, exercise diary or written material which provides structured exercise and educational components (**table 3**). These are usually supported by remote supervision from skilled PR healthcare professionals. Previous data suggest that this model does improve HRQOL and exercise capacity compared with usual care, although differences are modest.<sup>134</sup> Trials that have compared home-based models supported by manual and telephone support with outpatient, centre-based PR have produced short-term clinical outcomes that are similar to centre-based PR.<sup>135-137</sup> However, an interesting observation is that ‘gold-standard’ centre-based rehabilitation did not produce the expected improvements in exercise capacity (**figure 1**). In a real-world study, a home-based, manual-structured programme with weekly telephone supervision produced similar improvements in HRQOL, but smaller changes in exercise capacity, compared with a propensity-matched cohort undergoing twice-weekly centre-based supervised programme.<sup>138</sup>

Although home-based programmes typically involve less frequent staff contact than centre-based approaches, that contact is conducted one to one, and therefore, data are required to evaluate the cost-effectiveness of such an approach. Other home-based therapies include the use of neuromuscular electrical stimulation which improves muscle weakness in those with advanced disease.<sup>139 140</sup> However, the effect on exercise capacity is unclear.<sup>139 141</sup>

#### Home-based web platform

These are similar to home-based models described in the ‘Home based, non-digital’ section, except that the programme

**Table 3** Comparison of home-based, non-technology versus centre-based PR: summary of selective studies

Study	Population	Intervention/control	Outcomes
Maltais 2018 <sup>137</sup>	RCT; 252 participants with COPD (Canada)	Home-based (including one home visit and weekly telephone calls) vs outpatient centre-based rehabilitation supervised PR for 8 weeks. Both groups received 4 weeks of in-person centre-based education	Similar changes in dyspnoea (primary outcome) above the MCID for both groups. 6MWT change below the MCID both groups
Holland 2017 <sup>135</sup>	RCT; 166 participants with COPD (Australia)	Home-based (including one home visit and weekly telephone calls) programme versus outpatient centre-based supervised PR for 8 weeks	Clinical outcomes that were equivalent to centre-based pulmonary rehabilitation. 6MWT below MCID for both groups (primary outcome)
Horton 2018 <sup>136</sup>	RCT; 287 participants with COPD (UK)	Structured unsupervised home-based programme including a manual and telephone support for 7 weeks vs outpatient centre-based supervised PR for 7 weeks	Inconclusive that home-based PR was non-inferior to centre-based PR in CRQ-D (primary outcome). ISWT below MCID for both groups
Nolan 2019 <sup>138</sup>	154 participants with COPD (propensity-matched cohort study) (UK)	Home-based structured exercise programme with weekly telephone calls vs outpatient centre-based supervised PR for 8 weeks	Significant improvements in both groups in ISWT but home-based group demonstrated numerically smaller improvements; ISWT change above MCID for Centre-based PR; below MCID for home-based PR. Clinically and statistically significant improvements in HRQOL in both groups.

COPD, chronic obstructive pulmonary disease; CRQ-D, Chronic Respiratory Questionnaire-Dyspnoea Domain; HRQOL, health-related quality of life.; ISWT, incremental shuttle walk test; MCID, minimum clinically important difference; 6MWT, 6 min walk test; PR, pulmonary rehabilitation; RCT, randomised controlled trial.

is supported by a web-based platform or app (table 4). A home-based, online platform, 'myPR', was compared with face-to-face PR delivered in an outpatient setting, and demonstrated that 'myPR' was safe and well tolerated, and non-inferior to the control arm in terms of effects on exercise capacity and symptom scores.<sup>142</sup> However, the trial population was selective (exclusion criteria included exercise-induced oxygen desaturation, functional limitation, comorbidities, poor digital literacy), and the control arm was not a conventional supervised PR programme, but comprised exercise stations matched to those provided by the online platform.<sup>142</sup> Completers of both a home-based interactive web platform 'self management programme of activity, coping and education for COPD' and a standard care outpatient PR programme showed similar improvements in endurance shuttle walk and dyspnoea.<sup>143</sup> However, engagement with digital technology was challenging; only 103 of 2646 invited patients were randomised, while 57% of the web platform arm dropped out.<sup>143</sup> Both platforms provided an introductory face to face session, with either contact details provided for further

queries<sup>142</sup> or weekly contact via email or telephone using a standardised proforma.<sup>143</sup>

### Video telerehabilitation

Video telerehabilitation encompasses synchronous real-time PR supported by videoconferencing. A small trial showed that video telerehabilitation improved endurance exercise capacity and self-efficacy in patients with COPD when compared with usual care.<sup>144</sup> Two studies have compared video telerehabilitation with face-to-face centre-based PR, and shown similar effects on exercise capacity and HRQOL.<sup>145 146</sup> However, the improvements in exercise capacity were modest in both intervention and standard care arms (table 5). Furthermore, participants were provided with video technology and specialist exercise equipment to use in the home for free, which may not be generalisable to the NHS setting.

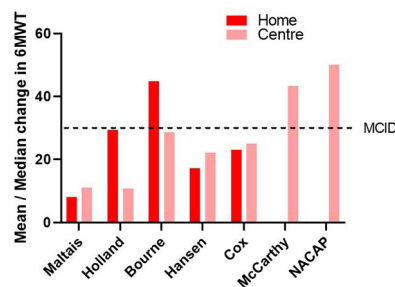
Outside of the home-setting, videoconferencing has also been used to support satellite telerehabilitation centres ('hub-and-spoke' model).<sup>147 148</sup> Trials are needed to test the effects of such models on patient throughput, staffing ratios and travelling for patients.<sup>148</sup> There are no published data on hybrid models (which combine limited centre-based PR with home-based alternative model of PR).

### Virtual reality

Virtual reality is an emerging technology that might provide an interactive and visually stimulating approach to providing PR in the home setting.<sup>149</sup> To date, there are few published data, of which most have limitations in the reporting quality.<sup>150</sup> Acceptability is also unknown in a patient population that traditionally have digital hesitancy.<sup>11</sup>

### Cultural adaptations to PR

In the 'Extending the Scope of PR' section, we discussed adaptations in order to extend the scope of the PR model for individuals other than COPD. There is increasing interest in adapting and personalising the PR intervention to be culturally and demographically appropriate. Examples include rhythmic movements, singing and dance, volleyball and yoga.<sup>151-153</sup> Currently,



**Figure 1** Mean or median change in 6MWT distance in trials comparing home-based PR models (non-technology, web platform and video telerehabilitation) with traditional supervised PR.<sup>135 137 142 145 146</sup> In comparison, the mean change in 6MWT distance recorded during traditional supervised PR reported in the Cochrane systematic review<sup>2</sup> and reported by PR services to NACAP in 2019.<sup>16</sup> 6MWT, 6 min walk test; COPD, chronic obstructive pulmonary disease; MCID, minimum clinically important difference (30 m for 6MWT); NACAP, National Asthma and COPD Audit Programme; PR, pulmonary rehabilitation.



**Table 4** Comparison of home-based, web platform versus centre-based PR: summary of selective studies

Study	Population	Intervention/control	Outcomes
Chaplin 2017 <sup>143</sup>	RCT; 103 participants with COPD (UK)	Web-based programme (SPACE for COPD) of exercise and education versus centre-based supervised PR, twice weekly, 2 hourly sessions for 7 weeks (4 weeks supervised; 3 weeks unsupervised).	Web-based PR was safe and well tolerated. Statistically significant improvements within both groups for endurance shuttle walk and dyspnoea meeting MCID.
Bourne 2017 <sup>142</sup>	RCT; 90 participants with COPD (UK)	Six-week web-based PR via log in and access to 'myPR' versus a supervised centre-based group sessions, twice weekly for 6 weeks.	Web-based PR was safe and well tolerated, and non-inferior to face-to-face centre-based programme in terms of effects on 6MWT distance and symptom scores. 6MWT exceeded MCID for web-based PR.

ESWT, endurance shuttle walk test; MCID, minimum clinically important difference; 6MWT, 6 min walk test; PR, pulmonary rehabilitation; RCT, randomised controlled trial; SPACE for COPD, self management programme of activity, coping and education for chronic obstructive pulmonary disease.

little data exist to support whether such adaptations or adjuncts can enhance PR delivery either through improvement in core outcomes, or better completion rates.

**Non-PR alternatives**

In some individuals, settings or situations, a PR model incorporating the core components outlined in box 1 cannot be delivered, or has been declined. The PR practitioner may still wish to offer an alternative intervention to PR which incorporates a physical-training component, such as PA coaching<sup>154</sup> or a self-management programme.<sup>155</sup> There may also be a role for social prescribing such as singing for lung health<sup>156</sup> or active mind-body movement therapies such as Tai Chi or yoga.<sup>157-159</sup> Although these might have positive benefits for some individuals, they should not be considered as PR, and therefore, not commissioned as such.

**Summary of alternative models of delivering PR**

Standardised reporting is crucial to our understanding and development of alternative models of delivering PR, which may improve accessibility to a more diverse population.<sup>160</sup> A frequent observation is the lower-than-expected benefits associated with the 'gold-standard' centre-based arm in equivalence or non-inferiority trials. This may reflect selective trial populations lacking equipoise. Furthermore, systematic reviews of telerehabilitation studies have shown that the mean change in 6 min walk distance with telerehabilitation are lower than the established minimum clinically important difference,<sup>161</sup> and lower than that observed with centre-based PR (figure 1).<sup>2</sup> Real-world observational data have shown that home-based, remotely supervised PR are associated with a smaller magnitude of change in exercise-capacity, about half of that seen in directly supervised, centre-based PR.<sup>138</sup>

Overall, the outcomes of alternative models of delivering PR have been heterogeneous and studies need to be interpreted with caution. Although systematic reviews have suggested that alternative models of PR achieve outcomes similar to those seen in traditional centre-based PR,<sup>161</sup> the certainty of evidence is limited by the small number of studies with relatively few participants, varying models of care and whether models are generalisable to the NHS setting. Furthermore, almost all published data are restricted to COPD.

**Clinical practice points**

- ▶ Every eligible individual referred for PR should have the opportunity to access directly supervised, centre-based PR in a timely way as this model is supported by a convincing evidence base.
- ▶ In patients who decline or drop out from supervised centre-based PR, providers should offer an alternative model of delivery. Any alternative model should have a supporting evidence base (ideally within the NHS setting), and incorporate a directly supervised, validated exercise test from which individualised exercise can be prescribed, and validated outcome measures to evaluate efficacy.
- ▶ Both staff and patients require training to support alternative PR models, particularly those involving digital technology, in order to promote digital inclusion.

**Research gaps**

- ▶ Further trials are required to evaluate the efficacy and clinical effectiveness of alternative models of PR, including hybrid models, particularly in the NHS setting.
- ▶ An agreed framework for the reporting of technology-based interventions, including core datasets and outcomes.

**Table 5** Comparison of video telerehabilitation versus usual care without exercise or standard care: summary of selective studies

Study	Population	Intervention/control	Outcomes
Tsai 2017 <sup>144</sup>	RCT; 37 participants with COPD (Australia)	Supervised home-based real-time video telerehabilitation (exercise three times/week for 8 weeks) vs usual care	Statistical, and clinically significant, improvement in ESWT in video telerehabilitation group, exceeding MCID for the ESWT in intervention group. Non significant changes in HRQOL.
Hansen 2020 <sup>146</sup>	RCT; 134 participants with COPD (Denmark)	10 week video telerehabilitation programme vs supervised centre-based rehabilitation	Videotelerehabilitation appeared safe. Similar changes in exercise capacity, breathlessness and HRQOL. Changes in the 6MWT were below the MCID for both groups
Cox 2021 <sup>145</sup>	RCT; 142 participants with chronic respiratory disease (100 with COPD) (Australia)	Video tele-rehabilitation programme vs supervised centre-based PR, both interventions 8 weeks with 16 sessions	Video-telerehabilitation appeared safe. There were no significant differences between groups for any outcome at either time point post intervention and 12 months). Changes in the 6MWT were below the MCID for both groups

COPD, chronic obstructive pulmonary disease; ESWT, endurance shuttle walk test; HRQOL, health-related quality of life; MCID, minimum clinically important difference; 6MWT, 6 min walk test; PR, pulmonary rehabilitation; RCT, randomised controlled trial.

- ▶ Alternative models of PR delivery should be evaluated in chronic respiratory diseases other than COPD.

## ADJUNCTS TO AND MAINTENANCE OF PR

Since the BTS Guideline,<sup>1</sup> several trials have informed on the potential utility of adjunctive strategies to improve PR outcomes.

### Oxygen supplementation

Oxygen supplementation in the experimental setting acutely enhances endurance exercise performance in individuals with COPD and allows for higher training intensity.<sup>162–165</sup> However, this has not translated to improved outcomes in PR. In a multi-centre trial, 111 participants with COPD and exercise-induced oxygen desaturation were randomised to receive either supplemental oxygen or room air during an 8-week exercise-training programme.<sup>166</sup> Exercise capacity and HRQOL improved in both groups, with no additional benefit from training with supplemental oxygen.<sup>166</sup> The majority of participants had only modest exercise induced oxygen desaturation, and the acute physiological response to oxygen was not tested prior to the training programme.<sup>167</sup> Limited clinical trial data exist regarding the role of supplemental oxygen during PR in conditions other than COPD. PR teams should have well-established bidirectional referral pathways with local home oxygen assessment and review teams.

### Non-invasive ventilation

Systematic reviews and meta-analyses of studies using NIV during supervised exercise training provide conflicting evidence of the benefits. One meta-analysis showed improvements in endurance exercise capacity with the addition of NIV,<sup>168</sup> while another meta-analysis found similar responses to exercise training between NIV supported and sham arms.<sup>169</sup> In hospitalised exacerbations of cystic fibrosis and bronchiectasis, Dyer *et al* demonstrated that application of NIV could acutely improve endurance cycling time,<sup>170</sup> but there were concerns about patient acceptability. Practical considerations include the additional equipment needed and time required to supervise patients on NIV during PR; this is less problematic in those already established on domiciliary NIV.<sup>171</sup>

### Inspiratory muscle training

Since the Guideline, three large RCTs have investigated the value of IMT as an adjunct to PR. Although IMT improved inspiratory muscle strength, particularly in those with inspiratory

muscle weakness,<sup>172</sup> significant additive benefits of IMT to PR in core outcomes such as exercise capacity or HRQOL are less convincing.<sup>172–174</sup> Limited and conflicting data exist in respiratory disease other than COPD.<sup>175 176</sup>

### PA counselling

Physical inactivity is associated with poor prognosis in COPD.<sup>66</sup> The effects of PR alone on PA levels are relatively modest.<sup>177</sup> A systematic review demonstrated that PA promotion with pedometers as an adjunct to PR improves step counts/day,<sup>178</sup> although studies were small and results heterogeneous. A trial conducted in the NHS setting randomised 152 participants with COPD to an 8-week PR programme either with or without pedometer-directed step targets reviewed weekly.<sup>179</sup> No significant differences in change in time spent in moderate intensity activity, exercise capacity or HRQOL were seen between groups.<sup>179</sup> Studies exploring behavioural counselling as an adjunct to PR, typically using motivational interviewing, have produced mixed results.<sup>180–182</sup> As discussed in the 'Functional assessments section', PA data collection and reporting should conform to international consensus recommendations.<sup>66</sup>

### Maintenance of PR

The beneficial effects of PR decline over 1 year.<sup>183</sup> The previous BTS Guideline recommended that PR graduates should be encouraged to continue exercise. However, the format and delivery of maintenance programmes reported in the literature vary significantly.<sup>184</sup>

The evidence for maintenance programmes after PR are inconsistent (table 6). A Cochrane review of supervised maintenance programmes showed clinically important improvements in HRQOL with maintenance intervention but no significant differences in exercise capacity.<sup>185</sup> In contrast, the long-term efficacy of PR with home-based or low frequency maintenance programmes showed improved maintenance of exercise capacity but no differences in HRQOL.<sup>186</sup>

Further studies are needed to explore the optimal frequency and duration of supervised and unsupervised maintenance programmes, and the cost-effectiveness of such programmes compared with alternative approaches (eg, repeated PR offers).

### Clinical practice points

- ▶ Oxygen supplementation should not be routinely used as an adjunct to PR except in individuals already established on long-term or ambulatory oxygen therapy.

**Table 6** Systematic reviews of maintenance PR: summary of selective studies

Study	No of trials	Review question	Results
Malaguti, 2021 <sup>185</sup>	21	Supervised maintenance programmes following pulmonary rehabilitation compared with usual care for COPD.	Supervised maintenance programmes not associated with increased adverse events, may improve health-related quality of life, and could improve exercise capacity at 6–12 months. Strength of evidence was limited (high risk of bias and small sample size).
Imamura, 2020 <sup>186</sup>	7	Long-term efficacy of pulmonary rehabilitation with home-based or low frequent maintenance programmes in COPD patients compared with those who had no maintenance programme.	PR with maintenance significantly improved 6MWT, but not HRQOL was observed.
Jenkins, 2018 <sup>187</sup>	8	Efficacy of supervised maintenance exercise programmes following pulmonary rehabilitation compared with usual care on healthcare use.	Supervised maintenance exercise led to clinically important reduction in the rate of respiratory-cause hospital, overall risk of an exacerbation and mortality).
Busby, 2014 <sup>188</sup>	8	Review of existing maintenance interventions following pulmonary rehabilitation	Most studies showed initial positive intervention effects, which declined to non-significance within 3–12 months after completion of maintenance.

COPD, chronic obstructive pulmonary disease; HRQOL, health-related quality of life; 6MWT, 6 min walk tests; PR, pulmonary rehabilitation.

- ▶ NIV should not be routinely used as an adjunct to PR in those naïve to domiciliary NIV, but could be offered to those already established on domiciliary NIV.
- ▶ IMT, as an adjunct to PR, is associated with improvements in respiratory muscle function, but this has not translated to improvements in core outcomes.
- ▶ PA counselling should be a core component of the PR educational component. The use of pedometers or/and additional PA counselling as adjuncts to PR require further evaluation.
- ▶ PR programmes should deliver self-management education and advice around the importance of regular exercise after the PR programme has been completed. There is insufficient evidence to support the routine formal delivery of maintenance programmes.

### Research gaps

- ▶ The role of oxygen supplementation during PR in specific subgroups: severe exercise induced oxygen desaturation (eg, below 80%), those who demonstrate acute physiological response to oxygen.
- ▶ Understanding the role of behavioural change on PA promotion and maintenance of the benefits of PR.
- ▶ Optimising the frequency, duration and content of supervised and unsupervised maintenance programmes with concomitant assessment of cost-effectiveness.
- ▶ Trials comparing maintenance interventions with repeated PR.

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