Effectiveness of home-based pulmonary rehabilitation: systematic review and meta-analysis

Md. Nazim Uzzaman [1], Dhiraj Agarwal[2], Soo Chin Chan[3], Julia Patrick Engkasan [3], G.M. Monsur Habib[4], Nik Sherina Hanafi[3], Tracy Jackson[1], Paul Jebaraj[5], Ee Ming Khoo [3], Fatim Tahirah Mirza[6], Hilary Pinnock [1], Ranita Hisham Shunmugam[7] and Roberto A. Rabinovich[8]

[1]NIHR Global Health Research Unit on Respiratory Health (RESPIRE), The University of Edinburgh, Edinburgh, UK. [2]Vadu Rural Health Program, KEM Hospital and Research centre, Pune, India. [3]Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia. [4]Community Respiratory Centre, Bangladesh Primary Care Respiratory Society, Khulna, Bangladesh. [5]Rural Unit for Health and Social Affairs, Christian Medical College, Vellore, India. [6]Faculty of Health Sciences, Universiti Teknologi MARA, Selangor, Malaysia. [7]Library, University of Malaya, Kuala Lumpur, Malaysia. [8]MRC Centre for Information Research, University of Edinburgh, Edinburgh, UK.

Corresponding author: Roberto A. Rabinovich (roberto.rabinovich@ed.ac.uk)

Shareable abstract (@ERSpublications)
Home-based pulmonary rehabilitation is as effective as centre-based in improving exercise capacity and quality of life, and is an option for people with COPD whose access to pulmonary rehabilitation centres is difficult. https://bit.ly/39HkMm4

Cite this article as: Uzzaman MN, Agarwal D, Chan SC, *et al*. Effectiveness of home-based pulmonary rehabilitation: systematic review and meta-analysis. *Eur Respir Rev* 2022; 31: 220076 [DOI: 10.1183/16000617.0076-2022].

Received: 27 April 2022
Accepted: 14 June 2022

Abstract

Introduction Despite proven effectiveness for people with chronic respiratory diseases, practical barriers to attending centre-based pulmonary rehabilitation (centre-PR) limit accessibility. We aimed to review the clinical effectiveness, components and completion rates of home-based pulmonary rehabilitation (home-PR) compared to centre-PR or usual care.

Methods and analysis Using Cochrane methodology, we searched (January 1990 to August 2021) six electronic databases using a PICOS (population, intervention, comparison, outcome, study type) search strategy, assessed Cochrane risk of bias, performed meta-analysis and narrative synthesis to answer our objectives and used the Grading of Recommendations, Assessment, Development and Evaluations framework to rate certainty of evidence.

Results We identified 16 studies (1800 COPD patients; 11 countries). The effects of home-PR on exercise capacity and/or health-related quality of life (HRQoL) were compared to either centre-PR (n=7) or usual care (n=8); one study used both comparators. Compared to usual care, home-PR significantly improved exercise capacity (standardised mean difference (SMD) 0.88, 95% CI 0.32–1.44; p=0.002) and HRQoL (SMD −0.62, 95% CI −0.88–−0.36; p<0.001). Compared to centre-PR, home-PR showed no significant difference in exercise capacity (SMD −0.10, 95% CI −0.25–0.05; p=0.21) or HRQoL (SMD 0.01, 95% CI −0.15–0.17; p=0.87).

Conclusion Home-PR is as effective as centre-PR in improving functional exercise capacity and quality of life compared to usual care, and is an option to enable access to pulmonary rehabilitation.

Introduction

An estimated 545 million people globally are affected by chronic respiratory diseases such as COPD, remodelled asthma, pulmonary impairment after tuberculosis, interstitial lung disease (ILD), bronchiectasis and cystic fibrosis [1]. Chronic respiratory diseases are associated with breathlessness, fatigue and muscle dysfunction, which contribute to reduced physical activity levels and functional exercise capacity [2], and impaired health-related quality of life (HRQoL) [3, 4].

Pulmonary rehabilitation is an individually tailored multifaceted intervention that improves the physical condition and psychological wellbeing of people with chronic respiratory diseases [5–7]. Despite proven effectiveness [8, 9] and guideline recommendations [10, 11], pulmonary rehabilitation is under-utilised.

The reasons for poor attendance and completion rates are multifactorial, but inconvenient timing of programmes and geographical distance to pulmonary rehabilitation centres are commonly identified barriers [12–16]. While pertinent even in high-income countries [17–19], poor transport infrastructure in low- and middle-income countries (LMICs) exacerbates these barriers [20]. Typically, pulmonary rehabilitation is provided in hospital centres (centre-PR) [21], but community-based centres [22], home-based pulmonary rehabilitation (home-PR) with telephone mentoring [23], or telerehabilitation programmes [24], are attracting increasing interest. The ongoing coronavirus disease 2019 pandemic has necessitated remote delivery of the treatment for reasons of infection control [25].

Evidence of the effectiveness of these options varies. A subgroup analysis in a Cochrane review favoured centre-PR [8], while three systematic reviews concluded that home/community-PR could be as effective as centre-PR for people with COPD [26–29]. However, combining home and community services overlooks the distinction between a community-based group supervised in-person by a healthcare professional and a programme delivered to an individual in their own home. In addition, these reviews are limited by disease (COPD only), although there is evidence that pulmonary rehabilitation is of benefit in bronchiectasis and ILD [30–32]. More recently, a Cochrane review concluded that telerehabilitation for people with chronic respiratory diseases, achieved similar effectiveness and safety outcomes to centre-PR [33]. "Telerehabilitation" defines the intervention by the means of communication and the review included pulmonary rehabilitation delivered to individuals or groups (either physical or virtual) in any location, including in the patient's home or at a healthcare centre. In contrast, we defined home-PR as sessions undertaken by individuals by themselves (although a family member may be involved) and typically at home. Apart from baseline and post-PR assessments [32], the patient does not attend a centre (either a hospital centre or a local "satellite" community centre) and is not supervised face-to-face by a healthcare professional (though there may be remote communication from a healthcare professional for some or all of the sessions), is not part of an "in-person" group. In addition, to distinguish from "exercise training programmes" included in some reviews [26, 27, 32, 33], our definition of pulmonary rehabilitation comprised both exercise and at least one nonexercise component.

We aimed to systematically review the literature to assess the effectiveness, completion rates and components used in effective home-PR for people with chronic respiratory diseases. Our hypotheses were that 1) home-PR is superior to usual care, and 2) home-PR is noninferior to centre-PR. In people with chronic respiratory diseases, our objectives were to 1) assess the clinical effectiveness of home-PR compared to centre-PR or usual care at improving health outcomes (*i.e.* exercise capacity (primary outcome), HRQoL (primary outcome), dyspnoea, muscle fatigue, exacerbations and hospitalisations for chronic respiratory disease); 2) describe the components of home-PR that are associated with successful interventions (*e.g.* intensity of exercise, duration of the programme, education and/or other nonexercise components, frequency of supervision, information/resources, involvement of family members); and 3) compare the completion rate (defined as participating in $\geqslant$70% of pulmonary rehabilitation sessions) of home-PR with centre-PR.

Methods

We followed Cochrane methodology [34], and used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [35] to report our review findings. The review is registered at www.crd.york.ac.uk/PROSPERO (CRD42020220137) and the protocol has been published [36].

Search strategy

We developed a search strategy to identify randomised controlled trials (RCTs) and controlled clinical trials of "chronic respiratory disease" AND "pulmonary rehabilitation" AND "home-PR" from 1990 (when pulmonary rehabilitation was first recommended by global COPD guidelines [37]) to 12 October 2020, without any language restrictions. In addition, we checked reference lists and conducted forward citation on included studies and on Cochrane reviews of pulmonary rehabilitation [8]. We searched MEDLINE, the Cumulative Index to Nursing and Allied Health, Cochrane, Embase, PeDRO, and PsycInfo (see appendix 1 in the supplementary material). Table 1 describes the PICOS (population, intervention, comparison, outcome, study type) search strategy and our definition of home-PR and centre-PR. A pre-publication update was conducted in August 2021 using forward citation of the Cochrane review [8] and all the studies included in this review [38].

Selection process

Following the search, all identified records were loaded into EndNote X9 (Clarivate Analytics, Philadelphia, PA, USA) and duplicates were removed. Six trained reviewers (M.N. Uzzaman, T. Jackson, J.P. Engkasan, F.T. Mirza, D. Agarwal, P. Jebaraj) worked in pairs to independently screen titles and

TABLE 1 PICOS (population, intervention, comparison, outcome, study type) table for the search strategy

	Description, inclusion	Exclusion criteria	Operational rules
Population	Adults with primary diagnosis of CRDs Age >18 years Comorbidity will not be an exclusion criterion	Pregnant women and paediatric population Rehabilitation provided to predominant condition is nonrespiratory conditions Recovery from acute infections or injury (*e.g.* immediately post-COVID-19) until the condition has been stable for 6 months Conference abstract Lung cancer Pulmonary hypertension	PR delivered to people with CRDs such as COPD, remodelled asthma, PIAT, bronchiectasis, ILD, CF, stable post-COVID-19 (but excluding post-ICU rehabilitation) will be studied. We will also include PR delivered to people with more than one CRD, or undifferentiated chronic respiratory conditions Conference abstracts will be excluded, but will prompt a search for a subsequent published paper
Intervention	Home-PR that comprises both exercise and at least one nonexercise component for a duration not less than 4 weeks	Formal hospital or community medical centre-based programmes	Home-PR: the key criterion is that the sessions are undertaken by individuals by themselves (although a family member may be involved) and typically at home. Apart from baseline and post-PR assessments, the patient does not attend a centre (either a hospital centre or a local "satellite" centre) and is not supervised face-to-face by a healthcare professional (although there may be remote communication from a healthcare professional for some or all of the session), and is not part of an "in-person" group Exercise sessions typically include aerobic, endurance, resistance and reconditioning exercises, although local resources and preferences may include other exercise modalities. Nonexercise components commonly include patient education, energy conservation training, smoking cessation, psychological support, self-management skill development or other recognised PR interventions, along with optimisation of pharmacotherapy
Comparison	Either population receiving centre-PR or receiving usual care	No control group	Centre-PR: the key criterion is that the sessions are under direct healthcare professional's supervision. The "centre" can be in a hospital, community setting or remote facility. Centre-based sessions are normally group-based (although it is recognised that this may be modified in the context of a pandemic). Telehealth services where patients attend a supervised satellite centre would be considered as centre-PR Usual care: the standard care received by individuals with CRD in the relevant healthcare system, but excluding the exercise components of PR
Outcomes	Either one of the following outcome measures: HRQoL Functional exercise capacity ± Additional outcome(s): Uptake of the service, completion rates Assessment of motivation/ other intermediate outcome Activities of daily living Physical activity level Symptom control Psychological status Healthcare burden, *e.g.* exacerbation rates, hospitalisation, *etc.* Adverse effect	Not including HRQoL or any measurement of exercise capacity as outcome	Any validated instruments will be considered: HRQoL: *e.g.* SGRQ, CRQ, EQ-5D Functional exercise capacity: *e.g.* 6MWT, ISWT, ESWT. We will also include step tests and sit-to-stand tests that are sometimes used in home-PR assessments Symptom control: *e.g.* mMRC, CCQ, Borg scale Psychological status: *e.g.* HADS, PHQ-9, STAI, Beck's inventory tests
Setting	Any settings		Low- or high-resource settings, irrespective of level of economies of the countries
Study designs	RCTs, CCTs	Cohort study, case series, case report	We will exclude studies that do not have a control group. We will consider RCTs to answer all of the three research questions (*i.e.* effectiveness, components and completion rate of home-PR), and consider CCTs to answer research questions 2 and 3
Language	No language restriction		

CRD: chronic respiratory disease; COVID-19: coronavirus disease 2019; PR: pulmonary rehabilitation; PIAT: pulmonary impairment after tuberculosis; ILD: interstitial lung disease; CF: cystic fibrosis; ICU: intensive care unit; HRQoL: health-related quality of life; SGRQ: St George's Respiratory Questionnaire; CRQ: Chronic Respiratory Questionnaire; EQ-5D: EuroQol Five Dimension; 6MWT: 6-min walk test; ISWT: incremental shuttle walking test; ESWT: endurance shuttle walking test; mMRC: modified Medical Research Council dyspnoea scale; CCQ: Clinical COPD Questionnaire; HADS: Hospital Anxiety and Depression Scale; PHQ-9: Patient Health Questionnaire-9; STAI: State-Trait Anxiety Inventory; RCT: randomised controlled trial; CCT: clinical controlled trial. Reproduced from [36] with permission.

abstracts, followed by full-text papers using the inclusion and exclusion criteria, defined by our operational rules (table 1). Disagreements were resolved by discussion with the review team (H. Pinnock, R.A. Rabinovich, Su May Liew (University of Malaya, Kuala Lumpur, Malaysia), G.M.M. Habib, N.S. Hanafi and S.C. Chan) as necessary. The process is reported in a PRISMA flow diagram (figure 1).

Outcome measurement

Our primary outcomes were functional exercise capacity and HRQoL: 1) functional exercise capacity measured with any validated tools such as the 6-min walk test (6MWT) [39], Incremental Shuttle Walking Test (ISWT) [40] or Endurance Shuttle Walking Test (ESWT) [41]; 2) HRQoL measured with any validated tools such as the St George's Respiratory Questionnaire (SGRQ) [42], Chronic Respiratory Questionnaire (CRQ) [43], COPD Assessment Test (CAT) [42] or Short Form (SF-36 or SF-12).

We were interested in between-group differences at the post-pulmonary rehabilitation assessment (or first follow-up assessment if post-pulmonary rehabilitation assessment was not reported). Where multiple assessment tools for an outcome (exercise capacity or HRQoL) were reported, we used the most frequently reported measure (*e.g.* 6MWT, SGRQ) in the meta-analysis.

Data extraction and risk-of-bias assessment

Data extraction was carried out by six reviewers (M.N. Uzzaman, T. Jackson, J.P. Engkasan, F.T. Mirza, D. Agarwal, P. Jebaraj) independently working in pairs, and checked by a third review author (H. Pinnock, R.A. Rabinovich). Data were extracted using a data extraction form in a Microsoft Excel spreadsheet and based on Cochrane Effective Practice and Organisation of Care guidance [44]. The following data were

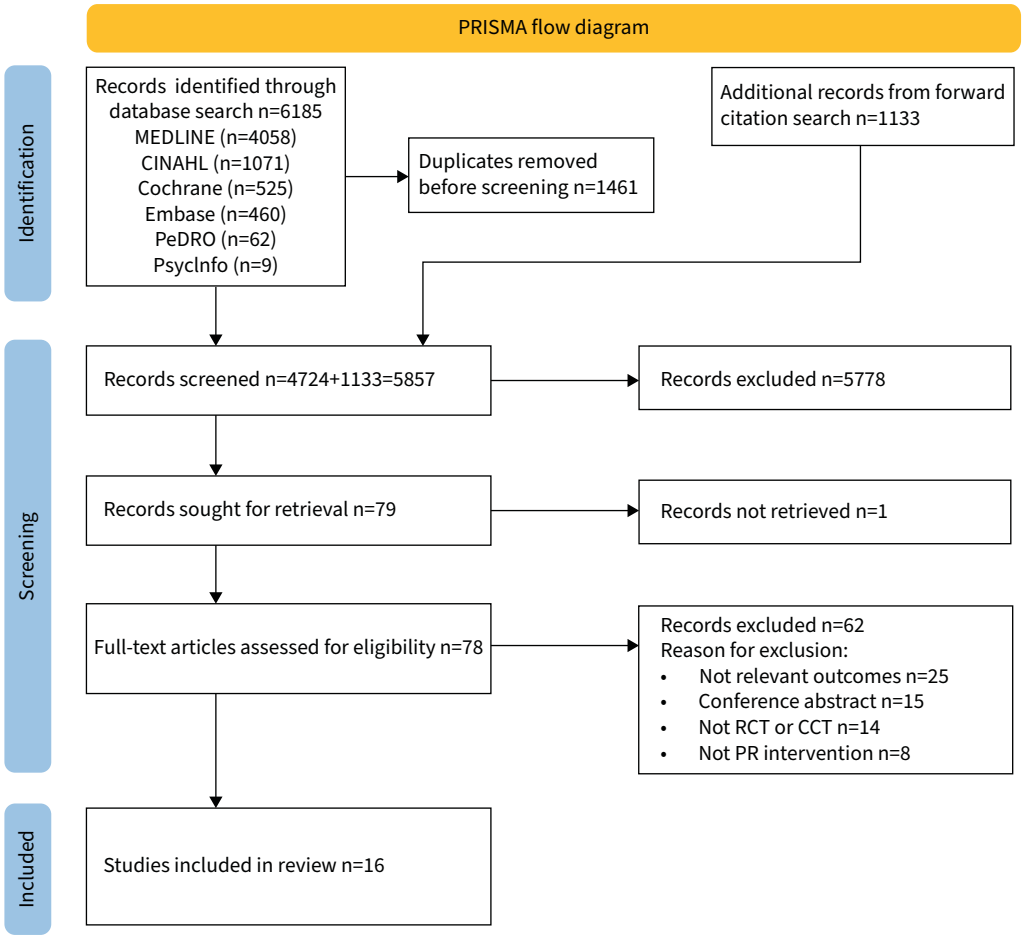


FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. CINAHL: Cumulative Index to Nursing and Allied Health; RCT: randomised controlled trial; CCT: clinical controlled trial; PR: pulmonary rehabilitation.

extracted from included studies: methods (study location, study design, duration of the intervention, duration of each pulmonary rehabilitation session, mode of supervision, follow-up period (if any)); participant characteristics (number, mean age, gender, diagnosis, severity of the condition); interventions (intervention, comparison); outcomes (primary and secondary outcomes specified and collected (at baseline and at the time of intervention completion) and follow-up measures at any other time point reported).

One review author (M.N. Uzzaman) transferred data into the Review Manager software (RevMan 2020, version 5.4.1) for conducting meta-analysis and another review author (R.A. Rabinovich) checked data accuracy. The six reviewers (M.N. Uzzaman, T. Jackson, J.P. Engkasan, F.T. Mirza, D. Agarwal, P. Jebaraj) also independently assessed methodological quality of all included studies using the Cochrane risk of bias tool for RCTs [45]. Discrepancies were resolved by discussion within the team. We assessed the risk of bias in the following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, other sources of bias and overall risk of bias. We assessed each potential source of bias as high, low or unclear and summarised the "risk of bias" judgements across different studies for each of the domains in a risk of bias table. We contacted the author(s) of included studies to obtain any incomplete or missing data, but did not perform any statistical calculation for missing data to include in the meta-analysis.

Heterogeneity and reporting bias

We assessed heterogeneity [46], and explored clinical and methodological reasons for substantial heterogeneity (I^2 statistic >50%) in our primary outcome as defined in our *a priori* subgroups [34], and a sensitivity analyses for the effect of risk of bias. We were not able to pool >10 studies and therefore did not create a funnel plot to test for publication bias [47].

Subgroups and sensitivity analyses

Our *a priori* subgroups were high-/low-income countries, chronic respiratory disease diagnosis, severity, intensity of intervention and arrangements for supervision of the home-PR programme [36]. We undertook a sensitivity analysis of our primary outcomes for the home-PR *versus* centre-PR comparison excluding studies at high risk of bias (there were too few studies for a sensitivity analysis of the home-PR *versus* usual care analysis).

Data analysis to answer the three objectives

Effectiveness of home-PR

We performed meta-analysis using Review Manager software for the primary and secondary outcomes, comparing home-PR with centre-PR or usual care. For continuous data, we calculated the mean difference (MD) (for same scale metric) or standardised mean difference (SMD) (for different scale metrics) with 95% confidence intervals. We used an inverse variance method, and chose a random-effects model to account for between-study heterogeneity in the meta-analysis. At least two studies were needed to perform a meta-analysis and measure the effect size. We used pooled mean differences if the same measurement tool was used in the included RCTs, or if the measurement tool varied among trials, we used SMDs for our primary analysis, but reported pooled MDs for the most commonly used outcome as a sensitivity analysis. A p-value <0.05 was considered statistically significant for the overall effect. For comparison of home-PR and centre-PR, if sufficient studies used the same measure for functional exercise capacity or HRQoL, we defined the noninferiority margin as the minimum clinically important difference (MCID) (*e.g.* 30 m for the 6MWT).

Components of home-PR

We identified the components described in internationally recognised guidelines for pulmonary rehabilitation [5, 7, 11, 48] and constructed a matrix comparing components used in the included trials reporting effective interventions *versus* those reporting no effect.

Uptake, adherence and completion

We used a narrative approach to synthesise reported uptake, engagement, completion and attrition in home-PR and centre-PR groups using the following definitions. Uptake: number of patients who attended the initial/baseline assessment and at least one pulmonary rehabilitation session; engagement: the proportion of pulmonary rehabilitation sessions attended. This reflects the "dose" of the intervention received and may be reported as the number of patients who attended a pre-defined proportion of pulmonary rehabilitation sessions (*e.g.* 70% of sessions); completion: the number of patients who attended the pulmonary rehabilitation discharge assessment and are regarded as having "completed" the pulmonary rehabilitation programme (regardless of the proportion of sessions attended); trial attrition: the number of

people who failed to attend for their post-pulmonary rehabilitaiton follow-up data collection in a trial. Trials of longer duration may have several follow-up assessments and thus several time points for recording attrition.

Assessment of the certainty of evidence

To assess the quality of evidence of included studies, we used the five GRADE (Grading of Recommendations, Assessment, Development and Evaluations) considerations (study design, risk of bias, inconsistency, imprecision and indirectness) for the primary outcomes. Using GRADEpro GDT software (gradepro.org), we followed the techniques and guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions [49]. We provide footnotes to explain any decisions to downgrade the quality of evidence.

Results

Study selection

We identified a total of 6185 records from six databases (figure 1) and found 1133 records from forward citation. After removing duplicates, a total of 5857 titles and abstracts were screened, and 78 full-text articles were considered for inclusion by the pairs of reviewers. All disagreements and decisions were discussed within the multidisciplinary team and 62 articles were excluded (supplementary table S1). Thus, we included 16 articles in our review [50–65]. No additional papers were added from the pre-publication update.

Characteristics of included studies

Of the 16 included studies, 15 were individually randomised trials, and one was a cluster randomised implementation trial [59]. The latter, while relevant to our inclusion criteria, had a very different trial design informing the challenge of implementing home-PR within routine COPD care, rather than providing evidence of effectiveness, and we therefore did not include it in the meta-analysis. Eight studies compared home-PR *versus* usual care [50, 53, 58, 59, 61, 63–65] and seven studies compared home-PR *versus* centre-PR [51, 54–57, 60, 62]. One study compared home-PR against two different comparators (centre-PR and usual care) and is therefore included in both analyses [52] (supplementary table S2 presents key characteristics of included studies, main findings and interpretation).

The trials were conducted in Australia (n=3) [50, 56, 59], Brazil (n=2) [52, 63], Spain (n=2) [54, 65], the United Kingdom (n=2) [57, 58], Canada (n=1) [60], China (n=1) [51], Denmark (n=1) [55], Egypt (n=1) [53], India (n=1) [64], Iran (n=1) [61] and Turkey (n=1) [62]. Of these, nine were high-income countries [50, 54–60, 65], four were upper-middle-income countries [51, 52, 62, 63] and three were lower-middle-income countries [53, 61, 64].

All studies were in people with COPD. In total, 1800 people with a range of severities were recruited to the included trials (range 39–314 participants). Out of the 1733 participants with reported baseline demographic data, 1048 (62%) were male and the mean age ranged from 56 to 79 years.

All pulmonary rehabilitation programmes included either aerobic and/or resistance exercises (aerobic (n=15) [50, 52–65], resistance (n=13) [50–60, 62, 63], both (n=12) [50, 52–60, 62, 63]). Stretching exercises were included in two trials [52, 63] and inspiratory muscle training in one trial [53]. All studies except one [57] had 24 or more exercise sessions; five trials had more than 48 sessions of exercise [50, 53, 56, 58, 64]. All but two [55, 62] of the home-PR programmes included face-to-face training sessions either as inpatients [53, 61], outpatients [51, 52, 54, 57, 58, 60, 63–65] or home visits [50, 56, 59]. Most of the programmes described some form of supervision of the home-based sessions, most commonly telephone calls [52, 56–59, 61, 63, 65] although one used videoconferencing [55] and one study in housebound individuals provided repeated home visits. Other strategies included provision of a manual or written information [51, 57, 58, 61, 62] activity diaries [50, 52, 55, 56, 60, 62, 63, 65], pedometers [54, 56, 65] and heart rate monitors [52].

Risk-of-bias assessment

Only three studies were at overall low risk of bias [55–57]. Two were at unclear/moderate risk of bias [58, 60] and 11 were at high risk of bias [50–54, 59, 61–65] (supplementary figure S1). Blinding of participants and personnel is impossible due to the nature of the intervention, but only six studies ensured outcome assessors were blind to allocation [54–58, 60]. Computer-generated randomisation sequence was used in 10 studies [51, 52, 55–61] and allocation concealment was described in seven [50, 54–58, 60]; the remaining studies did not provide sufficient information on randomisation [53, 62–65]. We were able to compare reported outcomes with published protocols or trial registrations for six studies [51, 52, 55–57, 59],

all of which were judged to be at low risk of selective reporting bias. Without a protocol for comparison, the remaining studies were designated as unclear risk of bias [50, 53, 54, 58, 60–65].

Effectiveness of home-PR (objective 1)

Primary outcome: functional exercise capacity

Home-PR *versus* usual care

Out of eight trials that compared home-PR with usual care, seven assessed at least one measure of functional exercise capacity [50, 52, 53, 58, 63–65]. Of these, five trials used the 6MWT [50, 52, 53, 63, 64], one trial used both ISWT and ESWT [58] and one trial used ESWT [65]. In one [52] of the seven studies, data were presented in a format that could not be retrieved for meta-analysis. Thus, we included six trials [50, 53, 58, 63–65] in the meta-analysis (figure 2). The pooled estimate showed a statistically significant increase in exercise capacity in home-PR compared with usual care (SMD 0.88, 95% CI 0.32–1.44; p=0.002). The only study not at high risk of bias showed no significant between-group differences [58].

In a subgroup meta-analysis of four RCTs [50, 53, 63, 64] with available data on 6MWT (supplementary figure S2), the pooled estimate showed a statistically significant increase in the mean difference in distance walked in home-PR compared with usual care (MD 61.58 m, 95% CI 45.88–77.29 m; p<0.01). Both the mean difference and the lower limit of the confidence interval exceeded the MCID for the 6-min walk distance (6MWD) of 30 m [66], indicating a clinically significant effect of home-PR.

Home-PR *versus* centre-PR

All the eight trials comparing home-PR with centre-PR assessed at least one measure of functional exercise capacity [51, 52, 54–57, 60, 62]. Of these, seven trials used the 6MWT [51, 52, 54–56, 60, 62], one trial used both ISWT and ESWT [57] and one trial used both cycle endurance test and 6MWT [60]. We included all eight trials [51, 52, 54–57, 60, 62] in the meta-analysis (figure 2). The pooled estimate showed no statistically significant difference in exercise capacity between home-PR and centre-PR (SMD −0.10, 95% CI −0.25–0.05; p=0.21). A sensitivity analysis including only the four studies at low/moderate risk of bias [55–57, 60] did not change the conclusion (SMD −0.02, 95% CI −0.18–0.15; I^2=28%; p=0.85) (supplementary figure S3).

In the meta-analysis of the seven RCTs [51, 52, 54–56, 60, 62] that used 6MWT (supplementary figure S4), the pooled estimates showed no statistically significant difference in the mean difference in distance walked in home-PR compared with centre-PR (MD −6.26m, 95% CI −18.55–6.02; p=0.32). This is within the noninferiority margin of 30 m for the 6MWT, indicating that the clinical effect of home-PR is not inferior to centre-PR for people with COPD.

Primary outcome: health-related quality of life

Home-PR *versus* usual care

All the eight trials comparing home-PR with usual care assessed at least one measure of HRQoL [50, 53, 58, 59, 61, 63–65]. Of these, four trials used the SGRQ [50, 59, 63, 65], two trials used CRQ [58, 64], one trial used both SGRQ and CAT score [59], one trial used SF-36 [53] and one trial used SF-12 [61]. We excluded the cluster RCT [59] from the meta-analysis because it informed implementation (as opposed to effectiveness) of home-PR in routine primary care management of COPD and was thus not comparable with the other trials. Thus, we included seven trials [50, 53, 58, 61, 63–65] in the meta-analysis (figure 2) and the pooled estimate (SGRQ-total, CRQ-mastery, SF-36-physical, SF-12) showed statistically significant improvement in HRQoL in the home-PR group compared with usual care (SMD −0.62, 95% CI −0.88–−0.36; p<0.01). The only study not at high risk of bias showed no significant between group differences [58].

Meta-analysis of the three RCTs that used SGRQ [50, 63, 65] (supplementary figure S5) showed a statistically significant improvement that exceeded the MCID of 4.0 in all the domains except the “impact” domain. The effect on overall SGRQ in the home-PR group compared with usual care showed an MD −5.66 (95% CI −7.94–−3.39; p<0.01) that exceeded the MCID.

Meta-analysis of the two RCTs [58, 64] that used the CRQ (supplementary figure S6) showed a statistically significant improvement (p=0.010) that exceeded the MCID of 0.5 in all the domains (dyspnoea, emotion, fatigue, mastery).

Home-PR *versus* centre-PR

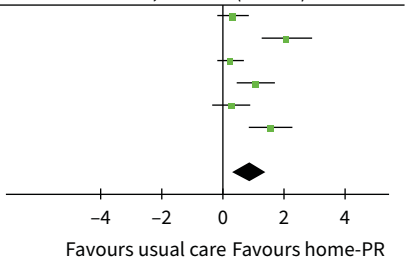
All seven trials comparing home-PR with centre-PR assessed at least one measure of HRQoL [51, 54–57, 60, 62]. Of these, four trials used the CRQ [54, 56, 57, 60] and three trials used the CAT score [51, 55, 62].

Comparison: Home-PR *versus* usual care

a) Functional exercise capacity

Study or subgroup	Home-PR Mean±SD	Total	Usual care Mean±SD	Total	Weight	SMD IV, random (95% CI)
Boxall, 2005 (6MWT)	39±91.85	30	4.2±114.36	30	17.9%	0.33 (−0.18–0.84)
Ghanem, 2010 (6MWT)	52.71±30.01	25	−15.44±35.83	14	14.5%	2.07 (1.26–2.89)
Johnson-Warrington, 2016 (ISWT)	45±51.85	39	30±70.37	39	18.6%	0.24 (−0.21–0.69)
Pradella, 2015 (6MWT)	65.7±65.7	32	5.6±24.2	18	16.7%	1.08 (0.46–1.70)
Singh, 2003 (6MWT)	54±62.19	20	6.3±222.74	20	16.7%	0.29 (−0.34–0.91)
Varas, 2018 (ESWT)	6.1±5.7	21	−0.9±2.1	19	15.6%	1.57 (0.85–2.28)
Total (95% CI)		167		140	100.0%	0.08 (0.32–1.44)

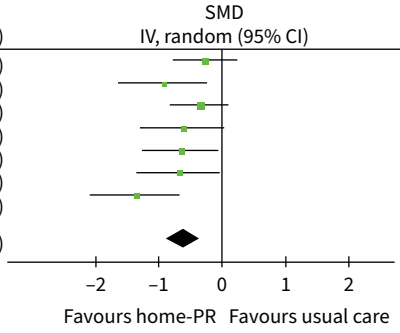
Heterogeneity: Tau^2=0.38; Chi^2=25.78, df=5 (p<0.0001); I^2= 81%
Test for overall effect: Z=3.09 (p=0.002)



b) Health-related quality of life

Study or subgroup	Home-PR Mean±SD	Total	Usual care Mean±SD	Total	Weight	SMD IV, random (95% CI)
Boxall, 2005 (SGRQ)	−5.8±16.13	30	−1.4±17.07	30	17.5%	−0.26 (−0.77–0.25)
Ghanem, 2010 (SF-36)	−30±40.0494	25	2.18±21.459	14	11.2%	−0.91(−1.60–−0.22)
Johnson-Warrington, 2016 (CRQ)	−1.41±1.48	39	−0.89±1.51	39	20.7%	−0.34 (−0.79–0.10)
Mohammadi, 2013 (SF-12)	−6.8±7.8309	20	−2.56±5.6748	20	12.7%	−0.61 (−1.24–0.03)
Pradella, 2015 (SGRQ)	−6.4±16.1	32	3.1±12.2	18	14.1%	−0.63 (−1.22–−0.04)
Singh, 2003 (CRQ)	−0.89±1.3103	20	−0.05±1.1315	20	12.6%	−0.67 (−1.31–−0.03)
Varas, 2018 (SGRQ)	−4.4±3.6	21	1±4.3	19	11.1%	−1.34 (−2.03–−0.65)
Total (95% CI)		187		160	100.0%	−0.62 (−0.88–−0.36)

Heterogeneity: Tau^2=0.03; Chi^2=8.18, df=6 (p=0.23); I^2= 27%
Test for overall effect: Z=4.68 (p<0.00001)

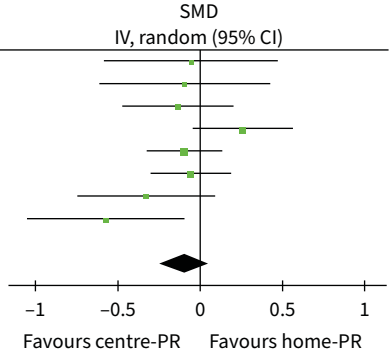


Comparison: home-PR versus centre-PR

c) Functional exercise capacity

Study or subgroup	Home-PR Mean±SD	Total	Centre-PR Mean±SD	Total	Weight	SMD IV, random (95% CI)
Chen, 2018 (6MWT)	38.29±78.66	29	43.01±86.62	26	6.8%	−0.06 (−0.59–0.47)
Güell, 2008 (6MWT)	54±103.13	28	65±126.67	29	7.0%	−0.09 (−0.61–0.43)
Hansen, 2020 (6MWT)	17.2±46.74	67	23.5±46.74	67	13.3%	−0.13 (−0.47–0.21)
Holland, 2017 (6MWT)	29.39±70.15	80	10.82±71.55	86	15.2%	0.26 (−0.04–0.57)
Horton, 2018 (ISWT)	21±209.307	145	41±216.4133	142	20.7%	−0.09 (−0.33–0.14)
Maltais, 2008 (6MWT)	8±51.0452	126	11±51.0452	126	19.4%	−0.06 (−0.31–0.19)
Mendes de Oliveira, 2010 (6MWT)	73.2±50.2	42	93.6±70.6	46	9.7%	−0.33 (−0.75–0.09)
Pehlivan, 2020 (6MWT)	18±61.18	39	66±102.75	32	8.0%	−0.58 (−1.05–−0.10)
Total (95% CI)		556		554	100.0%	−0.10 (−0.25–0.05)

Heterogeneity: Tau^2=0.01; Chi^2=10.38, df=7 (p=0.17); I^2= 33%
Test for overall effect: Z=1.26 (p=0.21)



d) Health-related quality of life

Study or subgroup	Home-PR Mean±SD	Total	Centre-PR Mean±SD	Total	Weight	SMD IV, random (95% CI)
Chen, 2018 (CAT)	−3.2±5.06	29	−1.27±4.95	26	7.5%	−0.38 (−0.91–0.15)
Güell, 2008 (CRQ)	−0.1±1.09	28	−0.65±1.27	29	7.7%	0.46 (−0.07–0.98)
Hansen, 2020 (CAT)	−1.7±6.1496	67	−0.3±6.1495	67	14.7%	−0.23 (−0.57–0.11)
Holland, 2017 (CRQ)	−2.43±4.6733	80	−2.02±4.6175	86	16.9%	−0.09 (−0.39–0.22)
Horton, 2018 (CRQ)	−0.28±1.9146	145	−0.61±1.7755	142	22.6%	0.18 (−0.05–0.41)
Maltais, 2008 (CRQ)	−0.49±0.9642	126	−0.51±0.9075	126	21.3%	0.02 (−0.23–0.27)
Pehlivan, 2020 (CAT)	−5±8.76	39	−6±9.34	32	9.3%	0.11 (−0.36–0.58)
Total (95% CI)		514		508	100.0%	0.01 (−0.15–0.17)

Heterogeneity: Tau^2=0.02; Chi^2=9.23, df=6 (p=0.16); I^2= 35%
Test for overall effect: Z=0.17 (p=0.87)

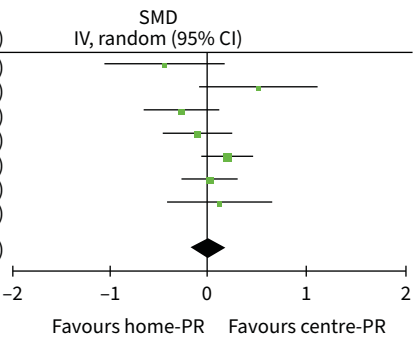


FIGURE 2 Comparison of primary outcomes. a, b) Comparing home-pulmonary rehabilitation (PR) with usual care for a) functional exercise capacity and b) health-related quality of life; c, d) comparing home-PR with centre-PR for c) functional exercise capacity and d) health-related quality of life. 6MWT: 6-min walk test; ISWT: incremental shuttle walking test; ESWT: endurance shuttle walking test; IV: inverse variance; SMD: standardised mean difference; SGRQ: St George's Respiratory Questionnaire; CRQ: Chronic Respiratory Questionnaire; CAT: COPD Assessment Test.

We included all seven trials [51, 54–57, 60, 62] in the meta-analysis (figure 2) and the pooled estimate (CRQ-mastery, CAT score) showed no statistically significant difference in the HRQoL in home-PR compared with centre-PR (SMD 0.01, 95% CI −0.15–0.17; p=0.87). A sensitivity analysis including only the four studies at low/moderate risk of bias [55–57, 60] did not change the conclusion (SMD −0.00, 95% CI −0.16–0.17; I^2=30%; p=0.98) (supplementary figure S7).

Meta-analysis of the four RCTs [54, 56, 57, 60] that used CRQ (supplementary figure S8) showed no statistically significant between-group differences (p=0.21) in any of the domains of CRQ (dyspnoea, emotion, fatigue, mastery).

Meta-analysis of the three RCTs [51, 55, 62] that used the CAT score (supplementary figure S9) favoured home-PR compared with centre-PR (MD −1.53, 95% CI −2.81–−0.24; p=0.02).

Secondary outcome: dyspnoea

Home-PR *versus* usual care

Two trials [59, 65] assessed dyspnoea using the modified Medical Research Council (mMRC) scale and compared home-PR with usual care. The implementation cluster RCT [59] concluded that mMRC grades were not significantly different between groups. The other RCT also showed no statistically significant changes (p=0.22) in dyspnoea level associated with home-PR compared to usual care [65].

Home-PR *versus* centre-PR

Two trials [56, 62] assessed dyspnoea using mMRC and compared home-PR *versus* centre-PR. Meta-analysis showed no statistically significant changes between the groups in dyspnoea level (supplementary figure S10) between home-PR and centre-PR (MD −0.12, 95% CI −0.44–0.21; p=0.48).

Secondary outcome: anxiety and depression

Home-PR *versus* usual care

One trial [59] measured anxiety and depression using the Hospital Anxiety and Depression Scale (HADS) and compared the effect between home-PR and usual care. There was no statistically significant between-group difference in either anxiety (p=1.00) or depression (p=0.09).

Home-PR *versus* centre-PR

Two trials [55, 57] measured anxiety and depression using HADS and compared the effects between home-PR and centre-PR. Meta-analysis showed no statistically significant between-group difference in anxiety or depression (supplementary figures S11 and S12) (anxiety: MD −0.33, 95% CI −1.81–1.15; p=0.66; depression: MD −0.03, 95% CI −1.28–1.22; p=0.97).

Association of components of home-PR with effective interventions (objective 2)

Table 2 presents a matrix of components of home-PR mapped to effectiveness.

There were no obvious differences in the components of the home-PR between effective and ineffective studies or in the number of components included, supervision provided or duration of the course.

Uptake, engagement, completion and trial attrition (objective 3)

Table 3 shows details of recruitment, uptake, engagement, completion of pulmonary rehabilitation sessions and trial attrition.

Screening and eligibility for the trials

Nine studies [51, 52, 55–61] provided details of the eligibility screening process, reporting recruitment rates between 12% and 56%. Five trials cited the presence of comorbidity as a reason for excluding between 3% and 14% of screened participants [51, 55–58]. Three studies reported that approximately one in five (22.8%, 18.3% and 12.0% [55–57]) potentially eligible patients declined to participate because of a strong preference for centre-PR. In contrast, one trial comparing home-PR *versus* centre-PR excluded 55% because they definitely wanted home-PR [55]. Distance/travel was cited as a reason for nonparticipation in two trials [51, 60].

Uptake of pulmonary rehabilitation

The implementation cluster RCT reported an uptake of 66% among the 107 patients referred by their general practitioner [59]. Two trials reported that two patients did not attend any pulmonary rehabilitation sessions [50, 65].

TABLE 2 Matrix of the home-pulmonary rehabilitation (PR) components in the included studies

Author, year [reference]	Exercise type				Edu	PR frequency; duration	Total sessions			Training, supervision and monitoring in the home-PR group	FEC	HRQoL
	AE	RT	Flex	RMT			<24	24–48	⩾48			
Home-PR *versus* usual care (n=9)												
Ghanem, 2010 [53]	✓	✓	X	✓	✓	2× per week; 8 weeks	X	✓	X	1 inpatient training session, then unsupervised home exercise	S#	S#
Pradella, 2015 [63]	✓	✓	✓	X	✓	3× per week; 8 weeks	X	✓	X	Outpatient training (first week), then diary + weekly TC to encourage home exercises	S#	S#
Varas, 2018 [65]	✓	X	X	X	✓	5× per week; 8 weeks	X	✓	X	5 outpatient training sessions, then diary + pedometer + weekly TC	S#	S#
Singh, 2003 [64]	✓	X	X	X	X	2× per day; 4 weeks	X	✓	X	Outpatient training sessions, then weekly supervision (mode not described)	NS#	S#
Boxall, 2005 [50]	✓	✓	X	X	X	Daily; 12 weeks	X	X	✓	Weekly home visits for 6 weeks + diary, then fortnightly home visits	NS#	NS#
Johnson-Warrington, 2016 [58]	✓	✓	X	X	✓	3× per week; 12 weeks	X	X	✓	1 face-to-face introductory session and given manual, then fortnightly TC	NS	NS#
Liang, 2019 [59]	✓	✓	X	X	✓	NR; 8 weeks	✓	X	X	1 home visit, then weekly TC	NS	NS
Mendes de Oliveira, 2010 [52]	✓	✓	✓	X	✓	3× per week; 12 weeks	X	✓	X	1 outpatient education + exercise training session, then diary + heart rate monitor + TC	NR	NS
Mohammadi, 2013 [61]	✓	X	X	X	✓	3× per week; 8 weeks	X	✓	X	3 inpatient training sessions, then manual + TC (alternate days)	NR	NS
Home-PR *versus* centre-PR (n=8)												
Pehlivan, 2020 [62]	✓	✓	X	X	✓	2–7× per week; 8 weeks	X	✓	X	Exercise sessions + daily walking + diary + manual Supervision NR	S	NS#
Chen, 2018 [51]	X	✓	X	X	✓	3× per week; 12 weeks	X	✓	X	1 outpatient education and training session, then home exercise + manual Supervision NR	NS#	NS#
Güell, 2008 [54]	✓	✓	X	✓	✓	3× per week; 9 weeks	X	✓	X	4 outpatient education and training sessions, then home exercise/ walking sessions + pedometer Supervision NR	NS#	NS
Hansen, 2020 [55]	✓	✓	X	X	✓	3× per week; 10 weeks	X	✓	X	3× per week exercise and education sessions, supervised by video-conference + diary	NS	NS
Holland, 2017 [56]	✓	✓	X	X	✓	Most days; 8 weeks	X	X	✓	1 home visit, then home exercise sessions supervised by weekly TC + diary + pedometer	NS	NS#
Horton, 2018 [57]	✓	✓	X	X	✓	3× per week; 7 weeks	X	✓	X	1 outpatient training session, then home exercise supervised by TC (×2) + manual	NS	NS
Maltais, 2008 [60]	✓	✓	X	X	✓	3× per week; 8 weeks	X	✓	X	Outpatient education and training sessions, then home-based exercise + diary	NS	NS
Mendes de Oliveira, 2010 [52]	✓	✓	✓	X	✓	3× per week; 12 weeks	X	✓	X	1 outpatient education + exercise training session, then diary + heart rate monitor + TC	NS#	NR

AE: aerobic training; RT: resistance training; flex: flexibility training; RMT: respiratory muscle training; Edu: education; FEC: functional exercise capacity; HRQoL: health-related quality of life; S: significant between-group difference; TC: telephone call; NS: nonsignificant between-group difference; NR: not reported. #: improved above minimal clinically important difference.

Engagement with the programme

Only four studies defined "engagement" as a pre-determined proportion of pulmonary rehabilitation sessions attended [55, 56, 59, 60]. Using the widely cited 70% threshold [67], Holland *et al.* [56] showed that engagement with home-PR was nearly twice that of centre-PR (91% *versus* 49%; relative risk of

TABLE 3 Recruitment, uptake, engagement and completion of pulmonary rehabilitation (PR) sessions and trial attrition

Author, year [reference]	Screened (reasons for ineligibility) Recruited: randomised	Uptake of PR/ usual care (reasons for nonstart)	Dose of PR and definition of engagement	Engaged with defined number of sessions (reasons for non-engagement)	Completed PR programme (reasons for dropout)	Trial attrition rate (reason for attrition)
Home-PR *versus* usual care						
Boxall, 2005 [50] RoB: high	Eligibility screening not reported 60 recruited: home-PR n=30, usual care n=30	Uptake of PR: home-PR 28/30 (93%) (2 ill-health)	Home-PR: 11 sessions (12 weeks: 11 visits + daily unsupervised exercise) Engagement not defined	Engagement not reported	Home-PR: 23/30 (77%) (3 withdrew, 1 died, 1 ill-health)	Post-PR Home-PR: 7/30 (23%) (3 withdrew, 1 died, 3 ill-health) Control: 7/30 (23%) (2 withdrew, 2 died, 1 ill-health, 2 moved)
Chen, 2018 [51] RoB: high	265 screened for eligibility (77 lost to contact, 44 distances >44 km, 53 declined, 36 comorbidity, 38 other) 55 (21%) recruited: home-PR n=29, usual care n=26	Uptake not reported	Home-PR: 36 sessions (12 weeks: 3× per week unsupervised exercise) Engagement not defined	Engagement not reported	Home-PR: 25/29 (86%) (3 ill-health, 1 moved) Usual care: 22/26 (85%) (1 ill-health, 3 not serious enough)	Post-PR Home-PR: 4/29 (14%) (1 moved, 3 ill-health) Usual care: 4/26 (15%) (1 not serious, 1 ill-health)
Ghanem, 2010 [53] RoB: high	Eligibility screening not reported 39 recruited: home-PR n=25, usual care n=14	Uptake not reported	Home-PR: 48 sessions (8 weeks: alternate days unsupervised exercise) Engagement not defined	Engagement not reported	Completion not reported	Post-PR Home-PR: 0/25 (0%) Usual care: 0/14 (0%)
Johnson-Warrington, 2016 [58] RoB: moderate	464 screened for eligibility 175 declined, 76 not eligible, 49 comorbidity, 90 lost to contact 78 (17%) recruited: home-PR n=39, usual care n=39	Uptake not reported	Home-PR: 42 sessions (12 weeks 6 TCs + 3× per week unsupervised exercise) Engagement not defined	Engagement not reported	Home-PR: 35/39 (90%) (2 ill-health, 1 preferred centre-PR, 1 not COPD) Usual care: 36/39 (92%) (3 died)	Post-PR Home-PR: 4/39 (10%) (1 wanted centre-PR; 2 ill-health; 1 not COPD) Usual care: 3/39 (8%) (3 died)
Mohammadi, 2013 [61] RoB: high	106 assessed for eligibility 40 (38%) recruited: home-PR n=20, usual care n=20	Uptake not reported	Home-PR: 24 sessions (8 weeks: 3 sessions then daily TCs + unsupervised sessions 3× per week) Engagement not defined		Completion not reported	Not reported No attrition reported
Pradella, 2015 [63] RoB: high	Eligibility screening not reported 50 recruited: home-PR n=32, usual care n=18	Uptake not reported	Home-PR: 24 sessions (8 weeks: weekly TCs + 3 unsupervised sessions per week) Engagement not defined	Engagement not reported	Home-PR: 29/32 (91%) (1 withdrew; 1 died, 1 AECOPD)	Post-PR Home-PR: 3/32 (9%) (1 died, 1 withdrew, 1 AECOPD) Usual care: 3/18 (17%) (2 withdrew, 1 AECOPD)

Continued

TABLE 3 Continued

Author, year [reference]	Screened (reasons for ineligibility) Recruited: randomised	Uptake of PR/ usual care (reasons for nonstart)	Dose of PR and definition of engagement	Engaged with defined number of sessions (reasons for non-engagement)	Completed PR programme (reasons for dropout)	Trial attrition rate (reason for attrition)
Singh, 2003 [64] RoB: high	Eligibility screening not reported 40 recruited: home-PR n=20, usual care n=20	Uptake not reported	Home-PR: 4 sessions (4 weeks: weekly visits + daily unsupervised exercise) Engagement not defined	Engagement not reported	Engagement not reported	Post-PR Home-PR: 0/20 (0%) Control: 0/20 (0%)
Varas, 2018 [65] RoB: high	Eligibility screening not reported 40 recruited: home-PR n=21, usual care n=19	Uptake of PR: home-PR 19/21 (90%) (2 withdrew)	Home-PR: 8 sessions (1× per week + unsupervised exercise ×8 weeks) Engagement not defined	Engagement not reported	Home-PR: 17/21 (81%) (2 did not complete)	Post-PR Home-PR: 4/21 (19%) (4 withdrew) Usual care: 3/19 (16%) (3 withdrew) 3 months and 12 months Home-PR: 4/21 (19%) Usual care: 3/19 (16%)
Cluster randomised implementation trial: home-PR *versus* usual care						
Liang, 2019 [59] RoB: high	Cluster RCT: 21 practices/ group 1050 screened for eligibility 272 (26%) recruited: home-PR n=157, control n=115	GP referred for PR: home-PR 107/157 (68%) Uptake of PR: home-PR 71/107 (66%)	Home-PR: 8 sessions (8 weeks: 1 session + weekly TC unsupervised exercise) Engagement defined as ⩾70% sessions attended	Engaged ⩾70% Home-PR: 49/107 (46%)	Completion not reported	6 months Home-PR: 39/157 (25%) Usual care: 21/115 (18%) 12 months Home-PR: 44/157 (28%) (27 lost to follow-up, 15 withdrew, 2 died) Usual care: 38/115 (33%) (29 lost to follow-up, 7 withdrew, 1 moved, 1 died)
Home-PR *versus* centre-PR						
Güell, 2008 [54] RoB: high	Eligibility screening not reported 57 recruited: home-PR n=28, centre-PR n=29	Uptake not reported	Home-PR: 27 sessions (9 weeks: 4 sessions + 3× per week unsupervised Centre-PR: 27 sessions (9 weeks: 3× per week) Engagement not defined	Engagement not reported	Home-PR: 23/28 (82%) (4 dropped out, 1 chest pain) Centre-PR: 28/29 (96%) (1 dropped out)	Post-PR Home-PR: 5/28 (18%) Centre-PR: 1/29 (4%) 6 months Home-PR: 8/28 (29%) (4 withdrew, 1 ill-health, 3 lost to follow-up) Centre-PR: 6/29 (21%) (1 dropped out, 5 lost to follow-up)

Continued

https://doi.org/10.1183/16000617.0076-2022

TABLE 3 Continued

Author, year [reference]	Screened (reasons for ineligibility) Recruited: randomised	Uptake of PR/ usual care (reasons for nonstart)	Dose of PR and definition of engagement	Engaged with defined number of sessions (reasons for non-engagement)	Completed PR programme (reasons for dropout)	Trial attrition rate (reason for attrition)
Hansen, 2020 [55] RoB: low	1099 assessed for eligibility: (608 declined centre-PR, 251 declined home-PR, 40 comorbidity, 66 other) 134 (12%) recruited: home-PR n=67, centre-PR n=67	Uptake not reported	Home-PR: 30 sessions (10 weeks: 3 sessions per week) Centre-PR: 20 sessions (10 weeks: 2 sessions per week) Engagement defined as ⩾70% sessions attended Attendance defined as participating in the whole session	Engaged ⩾70% Home-PR: 49/67 (73%) Centre-PR: 42/67 (63%) Median (IQR) number sessions attended Home-PR: 25/30 (20–28) Centre-PR 16/20 (8/19) Home-PR >70% engagement: OR 1.68, 95% CI 0.78–3.37; p<0.27	Home-PR: 57/67 (85%) (6 dropped out, 2 ill-health, 1 died, 1 AECOPD) Centre-PR: 43/67 (64%) (10 dropped out, 8 ill-health, 2 died, 4 AECOPD) Home-PR completing: OR 3.18, 95% CI 1.37–7.35; p<0.01	Post-PR Home-PR: 20/67 (30%) Centre-PR: 26/67 (39%) 3-month follow-up Home-PR: 29/67 (43%) Centre-PR: 26/67 (39%)
Holland, 2017 [56] RoB: low	295 assessed for eligibility (27 recent PR, 10 comorbidities, 5 recent AECOPD, 67 declined (54 wanted centre-PR), 120 other) 166 (56%) recruited: home-PR n=80, centre-PR n=86	Uptake not reported	Home-PR: 8 sessions (8 weeks: visit then weekly TCs + unsupervised sessions) Centre-PR: 16 sessions (8 weeks: twice weekly) Engagement defined as ⩾70% sessions attended	Mean/total sessions attended (range) Home-PR: 7.4/8 (0–8) Centre-PR 8.3/16 (0–16) Engaged ⩾70% Home-PR: 73/80 (91%) Centre-PR: 42/86 (49%) Relative risk of noncompletion in centre-PR 1.91 (95% CI 1.52–2.41)	Home-PR: 73/80 (91%) (1 died, 1 lost to follow-up, 5 declined) Centre-PR: 77/86 (89%) (1 died, 1 lost to follow-up, 7 declined)	Post-PR Home-PR: 7/80 (9%) Centre-PR: 9/86 (11%) 12-month follow-up Home-PR: 18/80 (24%) (4 lost to follow-up, 9 declined follow-up, 5 died) Centre-PR: 24/86 (28%) (10 lost to follow-up, 10 declined follow-up, 4 died)
Horton, 2018 [57] RoB: low	1162 assessed for eligibility (185 DNA, 32 comorbidities, 606 not eligible, 140 wanted centre-PR, 100 declined, 199 other) 287 (25%) recruited: home-PR n=145, centre-PR n=142	Uptake not reported	Home-PR: 21 sessions (7 weeks: 3 unsupervised sessions a week) Centre-PR: 14 sessions (7 weeks: twice weekly) Engagement not defined	Engagement not reported	Home-PR: 94/145 (85%) (16 lost to follow-up, 16 comorbidities, 2 died, 2 wanted centre-PR, 17 other) Centre-PR: 84/142 (59%) (30 lost to follow-up, 12 comorbidities, 1 died, 3 wanted home-PR, 12 others)	Post-PR Home-PR: 51/145 (35%) Centre-PR: 58/142 (41%) 6 months Home-PR: 70/145 (48%) (7 lost to follow-up, 3 DNA, 3 declined, 13 comorbidities, 3 other) Centre-PR: 72/142 (51%) (8 lost to follow-up, 1 comorbidity, 3 died, 2 others)

Continued

https://doi.org/10.1183/16000617.0076-2022

TABLE 3 Continued

Author, year [reference]	Screened (reasons for ineligibility) Recruited: randomised	Uptake of PR/ usual care (reasons for nonstart)	Dose of PR and definition of engagement	Engaged with defined number of sessions (reasons for non-engagement)	Completed PR programme (reasons for dropout)	Trial attrition rate (reason for attrition)
Maltais, 2008 [60] RoB: moderate	631 assessed for eligibility (214 declined, 27 transport problems, 1 died, 29 others) 252 (40%) recruited: home-PR n=126, centre-PR n=126	Uptake not reported	Home-PR: 24 sessions (8 weeks: 3 unsupervised sessions per week) Centre-PR: 24 sessions (4× 8 weeks: 3 sessions per week) Engagement defined as ⩾60% sessions attended	Engaged ⩾60% Home-PR: 123/126 (98%) Centre-PR:117/126 (93%)	Completion not reported	Post-PR Home-PR: 7/126 (6%) Centre-PR: 12/126 (10%) 12 months Home-PR: 19/126 (15%) (2 lost to follow-up, 16 withdrew, 1 died) Centre-PR: 17/126 (13%) (2 lost to follow-up, 14 withdrew, 1 died)
Pehlivan, 2020 [62] RoB: high	71 assessed for eligibility 71 recruited: home-PR n=39, centre-PR n=32	Uptake not reported	Home-PR: 32 sessions (8 weeks: 4 unsupervised sessions per week) Centre-PR: 16 sessions (8 weeks: 2 sessions per week) Engagement not defined	Engagement not reported 4 home-PR patients were excluded for "noncompliance"	Home-PR: 35/39 (4 discontinued) Centre-PR: 32/32	Post-PR Home-PR: 4/39 (10%) (4 withdrew) Centre-PR: 0/32 (0%)
Three-arm trial (home-PR *versus* centre PR *versus* usual care						
Mendes de Oliveira, 2010 [52] RoB: high	216 assessed for eligibility (65 declined, 32 ineligible, 2 died) 117 (54%) recruited: home-PR n=42, centre-PR n=46, usual care n=29	Uptake not reported	Home-PR: 36 sessions (12 weeks: TCs + 3 unsupervised sessions per week) Centre-PR: 36 sessions (12 weeks: 3 sessions per week) Engagement not defined	Engagement not reported	Home-PR: 35/42 (83%) (7 "abandoned" the programme) Centre-PR: 27/46 (59%) (7 "abandoned" the programme)	Post-PR Home-PR: 9/42 (21%) (2 lost to follow-up) Centre-PR: 22/45 (50%) (4 lost to follow-up) Usual care: 0/29 (0%)

Home-PR: home-based pulmonary rehabilitation; RoB: risk of bias; centre-PR: centre-based pulmonary rehabilitation; TC: telephone contact; AECOPD: acute exacerbation of COPD; RCT: randomised controlled trial; GP: general practitioner; IQR: interquartile range; DNA: did not attend.

nonengagement in centre-PR: 1.91, 95% CI 1.52–2.41). In contrast, two studies [55, 60] showed no between-group difference, although the latter used a lower threshold (⩾60%) and reported that >90% of the participants in both groups achieved this threshold. The implementation cluster RCT reported 46% engaged with ⩾70% of the pulmonary rehabilitation programme.

Completion of post-PR assessment and trial attrition

In the trial context, completion of the post-PR assessment was generally reported as attrition (*i.e.* loss to trial follow-up). Rates of attrition at the post-PR follow-up assessment ranged from 0% to 51%, but with no consistent pattern to suggest that mode of delivery affected follow-up.

Quality of evidence

Using GRADE, we judged primary outcomes (functional exercise capacity and HRQoL) of the review to provide low-certainty evidence when home-PR was compared with centre-PR and very low-certainty evidence when home-PR was compared with usual care. Downgrading for risk of bias was influenced by performance bias and some concerns in some or most of the domains of included studies. We additionally downgraded for imprecision because of use of SMD to assess the effect and/or small sample size, and for inconsistency due to heterogeneity in home-PR when compared with usual care (supplementary table S3).

Discussion

Summary of findings

Our systematic review identified 16 studies involving a total of 1800 COPD patients from 11 different countries. The effects of home-PR on exercise capacity and/or HRQoL in people with COPD were compared to either centre-PR (n=7) or usual care (n=8). One study had both comparators [52]. Overall, statistically significant improvement was found in functional exercise capacity and HRQoL in home-PR groups when compared with usual care, but no statistically significant differences were found in exercise capacity and HRQoL between home-PR and centre-PR groups. All studies that compared home-PR with usual care were at high risk of bias, except one which was at moderate risk of bias [58]. Conversely, among the studies that compared home-PR with centre-PR, three were at low risk of bias, one was at moderate risk of bias and four were at high risk of bias. No distinguishable patterns were found in exercise components, supervision and monitoring among the three trials [53, 63, 65] that had statistically significant between-group differences and exceeded MCIDs for both the primary outcomes when compared to other included studies. Rates of attrition at the post-PR follow-up assessment ranged from 0% to 51%, but with no consistent pattern to suggest that mode of delivery affected follow-up.

Strength and limitations

A strength of this systematic review is its comprehensive literature search constructed with the help of an expert librarian. We were open to including non-English language papers. We employed a rigorous methodology following a written protocol that has been published [36]. Although we searched for a wide range of chronic respiratory diseases, the included trials only recruited people with COPD, so the findings are not generalisable to people with other chronic respiratory diseases. We used generic terms for chronic respiratory diseases and named some of the commonest diseases, but our search might have missed some studies as all disease names were not explicitly included in the search strategy. Although we had low (home-PR *versus* centre-PR) or very low (home-PR *versus* usual care) confidence in our GRADE assessment for primary outcomes, this was influenced by multiple outcomes measures which we presented as an SMD in our meta-analysis. This emphasises the importance of agreed standardised outcomes for trials [68].

Six reviewers worked independently in pairs (as in the traditional model) and ensured that all titles and abstracts were duplicate-screened, and disagreements resolved in discussion involving the whole team as necessary. Involvement of six reviewers allowed us to complete the review in a timely manner and without overburdening any individual. The main limitation is the potential for inconsistency, so before starting screening, 100 articles were selected randomly from the total records by the study librarian and given to each pair to screen as a training exercise. Decisions were discussed within the study team and operational rules clarified and agreed.

Interpretation in the light of published literature

Effectiveness of home-PR

Our findings show that home-PR can be a clinically effective alternative to centre-PR for people with COPD in different settings [8, 27, 69] with the findings that both the MD and the lower limit of the confidence interval exceeded the MCID for the 6MWD [66] indicating a clinically significant effect in improving exercise capacity. This extends the findings of the recently published Cochrane review that

assessed the effect of telerehabilitation (either delivered in local community centres or at home) in two ways [33]. Firstly, the home-based programme remained effective despite the lack of the face-to-face group support available in a traditional centre-based pulmonary rehabilitation. This is of particular value in the context of a pandemic when infection control is an important consideration and may preclude group settings. Secondly, most of the telerehabilitation interventions in the Cochrane review [33] used video-conferencing or web-based systems to create virtual groups whereas in our home-based studies over half relied on individual telephone calls, and only one study provided a group-based structured pulmonary rehabilitation programme *via* video-conferencing [55]. This extends the findings to LMIC countries (and indeed some rural areas of high-income countries) with limited access to reliable internet connections. In addition to improving functional exercise capacity and HRQoL, meta-analysis of secondary outcomes showed that home-PR improved dyspnoea, anxiety and depression. These findings hint that home-PR may reduce stress associated with accessing and participating in centre-PR [13], as well as helping to develop confidence in the ability to exercise unsupervised [70].

Components of home-PR

Less than 2% of all patients with COPD globally can be served by the existing centre-PR programmes [71], and increasing access to and benefit from remote pulmonary rehabilitation remains a significant clinical and research priority [72]. To do this with confidence, providers of pulmonary rehabilitation services will want to know which components they should include and how to adapt them to home-PR. Although our review did not provide consistent evidence of which components or models of care were associated with effective interventions, others have reported that the intensity of supervision and monitoring increase chances of success in comparison to unsupervised programmes [73, 74]. Most of the interventions in our included studies provided between 24 and 28 home-based sessions with a broad range of arrangements for supervision, but no one approach was associated with effective interventions.

Uptake, engagement, completion and trial attrition

The terms uptake, engagement and completion are often used interchangeably without clear definition. Data are rarely reported in full; a recent systematic review only identified one trial with comprehensive uptake and completion data [75]. Uptake, defined as the number of patients who attended the initial/baseline assessment and at least one pulmonary rehabilitation session, may be referred to as “enrolled” or in a trial context “recruited” [67]. In our review, uptake was not reported in any of the studies that compared home-PR to centre-PR. Engagement is the proportion of pulmonary rehabilitation sessions attended. This is often assessed as the number of patients who have attended a pre-defined proportion of pulmonary rehabilitation sessions (*e.g.* 70% of sessions) and is sometimes referred to as “completion rate” [55, 56], or “adherence” [60] or “compliance” [50]. Of the included studies, only four trials defined engagement [55, 56, 59, 60] and only three trials reported this clearly [55, 56, 60]. Engagement with defined sessions in home-PR varied from 73% to 98%, whereas in centre-PR engagement ranged from 49% to 93%. Completion can also be defined as the number of patients who attended the post-PR discharge assessment and are regarded as having “completed” the pulmonary rehabilitation programme (even if they attended very few of the sessions). Some trials referred to participants who did not complete as having “dropped out” of the pulmonary rehabilitation programme [67].

From a trial design perspective, attrition is the number of people who do not attend follow-up assessments and may be described as having “withdrawn” from the trial. Trials of longer duration may have several follow-up assessments and thus several time points for recording attrition. Attrition rates at the post-PR follow-up evaluation ranged from 0% to 51% in our review, but there was no consistent pattern to suggest that mode of delivery influenced follow-up.

Implications for clinical practice and research

This systematic review gives confidence that home-PR can be an effective option to the traditional models of centre-PR programmes which could extend access for people with COPD to this effective intervention, although the low certainty of the evidence warrants further high-quality evaluation. Specifically, there is evidence that pulmonary rehabilitation improves outcomes in bronchiectasis [30] and ILD [31], but our studies were COPD-specific, so further investigation is required to establish whether home-PR is suitable for chronic respiratory diseases other than COPD. This may be of particular importance in rural areas of LMICs where poor access to investigations mean that the diagnosis may not be clear and limited facilities and travel infrastructure make remote delivery an important option [21].

While we may not have been able to identify specific components that contributed to effectiveness, providers will note that almost all the interventions included aerobic training and resistance training along with a programme of education. Regular remote supervision varied, but did not have to be technologically

complex; many used telephone calls often supplemented by maintaining an exercise diary. We recommend that future trials address issues of uptake, engagement, completion and attrition, and adopt standard terminology in order to provide clarity.

Conclusion

Our review concludes with low confidence that home-PR is as effective as centre-PR in improving functional exercise capacity and quality of life in people with COPD compared to usual care. Thus, home-PR is an option that could enable people whose lifestyles or geographical locations make attending a pulmonary rehabilitation centre difficult or who wish to socially distance to benefit from pulmonary rehabilitation.

Provenance: Submitted article, peer reviewed.

Acknowledgements: We acknowledge the contribution of Su May Liew (University of Malaya, Kuala Lumpur, Malaysia) who was a core member of the team until her untimely death in December 2021.

Author contributions: R.A. Rabinovich and H. Pinnock led the team, who all contributed to the systematic review process. M.N. Uzzaman drafted the first version of the manuscript with support from R.A. Rabinovich and which was revised with contributions from all members of the team (D. Agarwal, S.C. Chan, J. Patrick Engkasan, G.M.M. Habib, N.S. Hanafi, T. Jackson, P. Jebaraj, E.M. Khoo, F.T. Mirza, H. Pinnock, R.H. Shunmugam). All authors have critically reviewed and approved the final manuscript.

Conflict of interest: M.N. Uzzaman has nothing to disclose. D. Agarwal has nothing to disclose. S.C. Chan has nothing to disclose. J. Patrick Engkasan has nothing to disclose. G.M.M. Habib owns a Pulmonary Rehabilitation clinic in Bangladesh. N.S. Hanafi has nothing to disclose. T. Jackson has nothing to disclose. P. Jebaraj has nothing to disclose. E.M. Khoo reports grants from UK National Institute for Health Research (NIHR) Global Health Research Unit, during the conduct of the study; personal fees from AstraZeneca, personal fees and non-financial support from GlaxoSmithKline plc, and grants from Seqirus UK Ltd, and is President of the International Primary Care Respiratory Group, UK, outside the submitted work. F.T. Mirza has nothing to disclose. H. Pinnock reports grants from National Institute of Health Research (16/136/109 (2017-2021), during the conduct of the study. R.H. Shunmugam has nothing to disclose. R.A. Rabinovich has nothing to disclose.

Support statement: This research was funded by the UK National Institute for Health Research (NIHR) (Global Health Research Unit on Respiratory Health (RESPIRE); 16/136/109) using UK aid from the UK Government to support global health research. The views expressed in this publication are those of the author(s) and not necessarily those of the NIHR or the UK Government. The RESPIRE collaboration comprises the UK Grant holders, Partners and research teams as listed on the RESPIRE website (www.ed.ac.uk/usher/respire). T. Jackson is part-funded by the NIHR Global Health Research Unit on Respiratory Health (RESPIRE). G.M.M. Habib has a NIHR RESPIRE PhD studentship and M.N. Uzzaman holds a PhD studentship nested in the IMP^{2}ART programme at the University of Edinburgh. D. Agarwal holds an NIHR RESPIRE Fellowship. H. Pinnock, R.A. Rabinovich, E.M. Khoo, S.C. Chan, J. Patrick Engkasan, N.S. Hanafi are co-investigators of NIHR RESPIRE-funded pulmonary rehabilitation feasibility studies in their respective centres.

References

1 Soriano JB, Kendrick PJ, Paulson KR, *et al.* Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Respir Med* 2020; 8: 585–596.
2 Garcia-Aymerich J, Félez MA, Escarrabill J, *et al.* Physical activity and its determinants in severe chronic obstructive pulmonary disease. *Med Sci Sports Exerc* 2004; 36: 1667–1673.
3 Brien SB, Lewith GT, Thomas M. Patient coping strategies in COPD across disease severity and quality of life: a qualitative study. *NPJ Prim Care Respir Med* 2016; 26: 16051.
4 Hesselink AE, van der Windt D, Penninx B, *et al.* What predicts change in pulmonary function and quality of life in asthma or COPD? *J Asthma* 2006; 43: 513–519.
5 Spruit MA, Singh SJ, Garvey C, *et al.* An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med* 2013; 188: e13–e64.
6 Singh D, Agusti A, Anzueto A, *et al.* Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease: the GOLD science committee report 2019. *Eur Respir J* 2019; 53: 1900164.

7 Rochester C, Vogiatzis I, Holland A, *et al.* An official American Thoracic Society/European Respiratory Society policy statement: enhancing implementation, use, and delivery of pulmonary rehabilitation. *Am J Respir Crit Care Med* 2015; 192: 1373–1386.

8 McCarthy B, Casey D, Devane D, *et al.* Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2015; 2: CD003793.

9 Puhan MA, Gimeno-Santos E, Cates CJ, *et al.* Pulmonary rehabilitation following exacerbations of chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2016; 12: CD005305.

10 National Institute for Health and Care Excellence. Chronic Obstructive Pulmonary Disease in Over 16s: Diagnosis and Management. https://www.nice.org.uk/guidance/ng115/ Date last accessed: 9 August 2022. Date last updated: 26 July 2019.

11 Bolton CE, Bevan-Smith EF, Blakey JD, *et al.* British Thoracic Society guideline on pulmonary rehabilitation in adults. *Thorax* 2013; 68: Suppl. 2, ii1–ii30.

12 Alsubaiei ME, Cafarella PA, Frith PA, *et al.* Barriers for setting up a pulmonary rehabilitation program in the Eastern Province of Saudi Arabia. *Ann Thorac Med* 2016; 11: 121–127.

13 Cox NS, Oliveira CC, Lahham A, *et al.* Pulmonary rehabilitation referral and participation are commonly influenced by environment, knowledge, and beliefs about consequences: a systematic review using the Theoretical Domains Framework. *J Physiother* 2017; 63: 84–93.

14 Keating A, Lee A, Holland AE. What prevents people with chronic obstructive pulmonary disease from attending pulmonary rehabilitation? A systematic review. *Chron Respir Dis* 2011; 8: 89–99.

15 Romain D, Bernady A, Etchamendy E, *et al.* Coût des hospitalisations dues à une exacerbation de patients BPCO réhabilités à domicile. [Costs of hospitalisation for exacerbations of COPD in patients receiving domiciliary rehabilitation]. *Rev Mal Respir* 2011; 28: 864–872.

16 Trish E, Xu J, Joyce G. Medicare beneficiaries face growing out-of-pocket burden for specialty drugs while in catastrophic coverage phase. *Health Aff* 2016; 35: 1564–1571.

17 Brooks D, Lacasse Y, Goldstein RS. Pulmonary rehabilitation programs in Canada: national survey. *Can Respir J* 1999; 6: 55–63.

18 Wadell K, Ferreira TJ, Arne M, *et al.* Hospital-based pulmonary rehabilitation in patients with COPD in Sweden – a national survey. *Respir Med* 2013; 107: 1195–1200.

19 Yohannes AM, Connolly MJ. Pulmonary rehabilitation programmes in the UK: a national representative survey. *Clin Rehabil* 2004; 18: 444–449.

20 Habib GM, Rabinovich R, Divgi K, *et al.* Systematic review of clinical effectiveness, components, and delivery of pulmonary rehabilitation in low-resource settings. *NPJ Prim Care Respir Med* 2020; 30: 32.

21 Man WD, Puhan MA, Harrison SL, *et al.* Pulmonary rehabilitation and severe exacerbations of COPD: solution or white elephant? *ERJ Open Res* 2015; 1: 00050-2015.

22 Farias CC, Resqueti V, Dias FA, *et al.* Costs and benefits of pulmonary rehabilitation in chronic obstructive pulmonary disease: a randomized controlled trial. *Braz J Phys Ther* 2014; 18: 165–173.

23 Bove DG, Overgaard D, Lomborg K, *et al.* Efficacy of a minimal home-based psychoeducative intervention *versus* usual care for managing anxiety and dyspnoea in patients with severe chronic obstructive pulmonary disease: a randomised controlled trial protocol. *BMJ Open* 2015; 5: e008031.

24 Franke K-J, Domanski U, Schroeder M, *et al.* Telemonitoring of home exercise cycle training in patients with COPD. *Int J Chron Obstruct Pulmon Dis* 2016; 11: 2821–2829.

25 Yang F, Liu N, Hu J, *et al.* [Pulmonary rehabilitation guidelines in the principle of 4S for patients infected with 2019 novel coronavirus (2019-nCoV)]. *Zhonghua Jie He He Hu Xi Za Zhi* 2020; 43: 180–182.

26 Xavier DM, Galvão EL, Fonseca AA, *et al.* Effects of home-based pulmonary rehabilitation on dyspnea, exercise capacity, quality of life and impact of the disease in COPD patients: a systematic review. *COPD* 2022; 19: 18–46.

27 Wuytack F, Devane D, Stovold E, *et al.* Comparison of outpatient and home-based exercise training programmes for COPD: a systematic review and meta-analysis. *Respirology* 2018; 23: 272–283.

28 Neves LF, Reis M, Gonçalves TR. Home or community-based pulmonary rehabilitation for individuals with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Cad Saude Publica* 2016; 32: S0102-311X2016000602001.

29 Chen Y-Y, Xiao-Xiao Y, Meng F-J. Home *versus* centre-based pulmonary rehabilitation for patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *TMR Integrative Med* 2020; 4: 88888–e20012.

30 Bradley JM, Moran F, Greenstone M. Physical training for bronchiectasis. *Cochrane Database Syst Rev* 2002; 3: CD002166.

31 Dowman L, Hill CJ, Holland AE. Pulmonary rehabilitation for interstitial lung disease. *Cochrane Database Syst Rev* 2014; 10: CD006322.

32 Taito S, Yamauchi K, Kataoka Y. Telerehabilitation in subjects with respiratory disease: a scoping review. *Respir Care* 2021; 66: 686–698.

33 Cox NS, Dal Corso S, Hansen H, *et al.* Telerehabilitation for chronic respiratory disease. *Cochrane Database Syst Rev* 2021; 1: CD013040.
34 Higgins J, Thomas J, Chandler J, *et al.* Cochrane Handbook for Systematic Reviews of Interventions Version 6.3. 2022. https://training.cochrane.org/handbook/current Date last accessed April 2022.
35 Page MJ, McKenzie JE, Bossuyt PM, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372: n71.
36 Uzzaman MN, Chan SC, Shunmugam RH, *et al.* Clinical effectiveness and components of home-pulmonary rehabilitation for people with chronic respiratory diseases: a systematic review protocol. *BMJ Open* 2021; 11: e050362.
37 Casaburi R. A brief history of pulmonary rehabilitation. *Respir Care* 2008; 53: 1185–1189.
38 Greenhalgh T, Peacock R. Effectiveness and efficiency of search methods in systematic reviews of complex evidence: audit of primary sources. *BMJ* 2005; 331: 1064–1065.
39 Klein SR, Gulart AA, Venâncio RS, *et al.* Performance difference on the six-minute walk test on tracks of 20 and 30 meters for patients with chronic obstructive pulmonary disease: validity and reliability. *Braz J Phys Ther* 2021; 25: 40–47.
40 Tej PS, Kumar SV, Vishnukanth G. Correlation of six minute walk test and incremental shuttle walk test with severity of airflow obstruction in patients with chronic obstructive pulmonary disease. *J Assoc Chest Physicians* 2021; 9: 22–28.
41 Stoffels AA, van den Borst B, Peters JB, *et al.* Correlates of variability in endurance shuttle walk test time in patients with chronic obstructive pulmonary disease. *PLoS One* 2021; 16: e0249786.
42 Jones P, Shukla S, Tombs L, *et al.* Uncovering the relationship between the COPD Assessment Test and St George's Respiratory Questionnaire in patients with chronic obstructive pulmonary disease: a *post-hoc* analysis of IMPACT, FULFIL, and EMAX Trials. *Am J Respir Crit Care Med* 2021; 203: Suppl., A4565.
43 Moy ML, Wayne PM, Litrownik D, *et al.* Long-term Exercise After Pulmonary Rehabilitation (LEAP): a pilot randomised controlled trial of Tai Chi in COPD. *ERJ Open Res* 2021; 7: 00025-2021.
44 Cochrane Effective Practice and Organisation of Care (EPOC). Screening, Data Extraction and Management. Available from: https://epoc.cochrane.org/resources/epoc-resources-review-authors#conducting Date last accessed: September 2021.
45 Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0. 2011. The Cochrane Collaboration. Available from: http://handbook-5-1.cochrane.org/
46 Higgins JP, Thompson SG, Deeks JJ, *et al.* Measuring inconsistency in meta-analyses. *BMJ* 2003; 327: 557–560.
47 Egger M, Davey Smith G, Schneider M, *et al.* Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997; 315: 629–634.
48 Alison JA, McKeough ZJ, Johnston K, *et al.* Australian and New Zealand pulmonary rehabilitation guidelines. *Respirology* 2017; 22: 800–819.
49 Schünemann HJ, Vist GE, Higgins JP, *et al.* Interpreting results and drawing conclusions. *In*: Higgins JPT, Thomas J, Chandler J, *et al.* Cochrane Handbook for Systematic Reviews of Interventions. Chichester, John Wiley & Sons, The Cochrane Collaboration, 2019; pp. 403–431.
50 Boxall A-M, Barclay L, Sayers A, *et al.* Managing chronic obstructive pulmonary disease in the community. A randomized controlled trial of home-based pulmonary rehabilitation for elderly housebound patients. *J Cardiopulm Rehabil* 2005; 25: 378–385.
51 Chen Y, Niu M, Zhang X, *et al.* Effects of home-based lower limb resistance training on muscle strength and functional status in stable chronic obstructive pulmonary disease patients. *J Clin Nurs* 2018; 27: e1022–e1037.
52 Mendes de Oliveira JC, Studart Leitão Filho FS, Malosa Sampaio LM, *et al.* Outpatient *vs.* home-based pulmonary rehabilitation in COPD: a randomized controlled trial. *Multidiscip Respir Med* 2010; 5: 401–408.
53 Ghanem M, Abd Elaal E, Mehany M, *et al.* Home-based pulmonary rehabilitation program: effect on exercise tolerance and quality of life in chronic obstructive pulmonary disease patients. *Ann Thorac Med* 2010; 5: 18–25.
54 Güell MR, de Lucas P, Gáldiz JB, *et al.* Home *vs* hospital-based pulmonary rehabilitation for patients with chronic obstructive pulmonary disease: a Spanish multicenter trial. *Arch Bronconeumol* 2008; 44: 512–518.
55 Hansen H, Bieler T, Beyer N, *et al.* Supervised pulmonary tele-rehabilitation *versus* pulmonary rehabilitation in severe COPD: a randomised multicentre trial. *Thorax* 2020; 75: 413–421.
56 Holland AE, Mahal A, Hill CJ, *et al.* Home-based rehabilitation for COPD using minimal resources: a randomised, controlled equivalence trial. *Thorax* 2017; 72: 57–65.
57 Horton EJ, Mitchell KE, Johnson-Warrington V, *et al.* Comparison of a structured home-based rehabilitation programme with conventional supervised pulmonary rehabilitation: a randomised non-inferiority trial. *Thorax* 2018; 73: 29–36.
58 Johnson-Warrington V, Rees K, Gelder C, *et al.* Can a supported self-management program for COPD upon hospital discharge reduce readmissions? A randomized controlled trial. *Int J Chron Obstruct Pulmon Dis* 2016; 11: 1161–1169.

59 Liang J, Abramson MJ, Russell G, *et al.* Interdisciplinary COPD intervention in primary care: a cluster randomised controlled trial. *Eur Respir J* 2019; 53: 1801530.

60 Maltais F, Bourbeau J, Shapiro S, *et al.* Effects of home-based pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: a randomized trial. *Ann Intern Med* 2008; 149: 869–878.

61 Mohammadi F, Jowkar Z, Reza Khankeh H, *et al.* Effect of home-based nursing pulmonary rehabilitation on patients with chronic obstructive pulmonary disease: a randomised clinical trial. *Br J Community Nurs* 2013; 18: 398–403.

62 Pehlivan E, Yazar E, Balcı A, *et al.* A comparative study of the effectiveness of hospital-based *versus* home-based pulmonary rehabilitation in candidates for bronchoscopic lung volume reduction. *Heart Lung* 2020; 49: 959–964.

63 Pradella CO, Belmonte GM, Maia MN, *et al.* Home-based pulmonary rehabilitation for subjects with COPD: a randomized study. *Respir Care* 2015; 60: 526–532.

64 Singh V, Khandelwal DC, Khandelwal R, *et al.* Pulmonary rehabilitation in patients with chronic obstructive pulmonary disease. *Indian J Chest Dis Allied Sci* 2003; 45: 13–17.

65 Varas AB, Córdoba S, Rodríguez-Andonaegui I, *et al.* Effectiveness of a community-based exercise training programme to increase physical activity level in patients with chronic obstructive pulmonary disease: a randomized controlled trial. *Physiother Res Int* 2018; 23: e1740.

66 Holland AE, Spruit MA, Troosters T, *et al.* An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. *Eur Respir J* 2014; 44: 1428–1446.

67 Royal College of Physicians, National Asthma and Chronic Obstructive Pulmonary Disease Audit Programme (NACAP). Pulmonary Rehabilitation Clinical and Organisational Audits 2019. Available from: www.nacap.org.uk/nacap/welcome.nsf/reportsPR.html Date last accessed: 19 July 2021.

68 Williamson PR, Altman DG, Bagley H, *et al.* The COMET Handbook: version 1.0. *Trials* 2017; 18: 280.

69 Hwang R, Bruning J, Morris N, *et al.* A systematic review of the effects of telerehabilitation in patients with cardiopulmonary diseases. *J Cardiopulm Rehabil Prev* 2015; 35: 380–389.

70 Hoaas H, Andreassen HK, Lien LA, *et al.* Adherence and factors affecting satisfaction in long-term telerehabilitation for patients with chronic obstructive pulmonary disease: a mixed methods study. *BMC Med Inform Decis Mak* 2016; 16: 26.

71 Desveaux L, Janaudis-Ferreira T, Goldstein R, *et al.* An international comparison of pulmonary rehabilitation: a systematic review. *COPD* 2015; 12: 144–153.

72 Rochester CL, Vogiatzis I, Holland AE, *et al.* An official American Thoracic Society/European Respiratory Society policy statement: enhancing implementation, use, and delivery of pulmonary rehabilitation. *Am J Respir Crit Care Med* 2015; 192: 1373–1386.

73 Bourbeau J. Making pulmonary rehabilitation a success in COPD. *Swiss Med Wkly* 2010; 140: w13067

74 Puente-Maestu L, Sánz M, Sánz P, *et al.* Comparison of effects of supervised *versus* self-monitored training programmes in patients with chronic obstructive pulmonary disease. *Eur Respir J* 2000; 15: 517–525.

75 Jones AW, Taylor A, Gowler H, *et al.* Systematic review of interventions to improve patient uptake and completion of pulmonary rehabilitation in COPD. *ERJ Open Res* 2017; 3: 00089-2016.