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Effectiveness of pulmonary rehabilitation in post COVID-19 patients: a systematic review and meta-analysis

Efectividad de la rehabilitación pulmonar en pacientes post COVID-19: una revisión sistemática y metaanálisis

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Abstract

Introduction: Respiratory sequelae continue to be a prevalent problem in post-COVID-19 patients. Greater awareness among healthcare professionals regarding the effectiveness of rehabilitation could enhance its implementation.
Objective: To evaluate the effects of pulmonary rehabilitation on aerobic capacity, muscle strength, functionality, quality of life, and reduction of dyspnea in post-COVID-19 patients.
Methodology: It was developed in accordance with the PRISMA guidelines and registered in PROSPERO CRD42023368896. A search was conducted in four electronic databases (PubMed, Science Direct, Scopus, and Springer), with no language restrictions. Controlled clinical trials and cohort studies were selected, and their methodological quality was assessed using the PEDRO scale and the MINORS scale, respectively. The risk of bias of the controlled clinical trials included in the meta-analysis was assessed using the Cochrane Risk of Bias 2 (RoB 2.0) tool).
Results: Twenty-one articles were included in the analysis, with a total of 1,761 patients aged between 39 and 71 years. Fifty-seven percent of the programs were conducted in-hospital, while 43% were offered on an outpatient basis or through telehealth. The duration of the programs varied between 3 and 12 weeks, with a weekly frequency of 3 to 6 sessions, one to two sessions per day, with each session lasting 20 to 50 minutes.
Conclusions: Pulmonary rehabilitation, which includes strength training, endurance training, and aerobic capacity training, showed a positive effect on improving dyspnea, aerobic capacity, muscle strength, lung function, quality of life, and functionality in patients with post-COVID-19 sequelae.

Keywords

COVID-19; rehabilitation; cardiopulmonary exercise testing; respiratory function testing.

Resumen

Introducción: Las secuelas respiratorias continúan siendo un problema prevalente en los pacientes post COVID-19, un mayor conocimiento de los profesionales de la salud en relación a la efectividad de la rehabilitación, podría potencializar su implementación.
Objetivo: Evaluar los efectos de la rehabilitación pulmonar sobre la capacidad aeróbica, fuerza muscular, funcionalidad, calidad de vida y reducción de la disnea en pacientes post COVID-19.
Metodología: Se desarrolló de acuerdo a la guía PRISMA y se registró en PROSPERO CRD42023368896. Se realizó una búsqueda en cuatro bases de datos electrónicas (PubMed, Science Direct, Scopus, y Springer), sin restricción de idioma. Se seleccionaron estudios tipo ensayos clínicos controlados, y estudios de cohortes, su calidad metodológica fue evaluada con la escala PEDRO y la escala minors, respectivamente. El riesgo de sesgo de los ensayos clínicos controlados incluidos en el metaanálisis fue evaluado mediante la herramienta Cochrane Risk of Bias 2 (RoB 2.0).
Resultados: 21 artículos fueron incluidos en el análisis, con un total de 1761 pacientes, con edades entre 39 y 71 años. El 57% de los programas se realizaron a nivel intra-hospitalario, mientras que el 43% se ofreció de manera ambulatoria o a través de tele-salud. La duración de los programas varió entre 3 y 12 semanas, con una frecuencia semanal de 3 a 6 sesiones, una a dos sesiones diarias, con duración por sesión de 20 a 50 minutos.
Conclusiones: La rehabilitación pulmonar que incluye entrenamiento de fuerza, resistencia y capacidad aeróbica, mostró un efecto positivo en la mejora de la disnea, capacidad aeróbica, fuerza muscular, función pulmonar, calidad de vida y funcionalidad en pacientes con secuelas post COVID-19.

Palabras clave

COVID 19, rehabilitación, prueba de ejercicio cardiopulmonar, prueba de función respiratoria.

Introduction

In December 2019, cases of patients hospitalized with pneumonia of unknown origin were reported in Hubei Province, China. The cause was identified as a new virus in the coronavirus family, known as SARS-CoV-2, which causes respiratory failure. On February 11, 2020, the World Health Organization (WHO) named the disease caused by this virus COVID-19. Despite containment measures, the disease spread rapidly globally. In March 2020, the WHO officially declared COVID-19 a pandemic. (Ferrer, R.,2020). Which resulted in a global health crisis with a profound impact on public health, the economy, and social well-being (Galán et al.,2024).

Since its emergence, the pandemic has affected millions of people around the world, overwhelming healthcare systems and leaving physical and psychological scars on those who managed to survive (Intelangelo et al., 2022). The Ministry of Public Health implemented measures to mitigate the spread of the virus and adapted healthcare systems, with an emphasis on prevention and treatment of sequelae in survivors (Ponce et al.,2020). In this context, comprehensive care and rehabilitation for post-COVID-19 patients have become a priority, with physical therapy being an essential component in recovering lost functional abilities and improving patients' quality of life (Arbillaga et al.,2022).

COVID-19 affects multiple body systems, including the respiratory, cardiovascular, neurological, and musculoskeletal systems (Carcamo et al.,2022). Although most infected individuals experience mild or moderate symptoms and recover without hospitalization, some patients develop severe and persistent sequelae (Santos et al.,2022). These include chronic fatigue, dyspnea, neurological disorders (such as headache, anosmia, and acuity), and cardiovascular complications, such as myocarditis and left ventricular dysfunction (Gonzalez et al.,2022). In addition, thrombotic symptoms, such as thrombosis and coronary syndrome, are also common, along with endocrine disorders such as hyperglycemia in patients with no history of diabetes (Roncon et al.,2020).

As for the musculoskeletal system, patients with COVID-19 often suffer from myalgia, weakness, atrophy, and fatigue, which affects their mobility and functionality (López et al.,2022). Throughout the pandemic, it has also been observed that social isolation and fear associated with the disease have had a significant psychological impact on patients, contributing to their long-term vulnerability (Tascón et al.,2021).

Respiratory sequelae, particularly dyspnea, remain a prevalent problem in post-COVID-19 patients, many of these patients experience persistent breathing difficulties, chest pain, and limitations in their aerobic capacity, which severely affects their quality of life (Xie et al.,2025). Pulmonary rehabilitation has been established as a crucial strategy for improving lung function, reducing dyspnea, and restoring aerobic capacity. Well-structured pulmonary rehabilitation programs have been shown to be effective in improving patients' quality of life and functionality (Carvajal et al., 2020).

However, pulmonary rehabilitation protocols vary considerably in their structure and components, including the involvement of multidisciplinary care, exercise prescription parameters, and delivery format for example: hospitalized, outpatient, or telerehabilitation (Reychler et al.,2022). Such heterogeneity may contribute substantially to the variability observed in outcomes among this population (Isernia et al.,2022).

In this context, although the clinical importance of pulmonary rehabilitation (PR) in patients recovering from COVID-19 has been widely recognized, with evidence suggesting improvements in exercise capacity, respiratory symptoms, fatigue, and quality of life, the available literature remains heterogeneous (Chen et al., 2022). Previous reviews have examined the role of PR in post-COVID-19 populations; however, many of them have focused on narrative summaries, specific intervention modalities, or limited outcome domains (Reinert et al.,2022). Moreover, the rapid growth of research in recent years has generated new evidence that has not been consistently integrated through quantitative synthesis. Therefore, an updated systematic evaluation of the effectiveness of PR on key clinical outcomes is needed.

The evaluation of pulmonary rehabilitation outcomes in post-COVID-19 patients commonly relies on objective measures of pulmonary function and functional capacity. Spirometric parameters such as forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), and the FEV_1/FVC ratio are widely used indicators of respiratory function, while the six-minute walk test (6MWT) is a validated measure of functional exercise capacity in patients undergoing pulmonary rehabilitation. These outcomes were defined a priori in this review due to their clinical relevance and their frequent use in studies evaluating respiratory recovery and functional performance after COVID-19.

In this context, the present systematic review and meta-analysis analyzed the effectiveness of pulmonary rehabilitation in improving dyspnea, aerobic capacity, and functionality in post-COVID-19 patients. The research question guiding this study is: Is pulmonary rehabilitation effective in improving dyspnea, aerobic capacity, quality of life, and functionality in post-COVID-19 patients? The objectives of the review are: To characterize the available scientific evidence on pulmonary rehabilitation in post-COVID-19 patients between 2019 and 2023 and to identify the impact of pulmonary rehabilitation on dyspnea, aerobic capacity, pulmonary function, and quality of life in these patients.

Method

This systematic review was conducted following the protocol suggested in "The guideline of Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA)" (Moher et al.,2009). Registration in Prospero. CRD42023368896.

Search strategy

A search algorithm was applied to each of the electronic databases (PubMed, OVID, EBSCO, SciELO, Science Direct) between March 2023 and March 2024, according to PROSPERO registration, including articles between years 2019-2023 with no language restrictions. The search strategy used keywords and Medical Subject Heading (MeSH) terms with different combinations using Boolean operators. The exact terms varied depending on the database; some of the terms used were: "COVID 19", "SARS-CoV-2", "Infection", "Coronavirus Disease", "Post-Acute COVID-19 Syndromes", "Rehabilitation" , "Rehabilitation Center", "Physical and Rehabilitation Medicine", "Exercise Therapy", "Respiratory Function Test", "Pulmonary Function Test", "Lung Function Test", "Quality of Life", "Life Quality", "Health-Related Quality Of Life" , "Length of Stay" , "Hospital Stay", "Patient Discharge", "Survival".

Inclusion/exclusion criteria

Case-control studies, randomized clinical trials, and cohort studies were included in patients post-COVID-19 infection who underwent a pulmonary rehabilitation program and reported the following primary outcomes: Dyspnea assessed using the Borg Scale or Medical Research Council Scale (MRC), Aerobic capacity measured with a six-minute walk test (6MWT), lung function with forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC ratio, quality of life assessed with the Short Form Health Survey (SF-12) mental component score (MCS) and physical component score (PCS), Saint George Respiratory Questionnaire (STGQ), and functionality determined by the Barthel Index or Functional Independence Measure (FIM). Secondary outcomes included reports of perceived limitations in activities of daily living (PROMIS 8b), EuroQol Quality of Life Questionnaire (EQ-5D-3L), and Short Physical Performance Battery (SPPB).

Case studies, conference abstracts, letters to the editor, review articles, and those where the information was incomplete or no response was received from the authors regarding the information were excluded.

Extraction of information

A format designed in Excel for data collection was evaluated with the articles according to the eligibility criteria and the identifying information for each one. Each variable was entered into a box, and the results were evaluated by a reviewer and then discussed as a group to reach a consensus on the information that each cell should contain. The results from the databases were included in a spreadsheet using Microsoft Excel version 16.81, and duplicate results were eliminated.

The summary of the information extracted from the table describing pulmonary rehabilitation programs was carried out within a structured information framework, taking into account the TIDieR checklist and guide, developed for the detailed description of clinical trials and health studies (Hoffmann et al.,2014).

The extraction of information from the included articles was performed by four reviewers in pairs, and the selection of studies by title and abstract according to eligibility criteria and discrepancies were resolved by a third researcher from an alternative pair. Subsequently, the articles were reviewed in full text and the variables from each were extracted.

Risk of bias assessment

The PEDro scale was used to assess the methodological characteristics of the clinical trial reports. This scale consists of 11 items, where 1 indicates compliance and 0 indicates non-compliance. The total score allows a general description of the methodological characteristics of the study, considering aspects such as the presence of a control group, blinding, and randomization (Moseley et al., 2020). In this review, PEDro scores were used only for descriptive purposes to summarize methodological features of the included clinical trials and were not used to determine the risk of bias or to weight the quantitative synthesis.

The MINORS scale was implemented for cohort studies. This instrument consists of 12 items, where 0 is assigned if not reported, 1 if reported but inadequate, and 2 if reported and adequate. It evaluates aspects such as clearly stated objectives, prospective data collection, blinding, sample size calculation, and appropriate statistical analysis. Once the scores are summed, the ideal score is 16 for non-comparative studies and 24 for comparative studies (Slim et al., 2003). In the present review, MINORS was applied to describe the methodological characteristics of observational studies included in the qualitative synthesis and was not used to determine the risk of bias in the meta-analysis.

The risk of bias in the controlled clinical trials included in the meta-analysis was assessed using the Cochrane Risk of Bias 2 (RoB 2.0) tool, designed specifically for randomized studies. This tool allows a structured assessment of five key domains: the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. The judgments for each domain were classified according to the RoB 2 categories: low risk of bias, some concerns, or high risk of bias. The RoB 2 assessment was used to inform the interpretation of the pooled results and the overall certainty of the evidence. (Sterne et al., 2019).

Strategy for data synthesis and analysis

Due to the variation in outcome measures used in COVID-19 research, the data showed considerable heterogeneity. Therefore, a narrative synthesis of the included studies was conducted, considering population characteristics, the number of participants in each study, the databases consulted, the language, and the study variables. The synthesis of data without meta-analysis was carried out following the recommendations of the SWIM guideline (Campbell et al., 2020). Within this qualitative synthesis, observational studies and experimental studies without a control group were included in order to provide contextual information regarding the interventions and the reported outcomes.

Additionally, a meta-analysis was performed to quantitatively synthesize the effects of pulmonary rehabilitation programs on lung function and functional capacity in patients recovering from COVID-19. The quantitative synthesis included only randomized controlled clinical trials comparing an intervention group with a control group, in order to ensure methodological comparability among studies and preserve the internal validity of the pooled estimates. The outcomes included were forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), the FEV_1/FVC ratio, and the distance covered in the six-minute walk test (6MWT).

The analysis was performed using Review Manager (RevMan) software version 5.4.1, developed by The Cochrane Collaboration. For each study, the mean differences and their corresponding standard deviations, along with the sample sizes of the experimental and control groups, were entered into the analysis. When studies reported baseline and post-intervention values but did not provide change scores, the mean change was calculated as the difference between the post-intervention mean and the baseline mean. When the standard deviation of the change was not reported, it was estimated using the formula recommended in the Cochrane Handbook for Systematic Reviews of Interventions, based on the baseline and post-intervention standard deviations and the correlation between both measurements (Higgins et al., 2022). In cases where studies directly reported mean changes along with their corresponding standard deviations, these values were used as reported by the authors.

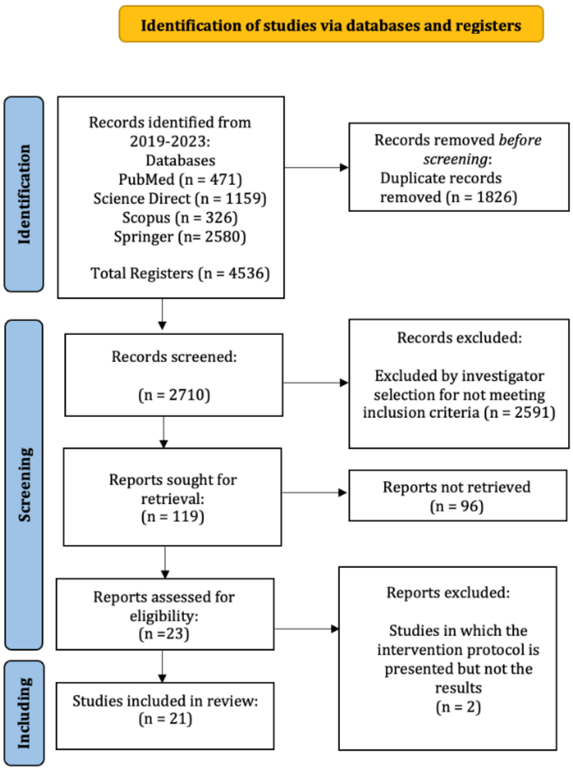
The overall effect of each outcome was estimated using the mean difference (MD) with its 95% confidence intervals (95% CI). Statistical heterogeneity was assessed using Chi^2 (Q), Tau^2, and I^2 statistics. Considering the expected clinical and methodological heterogeneity among pulmonary rehabilitation programs, including differences in the intervention setting, session frequency, level of supervision, and program components, a random-effects model was considered the most appropriate approach for the primary analyses. This model assumes that the true effect may vary between studies and therefore provides a more conservative estimate of the pooled effect. The magnitude of statistical heterogeneity was interpreted using the I^2 statistic. Although I^2 values were examined to quantify heterogeneity, the selection of the analytical model was based not only on the I^2 value but also on the clinical variability observed between studies. The results were represented using forest plots. A statistically significant difference was considered to exist when the p-value was < 0.05.

Results

Identification of studies and selection

A total of 4,536 studies from the four databases were identified in the initial search. 1,826 records were eliminated before the duplicate selection phase, which was limited to the period 2019-2023. A total of 2,710 records were evaluated by title and abstract, of which 2,591 were excluded for not meeting the inclusion criteria, leaving 119 studies for full-text reading. Of these, 96 studies were not retrieved, and of the 23 studies evaluated in full text for eligibility, two were excluded for being intervention protocols and not including results. A total of 21 articles were selected for analysis in this systematic review (see Figure 1).

Figure 1. Prisma flow diagram



Characteristics of the studies

Of the 21 studies included, 86% (n = 18) were found in the PubMed database, followed by 9.5% (n = 2) in Science Direct. Among them, twelve were Prospective and Retrospective Cohort Studies (ECP) (ECR)

57% n= (12) and nine were Controlled Clinical Trials (ECC) 43% n= (9). Scimago Q1 quartile 57% n = (12), followed by Q2 with 28.5% n = 6. From the European continent 66.6% n = 14, followed by Asia with 28.5% n = 6. In English 100% n = (21). From the year 2021, 52% n = 11, followed by 2022 with 33% n = 7 (Table 1).

Table 1. Characteristics of the studies

#	Authors	Title	Database	Journal	Scimago quartile	Type of study	Country	Continent	Language	Year	Objetive
1	Demoule et al.,2022	HRQOL after COVID-19 at 2 and 12 months after admission to the ICU	Pubmed	Annals of Intensive Care	Q1	PCS	France	Europe	English	2022	Describe HRQOL and dyspnea in COVID-19 patients 2 and 12 months after a stay in the ICU.
2	Wiertz et al.,2022	Life after COVID-19: the journey from intensive care back to life: a prospective cohort study	Pubmed	BMJ OPEN	Q1	PCS	Netherlands	Europe	English	2022	Evaluate the recovery of participation in post-COVID-19 patients during the first year after discharge from the ICU.
3	Eberst et al.,2022	Results of a one-year prospective follow-up of ICU survivors after SARS-CoV-2 pneumonia	Pubmed	Annals of Intensive Care	Q1	PCS	France	Europe	English	2022	Describe the one-year recovery profiles, defined by repeated assessment of respiratory function and exercise capacity, and quality of life, in a prospectively identified cohort of ICU patients who survived severe pneumonia.
4	Zampogna et al.,2021	PR in patients recovering from COVID-19	Pubmed	Respiration	Q1	RCS	Italy	Europe	English	2021	Evaluate the effectiveness of PR in muscle weakness and physical performance deterioration in a real-life setting.
5	Gloeckl et al.,2021	Benefits of PR in COVID-19: a prospective observational cohort study	Pubmed	ERJ Open Research	Q1	PCS	Germany	Europe	English	2021	Investigate the efficacy, feasibility, and safety of RP in patients with COVID-19 and compare outcomes between patients with mild/moderate and severe/critical disease.
6	Al Chikhanie et al.,2021	PR in patients recovering from COVID-19	Science Direct	Respiratory Physiology & Neurobiology	Q2	RCS	France	Europe	English	2021	Evaluate the effects of post-ICU PR in patients with COVID-19.
7	Spielmanns et al.,2021	Effects of comprehensive PR in critically ill post-COVID-19 patients	Pubmed	International Journal of Environmental Research and Public Health	Q2	PCS	Switzerland	Europe	English	2021	Compare post-COVID-19 patients referred to the PR program with patients referred with other lung diseases.

8	Liu et al.,2020	Respiratory rehabilitation in older adult patients with COVID-19	Pubmed	Complementary Therapies in Clinical Practice	Q1	CCT	China	Asia	English	2020	Investigate the effects of 6 weeks of respiratory rehabilitation training on respiratory function, mobility, and psychological function in older adults with COVID-19.
9	Li et al.,2021	Telerehabilitation program in patients discharged from hospital with COVID-19: a randomized controlled trial	Science Direct	Thorax	Q1	CCT	Jiangsu	Asia	English	2021	Investigate the superiority of a telerehabilitation program for COVID-19 over no rehabilitation, with respect to exercise capacity, lower limb muscle strength, lung function, HRQOL, and dyspnea.
10	Abodonya et al.,2021	IMT for COVID-19 patients after withdrawal from mechanical ventilation: A pilot controlled clinical study	Pubmed	Medicine	N/S	CCT	Saudi Arabia	Asia	English	2021	Evaluate the effectiveness of IMT in COVID-19 patients who have recovered after mechanical ventilation.
11	Hayden et al.,2021	Effectiveness of a three-week PR program for hospitalized patients after COVID-19: a prospective observational study	Pubmed	International Journal of Environmental Research and Public Health	Q2	PCS	Germany	Europe	English	2021	Assess pre- and post-changes in dyspnea, the most common primary symptom in the context of PR.
12	Büsching et al.,2021	Effectiveness of PR in severely ill and critically ill patients with COVID-19: a controlled study	Pubmed	International Journal of Environmental Research and Public Health	Q2	RCS	Germany	Europe	English	2021	Retrospective investigation of the clinical course of patients with COVID-19 during the PR.
13	Rodriguez et al.,2021	Short-term effects of a telerehabilitation conditioning program in confined patients affected by COVID-19 in the acute phase. A randomized controlled pilot trial	Pubmed	Medicina	N/S	CCT	Spain	Europe	English	2021	Evaluate the feasibility and effectiveness of a novel therapeutic exercise program using telerehabilitation tools in patients with COVID-19 with mild to moderate symptoms in the acute stage.
14	Teixeira et al.,2022	Cardiovascular, respiratory, and functional effects of home-based physical training after hospitalization for COVID-19	Pubmed	Medicine and Science in Sports and Exercise	Q1	CCT	Brazil	American	English	2022	To test the hypothesis that telemonitored home-based physical training is an effective strategy for improving cardiovascular, respiratory, and functional capacity parameters in people who were hospitalized due to COVID-19.

15	Pehlivan et al., 2022	The effectiveness of post-discharge telerehabilitation practices in patients with COVID-19: randomized controlled trial of the Tele-COVID study	Pubmed	Annals of Thoracic Medicine	Q2	CCT	Turkey	Asia	English	2022	Investigate the effectiveness of a telerehabilitation exercise program performed without the need for any special equipment on the physical condition of subjects with COVID-19.
16	Gonzalez et al.,2021	Short-term effects of a respiratory telerehabilitation program in patients confined due to COVID-19 in the acute phase: A pilot study	Pubmed	International Journal of Environmental Research and Public Health	Q2	CCT	Spain	Europe	English	2021	Evaluate the feasibility and effectiveness of a novel program based on breathing exercises using telerehabilitation tools in patients with COVID-19 with mild to moderate symptoms in the acute stage.
17	Paneroni et al.,2022	Feasibility of telerehabilitation in survivors of COVID-19 pneumonia	Pubmed	Pulmonology	Q1	PCS	Italy	Europe	English	2022	Investigate the safety, feasibility, and efficacy of a 1-month PR program in people discharged after recovering from COVID-19 pneumonia.
18	Şahın et al.,2023	Effects of a home-based PR program with and without telecoaching on health-related outcomes in COVID-19 survivors: a randomized control trial	Scielo	Jornal Brasileiro de Pneumologia	Q3	CCT	Turkey	Asia	English	2023	Compare the effects of a home-based PR program with and without telecoaching on health-related outcomes in COVID-19 survivors.
19	Dun et al.,2021	Six-month outcomes and effect of PR in patients hospitalized for COVID-19: a retrospective cohort study	Pubmed	Annals of Medicine	Q1	RCS	China	Asia	English	2021	Demonstrate changes in exercise capacity, COVID-19-specific immunoglobulins, T lymphocytes, blood chemistry, and explore the effects of PR on these outcomes in COVID-19 patients six months after hospital discharge.
20	Nopp et al.,2022	Outpatient PR in patients with long COVID improves exercise capacity, functional status, dyspnea, fatigue, and quality of life	Pubmed	Respiration	Q1	PCS	Austria	Europe	English	2022	To characterize the effectiveness and safety of outpatient PR in patients with persistent or progressive respiratory and/or functional limitations following COVID-19.
21	Vallier et al.,2023	Randomized controlled trial of	Pubmed	European Journal of	Q1	CCT	France	Europe	English	2023	Investigate whether home-

home versus hospital PR in post-COVID-19 patients	physical and rehabilitation Medicine	based rehabilitation would have similar effects compared to hospital-based rehabilitation on physical and respiratory variables in post-COVID-19 patients.

Abbreviations: Health-related quality of life (HRQOL), intensive care unit (ICU), pulmonary rehabilitation (PR), prospective cohort study (PCS), retrospective cohort study (RCS), controlled clinical trial (CCT), not specified (N/S), inspiratory muscle training (IMT).

Participant characteristics

The total number of participants was 1,761, aged between 39 and 71 years. Fifty-six percent (n = 980) of participants were men; all studies included both men and women, except for the study by Gloeckl et al.,2021 which only included women. The BMI of the patients ranged from 22.9 to 33 kg/m2. Comorbidities, inclusion and exclusion characteristics for the rehabilitation program are presented in Table 2.

Table 2. General characteristics of patients

#	Authors	n	F/M	EG/CG	Age (years)	BMI (kg/m^2)	Comorbidities n (%)	Inclusion characteristics	Exclusion characteristics
1	Demoule et al.,2022	94	F=27 M=67	94	63(49–70)	29.0 (26.3–33.6)	COPD=7(7) Asthma=11(12) DM=25(27) HTN=43(46) Dyslipidemia=24(26) Smoker=32(34) CKD=8(9) Immunosuppression= 12(13)	Patients admitted to an ICU in the Paris metropolitan area for acute respiratory failure with laboratory-confirmed SARS-CoV-2 infection and subsequently discharged and transferred to the inpatient respiratory rehabilitation center.	Patients under 18 years of age.
2	Wiertz et al.,2022	67	F=15 M=52	67	62(57-68)	N/S	Asthma/bronchitis=6(9) COPD =4(6) OSAS=12(17) DM=12(17) HTN=23(34) CVD=21(31) CKD=5(7) Depression=4(6)	All patients (aged 18 years or older) referred for inpatient rehabilitation after discharge from the ICU due to COVID-19 were eligible to participate in the study.	Not speaking or reading Dutch fluently.
3	Eberst et al.,2022	85	F=18 M=67	85	68.4(60.1-72.9)	Obesity=28 (32.9%) Class I=15 (30–34.9) (53.6%) Class II=10 (35–39.9%)=10 (35.7%) Class III (BMI ≥ 40)=3 (10.7%)	Obesity=28(32) CVD=9(10) HF=1(1.2) AF=7(8.2) CVA=2(2.4) COPD=7(8.2) Asthma=6(7.1) OSAS=16(18.8)	Patients were eligible if they had SARS-CoV-2 infection diagnosed by viral RNA detection using quantitative RT-PCR in nasal swabs or bronchoalveolar lavage.	Over 79 years of age, chronic renal failure, long-term oxygen therapy, PE, significant psychiatric disorders, or an estimated life expectancy of less than one year.
4	Zampogna et al.,2021	140	F=45 M=95	140	71(61.5-78.0)	25.2 (23.2–29.3)	COPD=22(16) Asthma=6(4.4)	Patients without functional limitations prior to COVID-19.	Persistent positive PCR test and clinical conditions that prevent active mobilization.
5	Gloeckl et al.,2021	50	F=50	AG=50 Mild/moderate COVID-19=24 BG= Severe/critical COVID=26	AG=52(47–56) BG=66 (60–71)	EG=24.7 (22.0–29.8) CG=26.9 (24.2–29.2)	HTN=5(21) Dyslipidemia=3(13) CVA=1(5) DM=1(5) CLD=7(30) OSAS=9(38) CKD=0(0) Obesity=5(21)	Patients in the post-acute phase of mild, moderate, severe, or critical COVID-19 as defined by the WHO, provide written informed consent.	Patients who could not walk.
6	Al Chikhanie et al.,2021	21	EG=21 M=7 F=14 CG=21	GE= 21 COVID-19 Post ICU GC = 21 NO COVID-19	EG=70.9±10.6 CG=69.1±9.4	EG=26.9±5.4. CG=24.7±7.2	All COVID-19 patients had at least one of the following comorbidities: respiratory disease,	Patients with COVID-19 who were in the ICU and had heart	Patients without COVID-19 or diagnosed with COVID-19 but who

			M=13 F=8	Post-ICU respiratory failure			cancer, obesity, CVD, DM. Depression= EG=6.5±4.8 CG=6.5±2.3	failure and breathing difficulties.	did not require ICU care.
7	Spielmanns et al.,2021	518	EG=99 M=55 F=44 CG=419 M=206 F=213	EG=99 post-COVID-19 CG=419 Lung diseases	EG=67.72 (±10.23) CG=69.28 (±11.29)	EG=28.21 (±6.11) CG=24.50 (±6.10)	EG= HTN=54(54) Smoker=27 (27) Adiposity=25 (25) MSD=25 (25) Dyslipidema=20 (20.2) CVD=20 (20) CKD=19 (19) CLD=18 (18.2) cancer=15 (15) COPD=11(11) CVA=9 (9) AF=8 (8.1) DM= 8 (8) OSAS=7 (7) HF=6 (6) VTE=5 (5) PE=5 (5) UI=5 (5)	Patients were admitted after remaining asymptomatic for 2 days and 10 days after the onset of infection.	Hemodynamically unstable with a need for catecholamine or invasive ventilation and continuous monitoring.
8	Liu et al.,2020	36	EG=36 M=24 F=12 CG=36 M=25 F=11	36	EG= 69.4 (8.0) CG= 68.9 (7.6)	EG=23.1 (3.5) CG= 22.9 (3.9)	MI= EG=25(69.4) CG=23(63.9), UI= EG=11(30.6) CG=13(36.1), HTN= EG=10(27.8) CG=8(22.2), PE=EG=4 (11.1) CG=3(8.3), DM= EG=9(25.0) CG=9(25.0), Osteoporosis= EG=8(22.2) CG=6(16.7)	Definitive diagnosis of COVID-19; aged 65 years or older; 6 months after the onset of another acute condition, Mini-Mental State Examination (MMSE) score > 21; no COPD or any other respiratory disease; and forced expiratory volume in 1 second (FEV1) 70%.	Moderate or severe heart failure (NYHA Class III or IV), ischemic or hemorrhagic stroke, or neurodegenerative diseases.
9	Li et al.,2021	119	F=53 M=66	EG=59 CG=60	EG= 49.17 (10.75) CG= 52.03 (11.10)	N/S	Heart disease = EG = 2 (3.4) CG = 7 (11.7) Hypertension = EG = 8 (13.6) CG = 18 (30.0) DM= EG=8 (13.6) CG= 9 (15.0) Obesity=EG=9 (15.3) CG= 8 (13.33) CLD= EG= 4 (6.8) CG= 3 (5.0)	Aged between 18 and 75 years, they had been discharged from one of the participating hospitals after hospital treatment for COVID-19 and had an mMRC dyspnea score of 2-3.	mMRC dyspnea of 4-5, resting HR >100 bpm, uncontrolled hypertension, DM glucose >16.7 mmol/l, hemoglobin A1C >7.0%).
10	Abodonya et al.,2021	42	F=9 M=33	EG= 21 CG= 21	EG=48.3±8.5 CG= 47.8±9.2	EG= 28.5±3.8 CG= 27.9±4.3	N/S	COVID negative, hemodynamically stable, respiratory rate <25 breaths/min, negative inspiratory force <25 cm H2O, minute ventilation <10 L/min, oxygen tension (PO2)/inspired oxygen fraction (FIO2) >200.	Neurological, neuromuscular, and musculoskeletal limitations, cognitive dysfunction, chronic terminal illnesses, and body mass index (BMI) >35 kg/m2.
11	Hayden et al.,2021	108	F=49 M=59	Severe acute GA = 55 Severe GB = 32 Moderate GC = 21	GA= 57.9 ± 10.8 GB= 54.0 ± 9.9 GC= 52.1 ± 6.8	GA= 29.9 ± 5.7 GB=31.5 ± 6.7 GC=28.9 ± 6.1	CVD=55.6% Obesity= 42.6% Orthopedic= 40.7% Hyperlipoproteinemia= 25.9% Psychological= 25.0% Neurological= 22.2% DM= 13.9%	All patients who were referred to the Bad Reichenhall Clinic due to persistent symptoms after COVID-19 between April 28, 2020, and January 8, 2021. All referred adult patients (≥18 years old).	Lack of language or cognitive skills to complete questionnaires.
12	Büsching et al.,2021	102	F=41 M=61	EG COVID-19= 51 CG= 51	EG=65.8 ± 11.7 CG=69.8 ± 9.6	EG=27.3 ± 4.9 CG=26.1 ± 6.5	HTN= EG=30 (59%) CG=19 (37%) ARDS= EG=26 (51%) CG=3 (6%) COPD= EG=2 (4%) CG=25 (49%) CVA= EG=8 (16%) CG= 10 (20%)	EG= Patients hospitalized for COVID-19 after discharge (confirmed by two negative CRP tests within 48 hours) CG= Age over 40 years; no history of thoracic and/or pulmonary surgery; no repeat PR	N/S
13	Rodriguez et al.,2021	36	F=19 M=17	EG= 18 CG= 18	EG= 39.39 (11.74) CG= 41.33 (12.13)	N/S	N/S	Age 18–75 years. Patients with a positive CRP test and/or antigen test for SARS-CoV-2 in the	CLD, CKD, and chronic neurological disorders. Hypertension and cardiovascular

								last forty days were in home confinement.	diseases without medical treatment, affected by grade III osteoporosis, with acute rheumatological diseases, and with acute disc abnormalities.
14	Teixeira et al.,2022	32	F=17 M=15	EG= 12 CG=20	EG= 51.9 ± 10.2 CG=53.3 ± 11.6	EG= 32.6 ± 7.4 CG=32.4 ± 7.8	HTN EG=5 (42) CG=1 (55) DM EG=4 (33) CG=1 (5) CVA= EG=0 (0) CG= 2 (10) Obesity EG=8 (67) CG=13 (65) Dyslipidemia Eg=1 (8) CG=2 (10) CLD EG=1 (8) CG=2 (10) Hypothyroidism EG=0 (0) CG= 1 (5)	Age ≥18 years; Laboratory-confirmed diagnosis of COVID-19 detected by reverse transcriptase CRP	Recent myocardial infarction, unstable angina, arrhythmias, or other uncontrolled heart disease); uncontrolled metabolic, pulmonary, hepatic, or renal diseases.
15	Pehlivan et al., 2022	34	F=9 M=25	EG=17 CG=17	EG=50.76 (32–82) CG= 43.24 (23–71)	EG= 27.98 (21–36) CG=27.43 (19–36)	Smoker EG=7 (41) CG=4 (24)	Subjects aged 18 to 75 years, diagnosed with COVID-19 and discharged after treatment.	With any comorbidity that could prevent exercise, subjects with neurological and cardiac deficits, and who did not agree to participate in the study.
16	Gonzalez et al.,2021	38	F=17 M=21	EG=19 CG=19	EG=40.79 ± 9.84 CG=40.32 ± 12.53	N/S	N/S	18 to 75 years old. Patients with positive PCR and/or antigen test results in the last forty days were in home confinement.	CLD, CKD, HTN, and cardiovascular conditions without medical treatment; patients affected by grade III osteoporosis, the acute phase of rheumatological diseases, or the acute phase of disc abnormalities.
17	Paneroni et al.,2022	24	F=13 M=11	24	66.0 ± 8.7	25.1 ± 5.6	N/S	Clinical stability; hypoxemia at rest or exercise-induced desaturation ≥4% decrease in SpO2 on the 6MWT, or exercise limitation 6MWT: <70% of predicted, home Internet availability, and ability to use technology.	Cognitive deficits, serious comorbidities, or physical impairment that prevent exercise without medical supervision.
18	Şahın et al.,2023	42	F=14 M=28	EG=21 CG=21	EG= 57.67 ± 8.42 CG=63.67 ± 7.90	EG= 29.98 ± 6.37 CG=28.75 ± 3.51	EG= 0 [0-1] CG= 1 [0-1]	Having been diagnosed with COVID-19; having stayed in the ICU or on the ward for more than 10 days with or without the need for IMV; having received NIV; having received high-flow oxygen therapy; and having completed medical treatment.	Orthopedic problems, treatment for active cancer, and patients who refused to participate.
19	Dun et al.,2021	98	F=53 M=45	EG= 27 CG=71	EG=54±16 CG=44±13	EG=23.8 ± 2.5 CG=23.8 ± 3.2	HTN EG= 3 (11.1) CG= 8 (11.3) DM= EG=4 (14.8) CG=3 (4.2) Dyslipidemia EG= 2 (7.4) CG=6 (8.5) CVA EG= 6 (22.2) CG= 6 (8.5) Cancer EG= 0 (0) CG=4 (5.6)	Post-COVID-19 patients discharged from hospital, aged 18 years or older; volunteered and signed informed consent; completed follow-ups at 2 weeks and 6 months and underwent blood tests.	Patients with cognitive impairment that could lead to an inability to cooperate in RP sessions, assessed using the mini-mental test, signs of respiratory distress, or

									cardiovascular instability.
20	Nopp et al.,2022	58	F=25 M=33	58	46.8 (±12.6)	26.2 (±5.3)	COPD = 1 (1.7) Emphysema = 2 (3.4) Asthma = 11 (19.0) Coronary heart disease = 3 (5.2) HTN = 13 (22.4) DM = 6 (10.3) AF = 1 (1.7) Dyslipidemia = 18 (31.0)	Consecutive adult patients admitted to an outpatient PR center due to persistent or progressive symptoms after COVID-19.	N/S
21	Vallier et al.,2023	17	F=5 M=12	GA Hospitalized = 9 GB Home Care = 8	GA= 53.1(13.9) GB= 56.9(18.9)	GA= 33.0(5.9) GB= 27.9(6.6)	Charlson comorbidity index GA= 0.4 (0.7). GB= 0.5 (0.5)	18 years of age; recent COVID-19 infection confirmed by nasopharyngeal CRP test; at least one physical and/or respiratory sequelae following COVID-19; internet access with functioning videoconferencing equipment.	Cardiovascular contraindication to exercise; respiratory instability, neuromuscular, joint, or psychiatric disease that prevents physical exercise.

Abbreviations: Chronic Obstructive Pulmonary Disease (COPD), Hypertension (HTN), Chronic Kidney Disease (CKD), Diabetes Mellitus (DM), Obstructive Sleep Apnea Syndrome (OSAS), Heart Failure (HF), Atrial Fibrillation (AF), Cerebrovascular Accident (CVA), Chronic Respiratory Failure (CRF), Interstitial Lung Disease (ILD), Cerebrovascular Disease (CVD), Chronic Lung Disease (CLD), World Health Organization (WHO), Intensive Care Unit (ICU), Not Specified (N/E), Multilobular Injury (LM), Unilobar Injury (LU), Pleural Effusion (PE), C-Reactive Protein (CRP), New York Heart Association (NYHA), Modified British Medical Research Council Dyspnea Scale (mMRC), Musculoskeletal Disease (MSD), Neurological Disease (ND), Coronary Heart Disease (CHD), Venous Thromboembolism (VTE), Liver Disease (LD), Acute Distress Syndrome (ARDS), Group A (GA), Group B (GB), Group C (GC), Experimental Group (EG), Control Group (CG), Pulmonary Rehabilitation (PR), polymerase chain reaction (PCR), 6-minute walk test (6MWT), Charlson Comorbidity Index (CCI), invasive mechanical ventilation (IMV), non-invasive mechanical ventilation (NIV).

Description of the pulmonary rehabilitation program

57% n= (12) of the PR programs were carried out at the hospital level and 43% n= (9) on an outpatient basis or through telerehabilitation. The intervention lasted between 3 and 12 weeks, 3 to 6 times per week, with 1 to 2 sessions per day, each lasting between 20 and 50 minutes. The programs included strength training, endurance training, and aerobic capacity training, with instructions on aspects of exercise prescription such as duration, intensity, progression, and type of exercises. To establish changes in exercise intensity, measurements such as the Borg Scale (BS), Maximum Inspiratory Pressure (MIP), and Maximum Heart Rate (MHR) were taken into account. Four studies: Spielmanns et al.,2021, Liu et al.,2020, Abodonya et al.,2021 and Dun et al.,2021, included respiratory muscle training as part of PR with devices such as the Threshold IMT® or the Power Breathe®. Other interventions such as psychological and nutritional support, occupational therapy, patient education, safety, and medical supervision were also mentioned. (Table 3).

Table 3. Description of the pulmonary rehabilitation program

#	Authors	Summary of the pulmonary rehabilitation program	
1	Demoule et al.,2022	Rehabilitation was carried out in an inpatient unit with a multidisciplinary approach that included adaptation and education on oxygen and respiratory devices, nutritional support, psychiatric and psychological assessment and treatment, occupational therapy, especially on walking aids and the sequelae of plexopathy, and physical therapy for neuromuscular electrostimulation. When possible, patients performed stretching and resistance training exercises on a treadmill or cycle ergometer, always with oxygen, twice a day.	
2	Wiertz et al.,2022	The indication was determined at the hospital by a consultant in rehabilitation medicine, based on their clinical judgment of the severity of physical, mental, and/or cognitive impairments. All patients received multidisciplinary inpatient rehabilitation treatment that included physical therapy, occupational therapy, speech therapy, and personalized psychology tailored to the patient's limitations and needs in accordance with the Dutch guideline for post-COVID rehabilitation in the ICU.	
3	Eberst et al.,2022	Prescription	After discharge from the ICU, all hospitalized patients underwent targeted rehabilitation exercises twice a day for at least 20 minutes with a physical therapist.
		Exercises	Rehabilitation with exercises consisted of passive range of motion, active range of motion, electrical muscle stimulation, sitting, leaning, standing, walking, and other mobilization techniques depending on the patient's condition. Cardiopulmonary rehabilitation was performed with aerobic physical activity.
		Psychological support	All patients included in the study were systematically offered early psychological follow-up.

4	Zampogna et al.,2021	General information	Healthcare operators with experience in pulmonary rehabilitation were trained to manage patients with COVID-19 using appropriate personal protective equipment, and a multidisciplinary program in accordance with the Italian position paper was implemented in all centers involved.
		Prescription	The type, intensity, timing, and modality of the intervention were tailored to each patient individually according to age, clinical severity, immobilization time, comorbidities, starting with a minimum of one 20-minute session per day up to two to three 30-minute sessions per day. Strengthening exercises, balance exercises, chest physiotherapy, educational sessions.
5	Gloeckl et al.,2021	Medical diagnosis and treatment	Initial physical examination including body plethysmography, electrocardiography, cardiac ultrasound, blood sampling. Continuous adjustment of drug treatment. Initiation and adjustment of long-term oxygen therapy, if necessary. If necessary, patients received a high-resolution computed tomography chest scan, sleep laboratory diagnosis, or an online consultation with a neurologist.
		Resistance training	Resistance training on a bicycle was performed for 10-20 minutes per session at 60-70% of maximum work rate 5 days a week. Strength training: Strength training was performed using resistance training machines. The following exercises were performed: leg press, knee extension, pull-down, and push-down. If possible, the following additional exercises were performed: forward/backward butterfly, rowing, back extension, and abdominal trainer. Patients performed three sets per exercise at an individual intensity to reach momentary muscle failure after 15–20 repetitions. Resistance training generally took 30 minutes per session and was performed 5 days per week.
		Patient education	Patients also attended two educational sessions per week on COVID-19 covering general topics such as physical activity, oxygen therapy, and smoking cessation.
		Respiratory physiotherapy	Individually tailored chest physiotherapy using various techniques, such as breathing retraining, coughing techniques, mucus clearance, connective tissue massage, and energy conservation techniques, was applied two to four times per week for 30 minutes each session.
		Training in activities of daily living	Training in activities of daily living (calisthenics) was carried out four to five times a week for 30 minutes. In addition, Nordic walking or aqua fitness was carried out twice a week for 30 minutes.
		Relaxation techniques	QiGong or progressive muscle relaxation (Jacobson technique) was applied twice a week for 30 minutes.
		Occupational therapy	Occupational therapy was used to treat individual neurological problems, such as limited motor skills in the hands or unsteady gait (if necessary). Brain training was performed to improve memory and concentration.
		Psychological support	A psychologist supported COVID-19 patients individually and during group therapy on aspects of disease management and how to cope with COVID-19 and its aftermath.
		Nutritional counseling	If necessary, nutritional counseling or nutritional supplements were provided to restore body composition (after weight loss during hospitalization).
6	Al Chikhanie et al.,2021	They performed PR consisting of breathing exercises, muscle strengthening, balance and walking when possible, cycling, and gymnastics according to current ATS/ERS recommendations.	
7	Spielmanns et al.,2021	Duration	3 weeks, 25-30 sessions, over 5-6 working days. The multimodal program consisted mainly of individualized endurance and strength training and was carried out according to a protocol adapted to the severity of the disease and physical functional limitations. From Monday to Friday, patients participated in a maximum of 4 exercise sessions per day. One exercise session was offered on Saturdays, and no exercise was performed on Sundays. Exercise therapy consisted of endurance training (cycling and treadmill), gymnastics (3 levels), indoor and outdoor walking (3 levels), and strength training.
		Intensity	For cycling exercise, a low-intensity interval program was chosen if the initial 6-MWT distance was <200 m. The duration of the higher and lower intensity intervals was set at 30-60 (55-70% of maximum heart rate) and 60 s, respectively. RPE measured by the adapted Borg scale (1-10) was used to define and adapt exercise intensity with a target Borg score of 4-6 (dyspnea) during exercise. Since most patients were very weak upon admission to the PR, exercise was started at a very low intensity and increased continuously according to patient tolerance. RPE was assessed after each exercise session.
		Progression	The duration of cycling was individually tailored, starting with 5-10 min at admission and increasing over time to 30-35 min at discharge. The duration of exercise was usually increased first, with the goal of reaching 20 min. After that, the intensity was also increased. A physical therapist or sports therapist instructed patients in strength exercises 3-4 times per week individually according to recent ATS recommendations. The modified Borg scale was used to define exercise intensity with a target Borg score of 4-5. Generally, 3 sets of 8-12 repetitions per exercise and 3-5 exercises for large muscle groups were chosen.
		Safety	All patients were monitored using pulse oximetry during exercise. The criteria for stopping or reducing the intensity of exercise were oxygen saturation (SpO_2) < 88% and symptoms of dyspnea (Borg ≥ 6). When a decrease in SpO_2 was observed, oxygen was added at a maximum of 6-8 L per minute via a nasal cannula to maintain SpO_2 > 90%.

		Respiratory physiotherapy	Patients received inspiratory muscle training and relaxation (progressive muscle relaxation). Respiratory physiotherapy consisted of teaching breathing control (pursed lip breathing, secretion mobilization, and diaphragmatic breathing), energy-saving techniques, and controlled coughing exercises. Twice a week (1 hour each session).
		Patient education	All patients participated in educational sessions, which included self-monitoring, coping skills, self-medication, treatment of infections and exacerbations, dyspnea, oxygen use, and nutritional interventions. If necessary, patients participated in a structured smoking cessation program, received psychosocial support, or counseling on diabetes.
8	Liu et al.,2020	Duration	Respiratory physiotherapy (2 sessions per week for 6 weeks), once a day for 10 minutes.
		Exercises	The interventions included: (1) respiratory muscle training; (2) coughing exercises; (3) diaphragmatic training; (4) stretching exercises; and (5) home exercises. For respiratory muscle training, participants used a commercial hand-held resistance device (Threshold PEP; Philips Co.). In stretching exercises, the respiratory muscles were stretched under the guidance of a rehabilitation therapist. The patient was placed in a supine or lateral position with the knees flexed to correct lumbar curvature. Patients were instructed to move their arms in flexion, horizontal extension, abduction, and external rotation. For home exercises, subjects were instructed in pursed-lip breathing and coughing training and asked to perform 30 sets per day.
		Intensity	Respiratory muscle training was performed in three sets of 10 breaths each; the parameters were set at 60% of the individual's maximum expiratory mouth pressure, with a 1-minute rest period between sets. For the coughing exercises, three sets of 10 active coughs were performed. For diaphragmatic training, each participant performed 30 maximum voluntary diaphragmatic contractions in the supine position, placing a medium weight (1-3 kg) on the anterior abdominal wall to resist diaphragmatic descent.
9	Li et al.,2021	Duration	A 6-week unsupervised home exercise program delivered via a smartphone app called RehabApp and monitored with a heart rate (HR) telemetry device worn on the chest. Teleconsultations with therapists were conducted once a week. The exercise program included 3-4 sessions per week. Compliance with the exercise protocol was considered when at least two-thirds (66.7%) of the total scheduled and effective target time was achieved for at least 5 of the 6 weeks.
		Exercises	Breath control and chest expansion, aerobic exercise, and exercises specified in a three-level exercise plan with difficulty and intensity programmed to increase over time.
		Progression	Physical therapists determined the initial exercise types and intensity based on the initial assessment, in accordance with the American College of Sports Medicine guidelines for exercise preparation. The intensity of the prescribed aerobic exercise was based on the HR reserve determined using the Karvonen formula. The intensity ranged from 30%–40% for level 1 to 40%–60% for level 3. The exercise intensity for level 2 was 30%-40% for level 3 and 40%-60% for level 4. The exercise intensity for level 5 was 30%-40% for level 5.
10	Abodonya et al.,2021	Duration	Both the IMT group and the control group performed an incentive spirometry exercise. After removal of the MV, each patient was instructed to perform an incentive breathing exercise in a relaxed sitting position twice a day for the following 2 weeks.
		Prescription	The IMT group received an IMT program using a threshold inspiratory muscle trainer (Respironics, Cedar Grove, NJ), 2 sessions daily, 5 days a week for 2 consecutive weeks. Each session consisted of 6 inspiratory cycles; each cycle lasted approximately 5 minutes of resisted inspiration, followed by 60 seconds of rest, with the aim of improving inspiratory muscle strength. In the fifth and sixth cycles, each patient was instructed to breathe as regularly as possible in order to improve inspiratory muscle fitness. The inspiratory threshold was controlled by a load valve on the device that provided a threshold load of 50% of the peak inspiratory pressure (PIP).
11	Hayden et al.,2021	Physical training	It consisted of two main mandatory components: (a) endurance training was scheduled for 3 to 5 supervised units per week for 30 to 60 minutes each time if the patient tolerated it; otherwise, the duration and frequency were adjusted individually. The initial training intensity was based on individual physical performance oriented to the 6MWD for cycling training and was monitored using a modified BORG scale from 0 to 10 [17] (target range 4 to 6). Accordingly, the therapist gradually adjusted the training intensities throughout rehabilitation in each session. Exercise intensity was monitored using a pulse oximeter (target range SpO2 ≥90%; oxygen administration if necessary) and heart rate. Field-oriented endurance exercises (e.g., Nordic walking) and indoor sports were also included. (b) Strength training was scheduled for 2-3 supervised sessions per week of 45-60 min each if tolerated; otherwise, duration and frequency were adjusted individually. Strength training was performed on strength training machines and focused on the major muscle groups (leg press, row, latissimus pull, reverse fly, cable pull, and abdominal exercises). Twelve repetitions were performed in three sets until individual local muscle exhaustion was reached at the end each set. In accordance with this principle, the intensity of the training was

			progressively increased. Whole-body vibration training (F) was performed seven times per week and was used only if there was no clinical evidence of thromboembolic complications and if no elevated D-dimer levels were identified. The training consisted of three sets of 1- to 2-minute sessions. The intensities (16-26 Hz, 1.5-4 amplitudes) were determined according to the patients' individual perception. The goal was muscle exhaustion at the end of the set and unit. The exercise was performed statically in a squatting position. Inspiratory muscle training (F) was provided to patients with inspiratory muscle weakness (max IP < 7 kPa) and was scheduled for 7 sessions per week of 21 min each, of which 1 session per week was supervised.
		Respiratory physiotherapy	Two group respiratory physiotherapy sessions per week, each lasting 45 minutes. If necessary, supplemented with (F): (a) individual breathing training by physiotherapists, (b) physiotherapy seminar on coughing techniques, (c) mucolytic inhalation therapies (e.g., NaCl inhalation), and (d) Buteyko breathing exercises.
		General physical therapy	For example, physiotherapeutic pain management, mobility training, or gait training to restore and train everyday functions, respectively, to manage everyday tasks (e.g., climbing stairs) or fascia training.
		Patient information about COVID-19	45-minute presentation by a physician.
		Routine medical diagnosis	Medical examination upon admission and discharge, complete pulmonary function and laboratory diagnosis, blood gas analysis, 6-minute walk test [18] with oxygen saturation measurement, and cardiac function diagnosis (mandatory electrocardiogram, echocardiography if indicated). If necessary, further imaging, psychological, psychiatric, or orthopedic examinations, or other specialized consultations were performed.
		Close medical supervision	All patients received regular medical visits, during which all components of therapy, including pharmacotherapy, were reviewed. Oxygen therapy was available at rest and especially during exertion, for example, as part of exercise therapy. Noninvasive ventilation could be continued during PR and monitored accordingly.
		Psychosocial support	Psychologically guided self-help group on COVID-19 (O). Social counseling (F) and/or individual psychological counseling (F) and/or neuropsychological assessment and training (F) were offered if necessary. In addition, relaxation techniques (F), such as progressive muscle relaxation or autogenic training, were offered.
		Nutritional counseling	Patients who are overweight, have diabetes, or other comorbid conditions.
		Occupational therapy	For example, prescribing and advising on necessary aids, memory training, or training in activities of daily living.
12	Büsching et al.,2021	Patients received standard PR as defined by the Swiss Respiratory Society. This includes admission and discharge assessment, goal setting, therapy planning, a minimum of 540 minutes of patient education, and therapy in individual and group settings. Physiotherapy units consist of cardiopulmonary training (cycling, guided walking) and strength exercises (weight training on machines, free weights, elastic resistance bands) with optional oxygen supply if necessary, breathing exercises (deep breathing, sputum evacuation), relaxation techniques (progressive muscle relaxation), and, if indicated, psychological counseling, speech, nutritional, and occupational therapy, and social services.	
13	Rodriguez et al.,2021	EG: The non-specific conditioning exercise program consisted of 10 exercises based on non-specific resistance and strength toning exercises. It was performed once a day, for seven days, at the patient's home. Based on the Borg scale (BS) score obtained during the assessment, patients performed 4 (BS 7–10), 8 (BS 5–7), or 12 (BS 1–5) repetitions per exercise per day; these repetitions took 10, 20, and 30 min, respectively. The exercise program was reinforced by a physical therapist at least twice (if the patient did not require further attention) through telematic monitoring via videoconference with each patient. CG: They underwent the two assessments on days 1 and 7.	
14	Teixeira et al.,2022	Duration	12-week exercise training (telesupervised and home-based).
		Resistance training	It included nine multi-joint and single-joint exercises (bodyweight squats, wall push-ups, bodyweight lunges, one-arm rows, deadlifts, lateral raises or shoulder presses, elbow flexions, calf raises, and chair sit-ups) using body weight and/or elastic bands/plastic bottles (filled with water or sand) as resistance. Participants were instructed to perform 1 set of 10 to 15 repetitions in week 1, 2 sets of 10 to 15 repetitions in weeks 2 to 3, 3 sets of 10 to 15 repetitions in weeks 4 to 6, and 3 sets of 15 to 20 repetitions in weeks 7 to 12. Participants were also instructed to rest for 1 minute between sets and exercises.
		Aerobic training	Participants were instructed to walk and/or cycle (depending on preference and available equipment) five times a week, and could choose to do some of the sessions after strength training or do all the sessions on separate days. The aerobic sessions consisted of 10-15 min in week 1 (depending on the participant's ability), 20 min in weeks 3 to 4, and 30 min in weeks 5 to 12. The exercise intensity was maintained between 11 and 13 on the RPE scale throughout the follow-up. During weeks 3 to 12, participants could choose to perform the aerobic exercise in a single session (20 or 30 min in a single session) or accumulate it in several sessions throughout the day (i.e., two 10-min sessions in week 3). –4, and two 15-min sessions or three 10-min sessions in weeks 5–12).
15	Pehlivan et al., 2022	Duration	Three days a week for six weeks.
		Exercises	The program included patient education, pacing/walking independently in the hallway, breathing exercises, active breathing cycle technique, range of motion exercises, and standing squats. The exercises were performed 10

		Intensity	times per session. The number of repetitions was modified according to the rate of fatigue. Taking into account the patient's fatigue and tolerance, the exercise intensity was set at a medium level (11-12 scores) when questioning the subjects about their perceived exertion on the Borg scale. In all exercises, patients were asked to place the camera in a location where the physical therapist could easily see the patient. The exercises were performed under the physiotherapist's instructions. Despite the possibility of any problems (such as the risk of falling), the presence of the subject's family member in the room during the exercise sessions was requested. The exercise was interrupted in case of excessive fatigue, palpitations, dyspnea, and request for interruption of the exercise by the subjects.
		Control group	They received a training session with exercises and a brochure that included exercises similar to those in the experimental group via smartphone. The booklet included patient education, breathing exercises, range-of-motion exercises, walking alone, and wall squats. Participants were asked to do their exercises 3 days a week for 6 weeks. If any problems were felt during the exercises (such as extreme tiredness, palpitations, and dyspnea), it was recommended to stop the exercise.
16	Gonzalez et al.,2021	EG: The Breathing Exercise Program was based on a proposal consisting of 10 exercises. These exercises were a modified version of breathing exercises already studied in the literature. The active cycle of breathing techniques uses an alternating depth of breathing to move mucus from the small airways at the bottom of the lungs to the larger airways, where it can be more easily cleared by coughing. They were performed once a day for seven days at the patient's home; depending on the score obtained on the Borg scale (BS), patients performed 4 (BS 7-10) (expected in 10 min), 8 (BS 5-7) (expected in 20 min), or 12 (BS < 5) repetitions per exercise per day (expected in 30 min). The exercise program was reinforced by a physical therapist at least twice (if the patient did not require further attention) through telematic monitoring via videoconference with each patient. Additionally, patients received a daily text message asking about the exercises as a method of follow-up and adherence. CG: They underwent the two assessments on days 1 and 7.	
17	Paneroni et al.,2022	Duration	The month-long program consisted of one hour of exercise per day. Upon admission to the program, patients received a pulse oximeter, a brochure illustrating the exercises, a diary to record daily activities, and instructions for exercising at home. Twice a week, a physical therapist contacted the patient via video call through a specific platform to monitor progress.
		Exercises	Aerobic reconditioning and muscle strengthening, and education on healthy lifestyles. If necessary, thoracic physiotherapy exercises (lung expansion, strengthening of the respiratory muscles) could be added.
		Intensity	Exercise intensity was based on the Short Physical Performance Battery (SPPB) and EID tests and divided into four arbitrary levels (1 = lowest intensity, 4 = highest intensity). Patients with SPPB<10 or EID were included in levels 1-2 and performed low-intensity aerobic exercises (walking, bodyweight exercises, sit-to-stand) and balance exercises. Patients with SPPB ≥ 10 and no EID were included in levels 3-4 and performed walking sessions with a pedometer, aerobic exercises with a cycle ergometer or leg and arm crank, and strengthening exercises with a light band. The intensity of the exercise session was progressively increased according to symptoms and the assessment of cardiorespiratory parameters. The programs could only be modified under the strict supervision of the physical therapist.
		Safety	In addition to physiotherapy follow-up, during the first two weeks, nurses monitored patients daily via telecare to check on their clinical needs; subsequently, patients received a weekly phone call/video call. If any symptoms or problems arose, patients could always contact the nursing staff (7 days a week) or doctors for a second opinion.
18	Şahın et al.,2023	Duration	8 weeks. A physical therapist prescribed breathing exercises for both groups, as well as exercises focused on strengthening the lower and upper extremities, as part of a home-based RP program. All patients were asked to keep an exercise diary to assess their compliance with the program. Although the CG was not contacted, a physical therapist contacted the EG every Monday.
		Breathing exercises	Techniques: diaphragmatic breathing, pursed-lip breathing, chest expansion exercises - Frequency: 8-10 repetitions per set, 1-2 sets per day, 5-7 days per week.
		Strength training	Intensity: perceived fatigue of ≤ 3 on the modified Borg scale. Frequency: 8-10 repetitions per set, 1-2 sets per day, 5-7 days per week Progression: Weights were increased when perceived dyspnea and fatigue were ≤ 3 on the modified Borg scale.
		Walking program	Intensity: Fatigue was objectively measured at ≤ 3 on the modified Borg scale. Frequency: 3-5 days per week, 20-30 min per day. Progression: Walking speed and increased duration with the goal of a score ≤ 3 on the modified Borg scale for perceived dyspnea and fatigue.
19	Dun et al.,2021	Duration	The PR program was provided free of charge to patients with COVID-19, who were advised to undergo three supervised sessions per week at the rehabilitation center of Changsha First Hospital for 12 consecutive weeks, beginning two weeks after discharge from acute hospital care.
		Exercises	Each session included: two sets of inspiratory muscle training; 30 sets of pursed-lip breathing and ACBT techniques; a set of 30 repetitions of maximum voluntary diaphragmatic contractions in the supine position,

		Prescription	placing a medium weight (1-3 kg) on the anterior abdominal wall to resist diaphragmatic descent; IV. Inspiratory muscle training was performed using PowerbreatheVR K5 devices with resistance adapted to the level of the inspiratory muscles being trained. Frequency: 3–5 days per week; intensity: 40–80% of predicted maximum heart rate (220 – age bpm) or a rating of 13–16 on the perceived exertion scale (RPE, Borg scale) [23]; time: 30–50 min per day; recommended exercises: brisk walking, jogging, and cycling; volume: 150 min per week; in the first month after discharge, patients were recommended an intensity of 40–60% of predicted maximum heart rate or an RPE of 13–14, and then gradually increased to the desired intensity.
20	Nopp et al.,2022	Multidisciplinary and individualized rehabilitation according to Austrian guidelines for outpatient pulmonary rehabilitation. In summary, participants completed individualized endurance, strength, and inspiratory muscle training over a period of 6 weeks, 3 times per week for 3-4 hours each session, under the supervision of physicians, physical therapists, and sports scientists. A key aspect of the program consisted of individualized patient education, psychosocial counseling by a psychologist, nutritional education by a dietitian, and smoking cessation sessions.	
21	Vallier et al.,2023	Over the course of four weeks, each participant completed 16 walks, 16 endurance sessions, 12 gym/muscle strength sessions, and 4 sophrology sessions.	

Abbreviations: Intensive Care Unit (ICU), Pulmonary Rehabilitation (PR), 6-Minute Walk Test (6-MWT), Rate of Perceived Exertion (RPE), American Thoracic Society/European Respiratory Society (ATS), Inspiratory Muscle Training (IMT), Control Group (CG), Experimental Group (EG), Inspiratory Muscle Training (IMT), Active Cycle Breathing Training (ACBT), Maximum Inspiratory Pressure (MIP)

Evaluation of the effect of RP in post-COVID-19 patients

Table 4 shows the results of the measurements taken in each study to evaluate the effect of RP on the variables of dyspnea, aerobic capacity, muscle strength, lung function, quality of life, and functionality. The main results are described below.

Dyspnea and subjective perception of fatigue during exercise

43% n= (9) used the Medical Research Council (mMRC) scale to assess the severity of shortness of breath (dyspnea) and its impact on functional capacity or activities of daily living (Demoule et al., 2022, Wiertz et al., 2022, Eberst et al., 2022, Gloeckl et al., 2021, Hayden et al., 2021, Pehlivan et al., 2022, Şahın et al., 2023, Nopp et al., 2022, Vallier et al., 2023). Baseline values ranged from 3 (2–4) (Demoule et al., 2022) to 1 (0–1) (Nopp et al., 2022), and after pulmonary rehabilitation (PR) they ranged from 2 (1–2) (Wiertz et al., 2022) to 0 (0–1) (Nopp et al., 2022). Followed by the Borg scale assesses the subjective perception of physical exertion and fatigue during exercise, evaluating how difficult an activity feels. It is used to monitor the intensity (Gloeckl et al., 2021, Al Chikhanie et al.,2021, Nopp et al., 2022) where the baseline values were 4.4±2.319 and 4 (3–5) and subsequently 4.1±1.819 and 4 (2–6) (Gloeckl et al., 2021). Three studies (Al Chikhanie et al.,2021, Pehlivan et al., 2022, Şahın et al., 2023), used the Saint George Respiratory Questionnaire (SGRQ) with baseline values between 31.47 (5–87) (Pehlivan et al., 2022) and 47.77 ± 4.97 (Şahın et al., 2023) and subsequent values of 17.70 (4–78) (Pehlivan et al., 2022) and 36.67 ± 5.45 (Şahın et al., 2023). One study (Paneroni et al.,2022) used the Barthel dyspnea scale with baseline values of 11.7 ± 9.0 and follow-up values of 5.3 ± 6.9. Another study (Gonzalez et al., 2021) used the Multidimensional Dyspnea Scale (MD12) with baseline values of 12.26 ± 5.92 and follow-up values of 5.89 ± 3.48. Meanwhile, another study (Büsching et al., 2021) used the Chronic Respiratory Questionnaire (CRQ) with baseline values of 91.7 ± 19.8 and follow-up values of 105.8 ± 18.0.

Aerobic capacity

86% n = (18) of the studies used the 6-minute walk test (6MWT) with baseline values between 138.7±144.4m (Al Chikhanie et al., 2021) and 584.1m (±95.0) (Nopp et al., 2022) and post-PR values of 212.3±82.5m (Liu et al., 2020) and 619.8±67m (Dun et al., 2021). Two studies (Rodriguez et al., 2021, Gonzalez et al., 2021) used the 30-second sit-to-stand test (30STST) with baseline values of 12.33 (4.81) (Rodriguez et al., 2021) and 12.68 ± 5.33 (Gonzalez et al., 2021) and post-PR 13.83 (5.70) (Rodriguez et al., 2021) and 14.00 ± 5.47 (Gonzalez et al., 2021). Meanwhile, two studies implemented the 1-minute sit-to-stand test (1MSTS) (Paneroni et al., 2022, Vallier et al., 2023), with baseline values between 18.0 ± 8.1 (Paneroni et al., 2022) and 23.2 (6.4) (Vallier et al., 2023) and post-PR values between 22.3 ± 9.1 (Paneroni et al., 2022) and 32.7 (9.9) (Vallier et al., 2023).

Muscle strength

PIM was evaluated in five studies (Eberst et al., 2022, Al Chikhanie et al., 2021, Hayden et al., 2021, Teixeira et al., 2022, Nopp et al., 2022), with baseline values ranging from 42.7±17.5 cmH_2O (Al Chikhanie et al., 2021) to 90.2 (±30.1) cmH_2O (Nopp et al., 2022), with follow-up values between 62.9±13 cmH_2O (Al Chikhanie et al., 2021) and 115.6 (±30.0) cmH_2O (Nopp et al., 2022). Handgrip strength was assessed in three studies (Gloeckl et al., 2021, Al Chikhanie et al., 2021, Teixeira et al., 2022), with baseline values between 18.1±8 kg (Al Chikhanie et al., 2021) and 37.5±11.2 kg (Teixeira et al., 2022) and post-intervention values between 23.5±8.5 kg (Al Chikhanie et al., 2021) and 40.8±12.0 kg (Teixeira et al., 2022). One study (Wiertz et al., 2022) evaluated mean muscle strength (HHD) with baseline values of 75.7% (15.3) and post-intervention values of 101.4 (15.3).

Lung function

Fifty-seven percent (n = 12) of the studies evaluated forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and FEV1/FVC ratio using spirometry.

Quality of life

For the assessment of quality of life, four studies used the EuroQol Quality of Life Questionnaire (EQ-5D-3L) (Demoule et al., 2022, Abodonya et al., 2021, Hayden et al., 2021, Nopp et al., 2022), four studies used the health survey (SF-36) (Gloeckl et al., 2021, Liu et al., 2020, Li et al., 2022, Şahın et al.,2023).

Functionality

Three studies used FIM (Spielmanns et al., 2021, Liu et al., 2020, Büsching et al., 2021) with baseline values between 97.3 ± 17.4 (Büsching et al., 2021) and 109.2±13 (Liu et al., 2020) and follow-up values between 109.4±11.1 (Liu et al., 2020) and 115.8 ± 14.0 (Büsching et al., 2021). Two studies evaluated the Short Physical Performance Battery (SPPB) (Zampogna et al., 2021, Pehlivan et al., 2022).

Table 4. Evaluation of the effect of pulmonary rehabilitation in post-COVID-19 patients

#	Authors	Measurements	Basal	Posterior	P value
1	Demoule et al.,2022	mMRC	3 (2–4)	1 (0–2)	<0,001
		EQ-5D-3L	0.80 (0.36–0.91)	0.91 (0.52–1.00)	0,012
2	Wiertz et al.,2022	mMRC	2 (1-3)	1 (1–2)	<0,01
		HHD (%)	75.7 ± 15.3	101.4 ± 15.3	0.18
		6MWT (m)	467 ± 91.2	531 ± 86.5	0.65
		FVC % of predicted	85.9 ± 16.3	92.2 ±15.6	0,16
		FEV1 % of predicted	87.6 ±15.8	93.6 ±17.7	0,07
		FEV1/FVC	79.6 ± 9.1	79.1 ±11.2	0,24
		PROMIS 8b	34.8 ± 7.4	44.8 ± 8.0	<0,01
3	Eberst et al.,2022	mMRC	1 (0 - 4)	1 (0–2)	0,33
		PIM (CmH2O)	74.5 (54-95)	99 (77-122)	<0,0001
		6MWT (m)	481 (400–564)	542 (495–600)	<0,0001
		FVC % of predicted	92.0 (80.0–103.6)	105.0 (92.0–120.0)	<0,0001
		FEV1 % of predicted	92.0 (81.0–103.2)	104.0 (92.0–118.0)	<0,0001
		FEV1/FVC	82.0 (74.0–86.0)	81.0 (73.0–85.0)	0,027
4	Zampogna et al.,2021	6MWT (m)	205.0 (160.0–280.0)	295.0 (250.0–370.0)	0
		SPPB	0.5 (3.2 ± 3.7)	7 (6.9 ± 3.8)	<0,001
		Barthel Index	55.0 (30.0– 90.0)	95.0 (65.0–100.0)	<0,001
5	Gloeckl et al.,2021	mMRC	GA=2 (2–2)	GA=2 (1–2)	0,003
		End-6MWT dyspnoea Borg Scale	GA= 4 (3–5)	GA = 4 (2–6)	Δ
			GB=5 (4–6)	GB = 5 (3–6)	Δ
		Handgrip (Kg)	GA=25(18-35)	GA= 30(20-39)	0,002
		6MWT (m)	GA=509 (426-539)	GA=557 (463-633)	<0,0001
			GB=344 (244-392)	GB=468 (374-518)	<0,0001
		FVC % of predicted	GA=80 (59.2-90.9)	GA=87.7 (67-98.9)	<0,01
			GB=75.1(59.8-90.6)	GB=86.4(67.6-96.3)	<0,0001
		FEV1 % of predicted	GA=83.3 (65.5-101.1)	GA=95.1 (84-106.8)	<0,0001
			GB=79.1 (65.8-99.7)	GB=94.8.1 (80.9-106.2)	<0,0001
		SF-36 mental component	GA=48.6 (37.2-53.8)	GA=54.2 (52.5-56.7)	Δ
			GB=38.5 (30.1-52.8)	GB=52.9 (32-58.2)	Δ
		SF-36 physical component	GA=31.8 (26.2-35.7)	GA=31.7 (31.7-42)	Δ
			GB= 30.2 (22.7-36.8)	GB=34.7 (30.2-41.3)	Δ
6	Al Chikhanie et al.,2021	Borg Scale	4.4±2.3	4.1±1.8	Δ
		Handgrip (Kg)	18.1±8	23.5±8.5	<0,05
		MIP (CmH2O)	42.7±17.5	62.9±13	<0,05
		6MWT (m)	138.7±144.4	343.4±139.6	<0,05
		FVC % of predicted	59.1±15.2	72.9±15.2	<0,05
		FEV1 % of predicted	66.7±16.0	81.2±14.2	<0,05

		Saint George respiratory Questionnaire (SGQ)	37.2±22.8	22.3±15.9	Δ
7	Spielmanns et al.,2021	6MWT (m)	176±141	357±132	<0,0001
		FIM (points)	100 ±15.1	111±15.0	<0,0001
8	Liu et al.,2020	FEV1(L)	1.10±0.08	1.44±0.25	<0,05
		FVC(L)	1.79±0.53	2.36±0.49	<0,05
		FEV1/FVC%	60.48±6.39	68.19±6.05	<0,05
		6MWT (m)	162.7±72.0	212.3±82.5	<0,05
		FIM (points)	109.2±13	109.4±11.1	Δ
		SF-36 mental component	61.5±6.5	73.7±7.6	<0,05
		SF-36 physical component	52.4±6.2	71.6±7.6	<0,05
		SF-36 general health	61.8±7.7	74.2±7.9	<0,05
9	Li et al.,2021	6MWT (m)	507.18 ± 88.27	Change from baseline 65.45 m (95%CI 43.8 to 87.1)	<0,001
		FVC(L)	2,77 ± 0,82	Change from baseline 0.02 (95%CI −0.14 to 0.18)	0,818
		FEV1(L)	2,19 ± 0,71	Change from baseline 0.08 (95% CI −0.08 to 0.25)	0,327
		FEV1/FVC	0.80 ± 0.13	Change from baseline 0.03 (95% CI −0.02 to 0.07)	0,224
		SF-12 PCS, media (SD)	39.42 ± 7.09	Change from baseline 3.79 (95% CI 1.24 to 6.35)	0,004
		SF-12 MCS, media (SD)	44.40 ± 8.48	Change from baseline 2.18 (95% CI −0.54 to 4.90)	0,116
10	Abodonya et al.,2021	FVC % of predicted	78.7 ± 13.5	84.2 ± 10.3	0,047
		FEV1 % of predicted	76.2 ± 12.7	83.7 ± 10.5	0,039
		EQ-5D-3L	38.6 ± 5.8	59.4 ± 8.3	<0.001
		6MWT (m)	332.6 ± 34.5	376.5 ± 39.4	<0.001
11	Hayden et al.,2021	mMRC	2.26 (0.00 - 4.00)	1.51 (0.00 - 4.00)	<0.001
		6MWT (m)	419 (13 - 663)	530 (175 - 740)	0,001
		VC % of predicted	89.6 (33.7 - 130.1)	98.0 (63.4 - 129.3)	0,003
		FEV1 % of predicted	92.3 (23.2 - 135.7)	100.9 (36.7 - 138.1)	<0,001
		PIM (CmH2O)	62.4 (6.6 - 133.3)	70.1 (19.9 - 133.3)	0,004
		EQ-5D-3L	11.65 (5.00 - 20.00)	9.23 (5.00 - 16.00)	<0,001
12	Büsching et al.,2021	6MWT (m)	336.2 ± 169.3	484.4 ± 146.6	<0,0001
		CRQ	91.7 ± 19.8	105.8 ± 18.0	<0,0001
		FIM (points)	97.3 ± 17.4	115.8 ± 14.0	<0,0001
13	Rodriguez et al.,2021	6MWT (m)	440.17 ± 164.36	519.94 ± 135.33	0,016
		Borg Scale	4.78 ± 1.70	2.56 ± 0.85	<0,001
		30-Second Sit-to-Stand Test (30STST)	12.33 ± 4.81	13.83 ± 5.70	0,011
14	Teixeira et al.,2022	FVC(L)	3.80 ± 1.13	4.35 ± 0.77	<0,001
		FEV1(L)	3.10 ± 0.93	3.65 ± 0.56	<0,001
		FEV1/FVC	GE=0.82 ± 0.06	GE=0.83 ± 0.04	Δ
		MIP (CmH2O)	73.1 ± 28	96.3 ± 21	<0,001
		Handgrip (Kg)	37.5 ± 11.2	40.8 ± 12.0	<0,05
		6MWT (m)	GE=522 ± 107	GE=543 ± 115	Δ
15	Pehlivan et al., 2022	mMRC	1 (0–2)	0 (0–2)	0,035
		SPPB	10.12 (5–14)	10.59 (8–14)	0,221
		Saint George respiratory Questionnaire (SGQ)	31.47 (5–87)	17.70 (4–78)	0,125
16	Gonzalez et al.,2021	Multidimensional Dyspnoea-12 questionnaire (MD12)	12.26 ± 5.92	5.89 ± 3.48	<0,001
		6MWT (m)	374.72 ± 151.59	487.58 ± 133.36	0,006
		30-Second Sit-to-Stand Test (30STST)	12.68 ± 5.33	14.00 ± 5.47	0,001
17	Paneroni et al.,2022	6MWT (m)	293.1 ± 111.8	369.0 ± 129.7	0,0006
		1 min Sit-to-Stand (1MSTS)	18.0 ± 8.1	22.3 ± 9.1	0,003
		Barthel dyspnoea	11.7 ± 9.0	5.3 ± 6.9	<0,001
18	Şahın et al.,2023	FEV1 % of predicted	GE=85.05 ± 4.44	GE=89.63 ± 4.96	0,066
			GC=80.00 ± 4.44	GC=84.68 ± 4.96	0,443
		FVC % of predicted	GE=83.94 ± 3.76	GE=90.94 ± 4.11	0,014
			GC=77.47 ± 3.76	GC=83.57 ± 4.11	0,232
		FEV1/FVC	GE=83.47 ± 3.92	GE=86.76 ± 4.05	0,237
			GC=86.15 ± 3.92	GC=86.84 ± 4.05	0,632
		mMRC	GE=2.63 ± 0.33	GE=1.21 ± 0.300	<0,001
			GC=2.31 ± 0.33	GC=1.84 ± 0.30	0,708
		Saint George respiratory Questionnaire (SGQ)	GE=47.77 ± 4.97	GE=36.67 ± 5.45	<0,001
			GC=50.91 ± 4.97	GC=39.03 ± 5.45	0,657
		SF-36 mental component	GE=63.57 ± 4.72	GE=69.21 ± 5.76	0,13
			GC=58.10 ± 4.72	GC=64.0 ± 5.76	0,418
		SF-36 physical component	GE=52.36 ± 6.25	GE=66.84 ± 6.97	0,023
			GC=52.89 ± 6.25	GC=59.47 ± 6.95	0,953

		SF-36 general health	GE=57.89 ± 5.53	GE=62.63 ± 5.81	0,283
			GC=53.94 ± 5.53	GC=57.36 ± 5.81	0,617
		6MWT (m)	GE=378.1 ± 28.9	GE=440.9 ±.25.8	<0,001
			GC= 325.1 ± 28.9	GC=381.7 ± 25.8	0,204
19	Dun et al.,2021	6MWT (m)	490.8 ± 101.4	603.5 ± 63.7	<0,001
20	Nopp et al.,2022	6MWT (m)	584.1 ± 95.0	647.0 ± 99.5	<0,001
		Borg Scale	7 (6–8)	7 (4–7)	<0,001
		mMRC	1 (0–1)	0 (0–1)	<0,001
		EQ-5D-3L	63.7 ± 17.9	78.6 ± 13.9	<0,001
		EQ-5D-3L	0.89 (0.81–0.91)	0.91 (0.84–1.00)	0,075
		FEV1 % of predicted	82.6 ± 18.4	89.5 ± 16.2	0,011
		FEV1/FVC	77.7 ± 10.1	78.6 ± 9.5	0,502
		MIP (CmH2O)	90.2 ± 30.1	115.6 ± 30.0	<0,001
21	Vallier et al.,2023	6MWT (m)	GA=447 ± 137	GA=542 ±111	<0,001
			GB=542 ± 97	GB=604 ±88	<0,001
		1 min Sit-to-Stand (1MSTS)	GA=23.2 ± 6.4	GA=32.7 ± 9.9	<0,001
			GB=28.4 ± 10.0	GB=35.9 ± 12.4	<0,001
		mMRC	GA=2.0 ± 0.0	GA=1.9 ± 0.3	<0,034
			GB=2.0 ± 0.0	GB=1.6 ± 0.5	<0,034
		FEV1 % of predicted	GA=82.6± 19.9	GA=88.3± 16.0	<0,076
			GB=87.0 ± 22.2	GB=90.5 ± 19.5	<0,076
		FVC % of predicted	GA=86.7 ± 23.2	GA=96.2 ± 18.1	<0,011
			GB=83.4 ± 19.4	GB=87.5 ± 19.2	<0,011
		FEV1/FVC	GA=79.3 ± 6.2	GA=76.1 ± 9.3	<0,152
			GB=82.4 ± 4.8	GB=82.1 ± 2.9	<0,152

Abbreviations: Experimental Group (EG), Control Group (CG), Group A (GA), Group B (GB), Group C (GC), Medical Research Council Dyspnea Scale (mMRC), Mean Muscle Strength (HHD), 6-Minute Walk Test (6MWT), Forced Vital Capacity (FVC), Forced Expiratory Volume in the First Second (FEV1), Maximum Inspiratory Pressure (MIP), Perceived Limitations in Activities of Daily Living (PROMIS 8b), EuroQol Quality of Life Questionnaire (EQ-5D-3L), Short Physical Performance Battery (SPPB), Saint George Respiratory Questionnaire (STGQ), Functional Independence Measure (FIM), Short Form Health Survey (SF-12), Mental Component Score (MCS), Physical Component Score (PCS), Chronic Respiratory Questionnaire (CRQ), 30-second sit-to-stand test (30STST), 1-minute sit-to-stand test (1MSTS), Multidimensional Dyspnea Questionnaire-12 (MD12); Barthel Dyspnea (BD), Standard Deviation (SD).Δ: The article reports that there was no statistical significance but does not report a p-value.

Methodological quality of cohort studies - Minors scale

Of the 21 studies included, 57.14% (n = 12) were evaluated using the Minors scale, with 50% (n = 6) being comparative studies and the remaining 50% (n = 6) being non-comparative studies. According to the scale for non-comparative studies, the ideal score would be 16, with 4 (66.6%) studies above this value and 2 (33.3%) below it. For comparative studies, the ideal score is 24, with none of the studies obtaining this score (Table 5).

Table 5. Methodological quality of cohort studies - Minors scale

#	Authors	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	Demoule et al.,2022	2	2	2	2	0	2	2	2	0	0	0	2	16
2	Wiertz et al.,2022	2	2	2	2	1	2	2	2	0	0	0	2	17
3	Eberst et al.,2022	2	2	2	2	0	2	2	2	0	0	0	2	16
4	Zampogna et al.,2021	2	1	0	2	0	2	2	2	0	0	0	2	15
17	Paneroni et al.,2022	2	2	2	2	0	1	2	1	0	0	0	2	14
20	Nopp et al.,2022	2	2	2	2	0	2	2	2	0	0	0	2	16

Minors scale criteria: (1) Clearly defined objective, (2) Consecutive patient inclusion, (3) Prospective data collection, (4) Results appropriate for the study objective in line with the intention to treat, (5) Impartial evaluation of results (blinding), (6) Follow-up period appropriate for the study objective, (7) Loss to follow-up less than 5%, (8) Calculation of study sample size, 95% confidence interval, (9) An adequate control group, (10) Groups managed at the same time for both control and study, (11) Baseline equivalence of groups, (12) Adequate statistical analysis. Abbreviations 0 = not reported, 1 = reported but inadequate, 2 = reported and adequate. The ideal score would be 16 for non-comparative studies and 24 for comparative studies.

Methodological quality of controlled clinical trials (PEDro score)

Of the 21 studies included, 42.85% (n = 9) were evaluated using the PEDro scale, with 77.77% (n = 7) resulting in high methodological quality and the remaining 22.22% (n = 2) resulting in intermediate quality (Table 6).

Table 6. Methodological quality of controlled clinical trials (PEDro score)

#	Authors	1*	2	3	4	5	6	7	8	9	10	11	Total	Methodological quality
8	Liu et al.,2020	—	1	0	1	0	0	0	1	1	1	1	6	Intermediate

9	Li et al.,2021	—	1	1	1	1	0	1	1	1	1	1	9	High
10	Abodonya et al.,2021	—	1	0	1	0	0	1	1	1	1	1	7	High
13	Rodriguez et al.,2021	—	1	1	1	1	1	1	1	1	1	1	10	High
14	Teixeira et al.,2022	—	1	1	0	1	0	0	1	1	1	1	7	High
15	Pehlivan et al., 2022	—	1	1	1	1	1	1	1	1	1	1	10	High
16	Gonzalez et al.,2021	—	1	1	1	1	1	1	1	1	1	1	10	High
18	Şahın et al.,2023	—	1	1	1	1	0	1	1	1	1	1	9	High
21	Vallier et al.,2023	—	1	1	0	0	0	0	1	1	1	1	6	Intermediate

PEDro scale criteria: (1) Selection criteria were specified (*- This item is not used to calculate the PEDro score), (2) Subjects were randomly assigned to groups (in a crossover study, subjects were randomly assigned as they received treatments), (3) Assignment was concealed, (4) The groups were similar at baseline in terms of the most important prognostic indicators, (5) All subjects were blinded, (6) All therapists who administered the therapy were blinded, (7) All assessors who measured at least one key outcome were blinded, (8) Measurements of at least one key outcome were obtained from more than 85% of the subjects initially assigned to the groups, (9) Results were presented for all subjects who received treatment or were assigned to the control group, or when this was not possible, data for at least one key outcome were analyzed by "intention to treat," (10) Results of statistical comparisons between groups were reported for at least one key outcome, (11) The study provides point measures and variability measures for at least one key outcome. Abbreviations 1 = item met, 0 = item not met. Quality criteria: ≥ 7 high quality. 5-6 intermediate quality. ≤ 4 low quality

Assessment of bias

The risk of bias was assessed using the Cochrane Risk of Bias 2.0 tool in Review Manager 5.4 software. The results are summarized in Figures 2 and 3. The risk of bias matrix per study shows that most trials have an uncertain risk of bias in several domains, mainly due to the lack of detailed information on randomization procedures and allocation concealment. Likewise, some studies showed a high risk of bias in specific domains, such as deviations from interventions and outcome measurement, reflecting possible methodological limitations.

Meta-analysis

Outcomes reported consistently in at least four controlled clinical trials were included in the meta-analysis. This allowed for a quantitative synthesis of the effect of pulmonary rehabilitation on lung function (FVC, FEV1, and FEV1/FVC ratio) and on functional capacity, measured using the six-minute walk test (6MWT). A total of four randomized controlled trials contributed data to the pooled analyses of lung function outcomes, while seven randomized controlled trials contributed to the meta-analysis of the six-minute walk test.

Lung function

For the pooled analyses of lung function, all spirometric outcomes were harmonized in comparable units across studies. Specifically, FVC and FEV1 were analyzed in liters, whereas the FEV1/FVC ratio was analyzed as a percentage. The pooled meta-analysis of studies evaluating forced vital capacity (FVC) showed a slight effect in favor of the rehabilitation group, without reaching statistical significance (MD: −0.01 L; 95% CI −0.04 to 0.06), with moderate heterogeneity (I^2 = 70%). This heterogeneity may reflect differences across studies in rehabilitation protocols, including setting, supervision, and intervention characteristics. For forced expiratory volume in the first second (FEV1), the combined effect also showed no significant differences between groups (MD: −0.01 L; 95% CI −0.07 to 0.05), with low heterogeneity (I^2 = 38%). Regarding the FEV1/FVC ratio, the values showed a slight deviation toward the experimental group; however, the overall effect was not significant (MD: −0.00; 95% CI −0.06 to 0.06), accompanied by high heterogeneity (I^2 = 80%). The variability observed in this outcome may also be associated with clinical and methodological differences among the included trials.

Six-minute walk test (6MWT)

The meta-analysis of seven randomized controlled trials showed a significant effect in favor of the pulmonary rehabilitation group on the distance walked in the 6MWT. The intervention group improved, on average, 89 meters more than the control group (MD: −89.15 m; 95% CI −96.30 to −81.99; $p < 0.00001$), with high heterogeneity (I^2 = 93%). This high heterogeneity may be related to differences in rehabilitation setting, duration and supervision of the interventions, as well as variability in participants' baseline functional status. These pooled findings should be interpreted with caution, as the risk-of-bias assessment identified some concerns in several included trials, particularly in domains related to the randomization process and outcome measurement.

Figure 2. Risk of bias graph presented in percentages

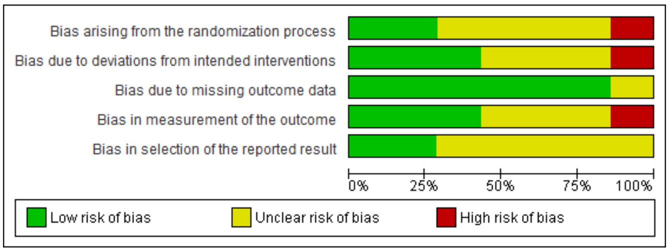


Figure 3. Summary of risk of bias

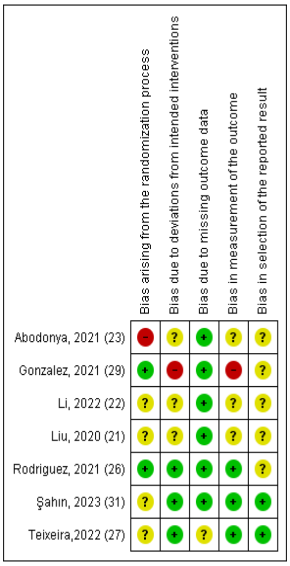


Figure 4. Forest plot

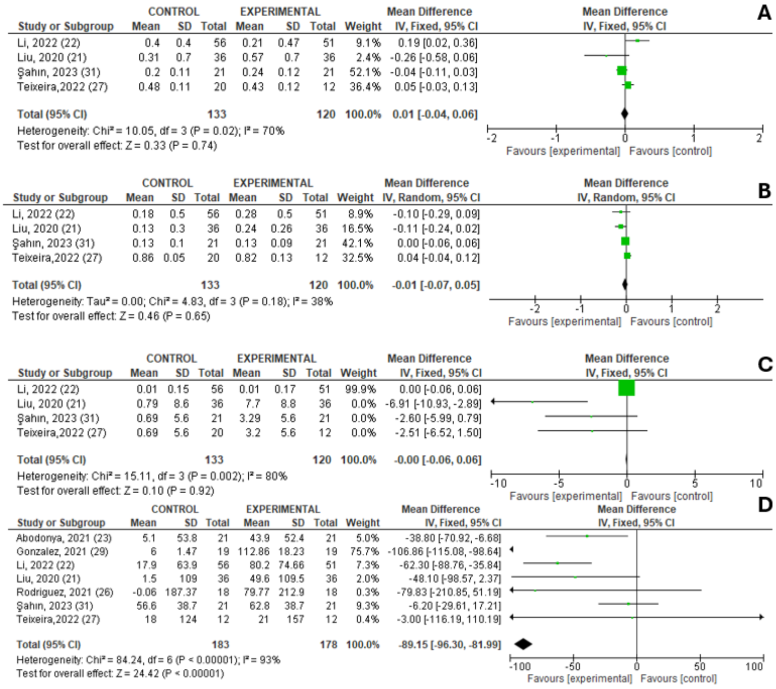


Figure 4. Forest plots showing the effect of pulmonary rehabilitation programs on pulmonary function and functional capacity outcomes in post-COVID-19 patients. Panel A: forced vital capacity (FVC); Panel

B: forced expiratory volume in the first second (FEV1); Panel C: FEV1/FVC ratio; Panel D: distance covered in the six-minute walk test (6MWT). The horizontal lines represent the 95% confidence intervals for each study. The squares indicate the statistical weight of each study, and the diamonds show the combined effect calculated by the difference in means. The vertical line marks the point of no difference between the experimental and control groups. Values to the left favor the experimental group, and values to the right favor the control group.

Discussion

Our study showed that although most PR programs were carried out in hospitals (57%), a significant percentage (43%) were developed using outpatient or telerehabilitation strategies, which gives this type of intervention an important role given the Covid-19 contingency. However, for professionals in the field of rehabilitation, it emerges as a possibility for user intervention. Wootton et al.,2020, mention in their study that PR through telehealth allows a personalized program to be offered to each patient in their post-COVID-19 recovery, without putting the lives of healthcare professionals at risk by avoiding direct contact but still meeting treatment objectives.

COVID-19 causes a significant deterioration in the ventilation/perfusion ratio and lung volumes, and lung recovery in these patients can be quite extensive, and may even be incomplete due to tissue destruction from alveolar damage that changes the structure of the lungs and prevents adequate gas exchange. It has been reported that nearly 80% of the population infected with Covid-19 show changes in lung structure and function, which is why it is important to start rehabilitation as early as possible in order to achieve a significant improvement in lung function (Pancera et al.,2020). In our study, we found that of the 21 articles reviewed, 57% (n = 12) of the studies performed spirometry assessments with variables such as FVC, FEV1, and FEV1/FVC ratio, which are relevant parameters that provide information on lung function to initiate the PR process and adequately monitor and control patients.

According to Rapela et al., 2022, who conducted a study on a patient hospitalized for post-COVID-19 hypoxemia, pulmonary function is affected by bilateral pneumonia with hypoxemia, which is why in these cases they recommend starting RP early in order to reduce muscular dystrophy, high oxygen requirements, and especially to limit the physical, mental, and emotional deterioration of patients. Achieving recovery of lung function, in this case within a period of 4 weeks, allowed the patient to regain their quality of life in both the physical and social spheres. However, this does not mean that their rehabilitation is complete, as the goal is to achieve the lung function and physical condition they had before contracting COVID-19.

Our study shows that 43% n= (9) used the Medical Research Council (mMRC) scale to assess dyspnea, with baseline values ranging from 3 (2–4) to 1 (0–1) and post-PR values ranging from 2 (1–2) to 0 (0–1). These results coincide with the article by Chen et al., 2022, who conducted a systematic review and meta-analysis using the scale with favorable results with PR intervention 1.46 (95% CI: 1.17 to 1.82; p = 0.001) between the experimental and control groups at 6 weeks from the start of the intervention. This suggests that the use of pulmonary rehabilitation could improve aspects related to muscle function and strength in patients.

86% n= (18) of the studies used the 6-minute walk test (6MWT) to assess aerobic capacity in our study, showing improvement in baseline values between 138.7±144. 4m and 584.1m (±95.0) and subsequent values of 212.3±82.5m and 619.8±67m. Previous studies in respiratory populations have suggested that the minimal clinically important difference for the 6MWT is approximately 25–35 meters. In our meta-analysis, the pooled mean difference between the pulmonary rehabilitation and control groups was 89.15 meters, which substantially exceeds this threshold (Bohannon et al.,2017).

These results coincide with Ahmed et al.,2022, who conducted a systematic review evaluating the safety and efficacy of PR in patients with acute and/or chronic COVID-19, and in which seven of the articles in this review evaluated aerobic capacity using the 6MWT. This study showed that RP significantly improved aerobic capacity (mean difference 65.85 m [95% confidence interval, 42.86 to 88.83; P<.001]). The results show clinically important improvements in patients with acute and chronic COVID-19 with mild to severe symptoms.

Muscle strength was measured using PIM, handgrip strength, and mean muscle strength (HHD) in our study. On the other hand, a case report was found of a young COVID-19 patient with respiratory distress syndrome who underwent RP and whose muscle strength was assessed with PIM with initial values of 68 (59) and final values of 79 (68)/ and the MRC scale baseline value of 52/60 and final value of 58/60. The above shows the use of standardized scales for the evaluation of strength and the importance of the measurement process of this physical component in rehabilitation processes (Rapela et al., 2022). After the COVID-19 pandemic, it has been important to analyze the general health status of surviving patients, taking into account that quality of life goes beyond good health, and it is necessary to use diagnostic tools that facilitate physical and mental assessment.

Taking the above into account, our research revealed the use of questionnaires or scales such as the EuroQol Questionnaire, FS-36, and SF-12 to assess quality of life. A case report was found on a patient hospitalized for post-COVID-19 hypoxemia who underwent RP. In the study of Zhang et al.,2023 conducted in PR in patients with COPD, the SGRG scale was used to assess the quality of life of 94 patients with COPD, where PR intervention significantly improved the quality of life of the participants. This indicates the importance of assessing this aspect in rehabilitation programs with standardized scales that show the impact on quality of life. However, given that there are few studies reporting on the assessment of quality of life after pulmonary rehabilitation, it is necessary to continue conducting studies that strengthen the specific findings in this component.

Regarding geographical distribution, most of the included studies were conducted in Europe and Asia, which may limit the generalizability of the findings to other regions. It is important to avoid attributing potential differences in outcomes to the physical characteristics of the populations, as this would be speculative and not directly supported by the available data. More plausible explanations include differences in healthcare systems, access to rehabilitation services, post-acute care models, and research infrastructure, all of which may influence the implementation and effectiveness of pulmonary rehabilitation and should be considered when interpreting the results. Similarly, although the search strategy was conducted without language restrictions, all included studies were published in English. This should not be considered a methodological limitation, but rather a reflection of prevailing publication patterns in this field.

On the other hand, in this study we were able to find very comprehensive articles describing more than three measurements to evaluate the effect of PR on COVID-19. However, other studies mention only two or at most three measurements, which on the one hand limits the comparison of the effect and also provides more restricted information on the scope of the PR program. Similarly, we found studies that describe in great detail the components of the PR program, including aspects such as exercise prescription, psychology, nutrition, occupational therapy, and patient education, demonstrating the importance of a multidisciplinary team in achieving the proposed objectives. However, other studies were limited in their detailed description of this information.

Regarding the tests performed, it was evident that most of the articles in our study included the 6MWT test, which is a useful tool for assessing aerobic capacity both for initial assessment and for monitoring patients in the program. Similarly, the assessment of lung function is considered relevant, with emphasis on spirometry as a reliable and clinically useful measure.

The findings of the meta-analysis indicate that pulmonary rehabilitation produced only modest improvements in pulmonary function, without reaching statistical significance in any of the parameters evaluated (FVC, FEV1, and the FEV1/FVC ratio). One possible explanation for this behavior is that, in post-COVID-19 patients, functional limitation seems to depend less on residual obstructive or restrictive compromise and more on extrapulmonary factors, such as peripheral muscle weakness, diaphragmatic dysfunction, or exercise intolerance secondary to deconditioning, elements that respond more quickly to aerobic and resistance training than spirometric variables (Iversen et al.,2025). In addition, lung function usually shows progressive spontaneous recovery during the first few weeks after infection, demonstrating that initial spirometric abnormalities improve over time, regardless of whether pulmonary rehabilitation is performed or not, which may reduce the magnitude of the effect attributable exclusively to the intervention.

Functional capacity showed a statistically significant improvement after pulmonary rehabilitation, reflected in an average increase of 89 meters in the distance covered during the 6MWT. This finding suggests that rehabilitation programs have a clinically relevant impact on exercise tolerance in post-COVID-19 patients, probably due to improvements in ventilatory efficiency, peripheral muscle recovery, and reduced physical deconditioning, phenomena widely described in the pathophysiology following infection. However, the heterogeneity observed between studies was high (I^2 = 93%), which may be attributed to variations in the duration, intensity, and specific components of the interventions, as well as differences in baseline functional level, disease severity, and time from infection to program initiation. Despite this variability, all included studies showed a consistent effect in favor of rehabilitation, reinforcing the robustness of the observed improvement in functional capacity.

The risk-of-bias assessment showed methodological variability among the trials included in the meta-analysis. Judgments of some concerns predominated in key domains, particularly those related to the randomization process and outcome measurement, which may reduce confidence in the magnitude of the observed effects. This is partly explained by the nature of rehabilitation interventions, in which blinding of participants and personnel is often impractical, although the implications of this limitation may differ according to the type of outcome assessed. More objective outcomes, such as spirometric parameters and the six-minute walk test, are likely to be less affected by measurement bias, whereas more subjective outcomes, such as dyspnea perception and quality-of-life scales, may be more susceptible to this limitation. On the other hand, bias due to missing data was generally low, as most studies reported complete follow-ups. Therefore, the pooled findings should be interpreted with methodological caution, particularly for outcomes based on patient-reported measures.

This review could be used as an evidence-based guide for healthcare personnel involved in the rehabilitation process of patients, enabling them to implement assessment and intervention processes with theoretical and practical foundations. However, it should be recognized that the rehabilitation of the sequelae of COVID-19 requires continued research to enable a comprehensive approach for these patients. The scientific community is therefore invited to continue researching in this area and to include aspects such as a detailed description of the PR program, as well as the measurement of the effects of PR on dyspnea, lung function, strength, functionality, aerobic capacity, quality of life, among other variables, which will expand the information available and allow for greater knowledge for the benefit of patients.

Conclusions

57% of PR programs were carried out at the hospital level, however, a significant percentage (43%) were carried out on an outpatient basis or through telerehabilitation, making it an innovative strategy to consider in rehabilitation processes.

The duration of the PR ranged from 3 to 12 weeks, 3 to 6 times per week, 1 to 2 sessions per day, with each session lasting 20 to 50 minutes. This prescription could show positive effects related to variables such as: dyspnea, aerobic capacity, muscle strength, lung function, quality of life, and functionality.

In assessing the effect of PR, the most commonly used scale for evaluating dyspnea was the MRC, followed by the Borg scale. While 87% of studies implemented the 6MWT as a simple and useful tool for assessing aerobic capacity, PIM and handgrip strength were used to assess muscle strength. Finally, for the assessment of pulmonary function, 57% of the studies used spirometry, which was widely used.

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