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Review Article

Pulmonary Rehabilitation Strategies for the Treatment of Pneumoconiosis: A Narrative Review

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Abstract

Pneumoconiosis is a collection of lung diseases caused by inhaling mineral dust that poses an important risk to public health worldwide. Effective clinical treatments are currently limited, but pulmonary rehabilitation (PR) has shown promise in treating respiratory diseases. This review aims to assess the effectiveness of PR strategies for treating pneumoconiosis. We searched research studies that investigated the effectiveness of PR interventions for pneumoconiosis patients in international scientific databases and comprehensively reviewed PR strategies for the treatment of pneumoconiosis. Pneumoconiosis patients are increasingly being treated with a multimodal PR program. PR interventions could save healthcare costs, reduce dyspnea, improve exercise performance, and enhance overall health-related quality of life in patients with pneumoconiosis. PR interventions are effective in improving respiratory function and quality of life in patients with pneumoconiosis. However, further research is needed to determine the optimal PR strategies for pneumoconiosis patients and to investigate the long-term effects of these interventions.

Keywords: Pneumoconiosis; Pulmonary rehabilitation; Treatment

Introduction

Pneumoconiosis is a collection of occupational interstitial lung disorders caused by inhaling mineral dust (1). The most of this dust is made up of inorganic materials, including free silica dust, asbestos fibers, coal mine dust, and mixed silicate dust, which can cause chronic lung inflammation and fibrosis. Pneumoconiosis develops when inflammation leads to pulmonary fibrosis (2), and it is commonly found worldwide, especially in low- and middle-income countries, and among gold, iron, and tin miners (3). Pneumoconiosis is classified into four subtypes based on the composition of the mineral dust that causes it: silicosis pneumoconiosis (the most common form) that is caused by dust with high levels of free silica; silicate pneumoconiosis (including asbestos's, talc's, cement's, mica's, and potter's pneumoconiosis); pneumoconiosis resulting from coal dust and carbon-based dust (including coal worker's, graphite, and carbon black pneumoconiosis); and metal pneumoconiosis resulting from metal dust (including aluminum's, welder's, and caster's pneumoconiosis) (4). In recent years there has been a decline in the worldwide prevalence of pneumoconiosis; however, the number of people affected by this disease is still substantial. The

economic and health implications of pneumoconiosis on the nation, society, family, and individual continue to be considerable because the disease cannot be properly cured. Pneumoconiosis patients have an average survival rate of 32 years after their diagnosis (4-6).

Pneumoconiosis is a rare disease that is currently untreatable (7). To alleviate suffering, slow disease progression, and increase survival rates, management of the condition must begin with a holistic strategy for overall health and active interventions, such as symptomatic treatment, complication/combination treatment, and rehabilitative treatment (8). There is conclusive evidence that comprehensive intervention can reduce dyspnea, improve exercise performance, and enhance health-related quality of life (9). Pulmonary rehabilitation (PR) is a comprehensive intervention based on a thorough patient assessment followed by patient-tailored therapies that include, but are not limited to, exercise training, education, and behavior change (10-13). It is designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors (14). PR can benefit people diagnosed with chronic obstructive pulmonary disease (COPD), bronchiectasis, pulmonary hypertension, interstitial lung disease, and other chronic pulmonary disorders (15). Patients with non-malignant respiratory diseases can benefit from PR to increase their physical capacity and quality of life. However, pneumoconiosis patients have been underrepresented in previous studies (16). Therefore, in this review, we summarized PR strategies for the treatment of pneumoconiosis.

Treatment strategies for pneumoconiosis

Present situation

Pneumoconiosis has become a substantial burden in recent decades, but there are currently few proven clinical treatments available (17). Lung transplantation is the only treatment for advanced pneumoconiosis, which has a chance of preserving the patient's life (18). Treatment plans are based on patient complaints, such as coughing, chest pain, and difficulty breathing, and may include managing associated complications like respiratory infections, tuberculosis, chronic obstructive pulmonary disease, and pneumothorax, as well as encouraging patients to engage in rehabilitative exercises (19, 20). Some clinical treatments have reduced symptoms and improve quality of life (21), including whole lung lavage (WLL) as part of an integrated treatment plan for pneumoconiosis (22). WLL can help slow the development of pneumoconiosis by clearing the airway of sputum, secretions, dust, and fibrotic cytokines, but it is most effective when implemented early in the course of the disease when the majority of the inhaled dust is still lodged in the pulmonary alveoli (23).

However, there is currently no proof that WLL could improve pulmonary function or reduce lung fibrosis, and it is an intrusive technique with unknown long-term effects on lung homeostasis. Lung transplantation is a viable option for people with terminal lung disorders like silicosis, and the results are often the reasonable when the patient is young. Patients with silicosis who undergo a lung transplant had a 76% chance of survival after three years (18). However, only 6–7 years is the median survival time for people who have received a lung transplant. Lung transplantation has been enormously hampered by factors such as the scarcity of donor's lungs, the seriousness of the potential side effects, the expense of the procedure, its perceived complexity, and the inherent dangers of the operation itself. The pneumoconiosis treatment classification is detailed in Fig. 1.

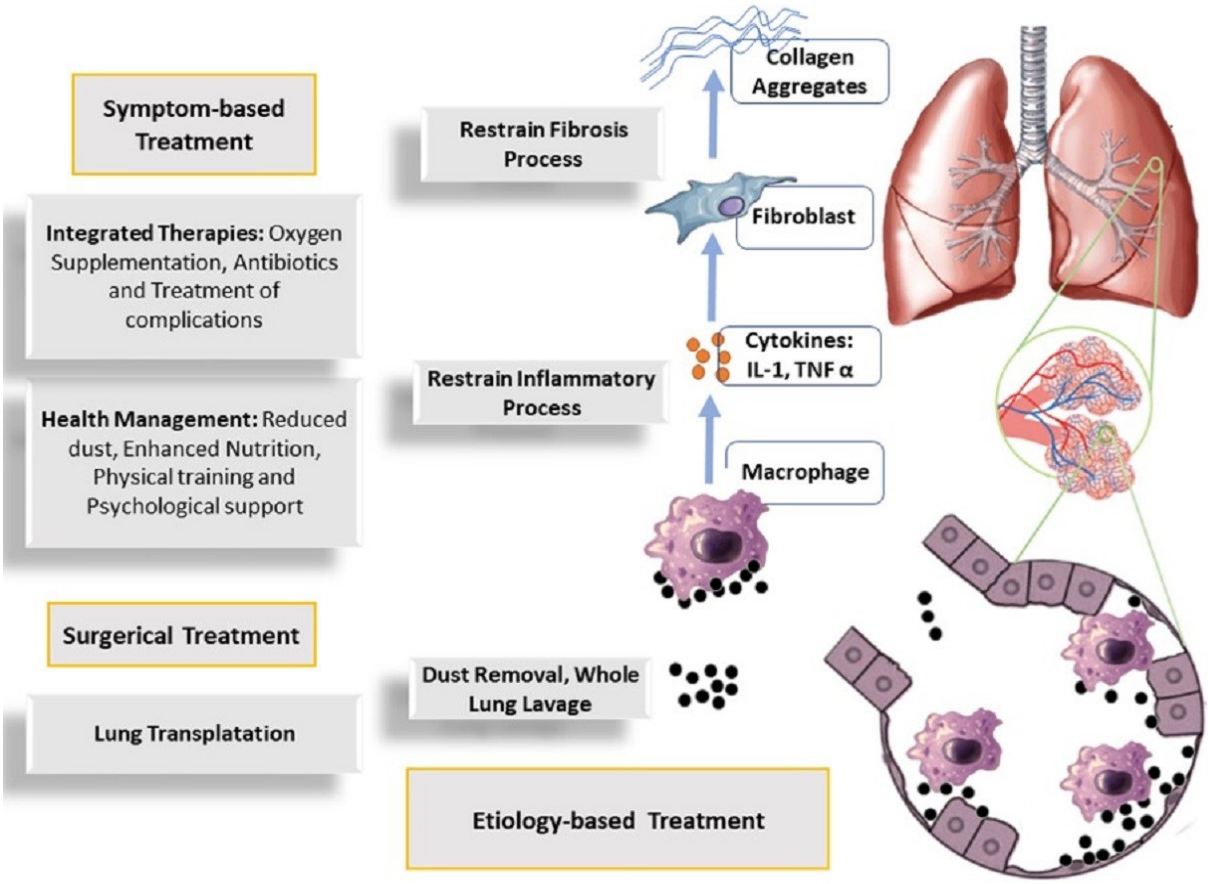

Fig. 1: The pneumoconiosis treatment classification (Original)

Potential treatments for pneumoconiosis

Some medications have recently been discovered to be effective in treating pneumoconiosis. Drugs that suppress the immune system's inflammatory response, such as hydroxychloroquine (24), corticosteroids, infliximab (25), as well as the antioxidant N-acetylcysteine (26), the vasodilators nicorandil and carvedilol (27, 28), have the potential to reduce pulmonary inflammation and fibrosis in experimental models of pneumoconiosis. Corticosteroids with anti-inflammatory characteristics have been demonstrated to alleviate clinical symptoms of people with chronic beryllium illness (29). Additionally, some traditional Chinese medicine extracts, such as dioscin (30), astragaloside IV (31), kaempferol (32), tanshinone IIA (33), and dihydrotanshinone (34), have shown promise in reducing inflammation and fibrosis in animal models. Moreover, stem cell therapy has shown great promise in preclinical studies, with therapeutic results in a mouse model of silicosis (35, 36). Although successful in preclinical and clinical tests, the underlying mechanism for the anti-inflammatory and anti-fibrotic capabilities of mesenchymal stem cells (MSCs) in treating pneumoconiosis remain unknown. Moreover, many challenges must be addressed before stem cell therapy can be used in clinical practice, including assessing its viability and effectiveness, resolving scientific and practical challenges, addressing ethical concerns, and conducting extensive clinical studies. Despite these challenges, stem cell therapy shows considerable promise and will continue to drive research in the coming years (37).

Definition and Clinical impact of pulmonary rehabilitation

The American Thoracic Society Pulmonary Rehabilitation Statement (2013) defines PR as a comprehensive intervention that includes exercise training, education, and behavior change tailored to improve the physical and psychological condition of people with chronic respiratory disease and promote long-term adherence to health-enhancing behaviors (38). While this definition highlights the aims and components of PR, it does not specify the necessary structure, setting, and supports for successful PR models. At the time of its development, PR programs in North America and Europe were mostly center-based, and very few were delivered in other settings (39). Given these developments, the workshop committee was asked to evaluate this definition in light of more recent advancements in PR science and practice (39).

In recent years, PR programs have expanded beyond center-based models to other settings. Patients with pneumoconiosis can benefit from PR, which typically lasts 6-12 weeks and includes aerobic activity, education, and muscle strengthening tailored to each patient (40). Patients often have training sessions twice or thrice a week for 30-60 minutes each. To achieve the greatest possible functional gains, therapies are tailored to each patient. PR can improve symptoms, including dyspnea, exercise tolerance, and general health, and have positive effects on patients' physical, emotional, social, and financial well-being (41).

The components of pulmonary rehabilitation

PR comprises essential components, each of which plays a substantial role in enhancing the patient's quality of life. The combined use of these components yields the best rehabilitation outcomes. Physical training, strength training, respiratory muscle training, use of oxygen during training, psychological treatments, physiotherapy and relaxation training, nutrition, and rehabilitation surgery are discussed in detail in the following sections (42). The components of PR are specified in Fig. 2.

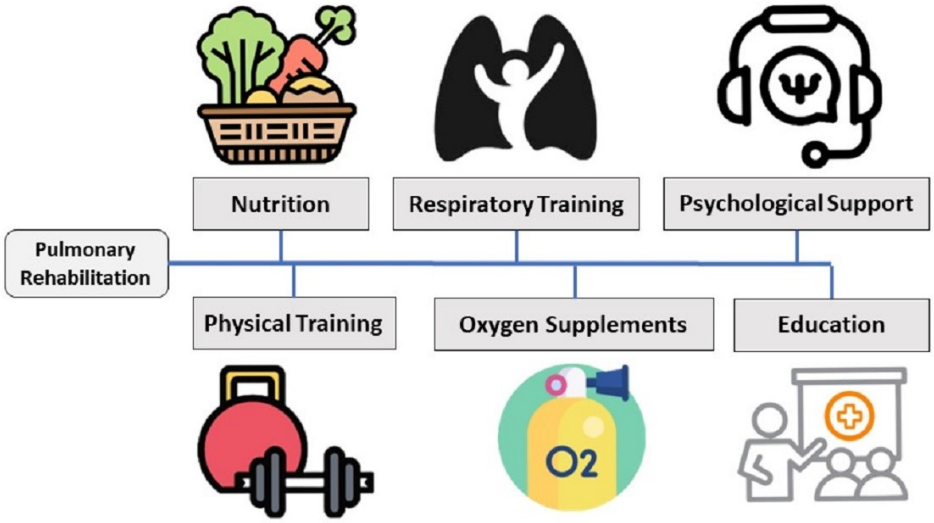

Fig. 2: Components of the pulmonary rehabilitation (Original)

Physical training

Pneumoconiosis patients engage in less physical activity due to dyspnea and to avoid experiencing pulmonary symptoms during physical activity (43). This leads to a reduction in skeletal muscle strength, making it more challenging for them. Thus, physical workouts are crucial during PR (14). The duration of physical training weeks should be between 4 and 12 weeks, with 2 to 5 sessions per week (44, 45). Nonetheless, the rehabilitation group emphasizes 2 sessions per

week in addition to the individual's own training sessions (46, 47). Various exercises focus on specific muscle groups, such as the upper or lower limbs, and on endurance or strength (48). A combination of endurance and strength exercises, focusing on different body muscles, is recommended during PR (49-51). The intensity of the exercise should correspond to 60 to 75% of maximum oxygen absorption, performed for 20 to 30 minutes and repeated many times each week, to boost the patient's endurance (52). If facilities are unavailable to measure oxygen levels, symptoms can be used to gauge the intensity of the activity. Modest dyspnea-inducing exercise has been shown to increase a patient's endurance (53).

Respiratory muscle training

The PR program may include respiratory muscle training (RMT) to alleviate respiratory muscle weakness caused by pneumoconiosis. Weak respiratory muscles lead to fatigue, effort restriction, dyspnea, and hypercapnic respiratory failure (54, 55). RMT aims to enhance respiratory muscle function and relieve dyspnea, hypoxia, and hypoventilation. Flutter valves, threshold inspiratory muscle trainers, and incentive spirometers are some of the equipment used for RMT based on the patient's specific needs (9, 56). RMT comprises two components: inspiratory muscle training (IMT) and expiratory muscle training (EMT) (57). IMT is usually prescribed for shortness of breath, while EMT is for productive cough (58). IMT has two approaches: strength training and endurance training. Endurance training technique utilizes more training volume with fewer external loads, while strength training approach utilizes less training volume with a greater number of external loads (59). In a popular IMT technique, the patient resists a load equal to 30-60% of their steady inspiratory pressure for 15-30 minutes per day, with the load gradually increasing by up to 5% per week based on the patient's strength (55).

Use of oxygen during training

Many patients requiring PR have an imbalance between ventilation capacity and demand, which worsens shortness of breath during activities and physical training, hindering completion of the program and reaping its benefits (60). Continual hypoxemia can also lead to inadequate tissue oxygenation, pulmonary hypertension, and eventually right heart failure. Thus, oxygen assistance is necessary to eliminate hypoxemia and enhance the capacity for physical training (61). Currently, many PR programs suggest supplementing blood oxygen saturation above 88 percent with oxygen (62). The efficacy of oxygen supplementation in enhancing PR's effect and improving patients' quality of life is yet to be demonstrated, and studies in this area have conflicting results. Studies have suggested that a mixture of oxygen and helium can be more effective due to the low density of helium gas, reducing airflow resistance and trapped air (62-64).

Education

Patient education is a crucial component of PR for pneumoconiosis patients, although it is not very successful when provided alone. When combined with other components, patient education can improve the patient's quality of life (65). Typically, patient education is provided weekly in PR programs before or after physical training. While individual instruction is sometimes given, it usually takes place in group settings (66). Currently, the focus is on patient-centered training and self-management to improve the patient's quality of life and alleviate symptoms (67). These education sessions cover the topics listed below (Table 1).

Psychological support

Psychological concerns substantially affect the quality of life of individuals with chronic respiratory disorders. Anxiety, depression, panic, cognitive impairment, and tobacco addiction are among the most important psychological problems faced by these people (68). During physical exercise, dyspnea causes anxiety, panic, and limits social activities, leading to sadness. Therefore, evaluating the patient's levels of anxiety and depression is a common component of many PR programs (67). Additionally, patients in various PR programs receive psychological support from

psychologists and sometimes physiotherapists. This support includes assistance with improving mood, adaptive behavior, anxiety management strategies, and positive thinking (67, 69). Patients with sexual activity issues require sexual counseling. Individuals with serious mental issues, such as debilitating anxiety and depression, must be referred to a psychiatrist (14).

Table 1: Education as a component of the pulmonary rehabilitation

No.	*Common topics covered in training*
1	Introducing chronic respiratory disease to the patient
2	Breathing techniques including Diaphragmatic breathing and Pursed lip breathing
3	Energy conservation techniques
4	Respiratory medications
5	Home exercise training
6	Introduction of respiratory medications
7	Nutrition
8	Use of oxygen
9	Airway clearance training
10	Stress and emergencies management
11	Exacerbation management

Nutrition

Nutritional monitoring of patients is another crucial aspect of PR. Typically, nutritionists who are in contact with the rehabilitation team are responsible for this task as there is no full-time nutritionist on the team (70). In PR, nutrition assessment is performed by measuring body mass index (BMI) or weight. Some rehabilitation programs use skinfold anthropometry or bioimpedance analysis to estimate fat-free mass for more accurate screening (71). Nutritional interventions to improve nutritional status include utilizing nutritional supplements and modifying the frequency, volume, and composition of meals. Combining nutritional therapies with physical exercise boosts the patient's fat-free mass and muscle strength, thus enhancing the patient's quality of life (72).

Indications and contraindications of pulmonary rehabilitation

PR is primarily recommended for patients with COPD and other chronic respiratory disorders who experience activity-related dyspnea and cannot tolerate everyday activities, especially those who cannot manage their illness despite receiving appropriate medical and therapeutic measures (9, 73). Interestingly, PR is not limited to people with chronic lung conditions but also recommended for patients with musculoskeletal disorders and heart failure. Starting PR in the earlier stages of the disease has a greater impact on the treatment process and enhancing the patient's quality of life (8, 74). The modified Medical Research Council Breathlessness (mMRC) is used to assess the degree of baseline functional disability due to dyspnoea. It is useful in characterising baseline dyspnoea in patients with respiratory disease such as COPD. The mMRC breathlessness scale ranges from grade 0 to 4. Grade 0 indicates being breathless only with strenuous exercise while Grade IV indicates being too breathless to leave the house or dress and undress. Patients in grades between 2 and 4 are potential candidates for PR (75-77). However, PR is not always advantageous or practical for patients and may have absolute or relative contraindications. The most important contraindications include persistent orthopedic or unstable cardiovascular diseases, transmissible infectious diseases, unstable psychiatric conditions, and severe cognitive impairment that makes it difficult to follow in-

structions. Other important contraindications include severe uncontrolled anemia, limited life expectancy, severe debilitating fatigue, severe visual impairment, and inability to perform training due to other diseases (73, 74, 76, 78). Table 2 shows the contraindications and indications of pulmonary rehabilitation.

Table 2: Contraindications and indications of pulmonary rehabilitation

	Contraindications of PR	*Indications of PR*
1	Persistent orthopedic disease such as unstable bone fracture	Chronic obstructive pulmonary disease (COPD)
2	Unstable cardiovascular disease such as unstable angina and arrhythmia	Pneumoconiosis
3	Transmissible infectious disease that is dangerous for others	Pulmonary hypertension
4	Unstable psychiatric conditions that are dangerous for others	Restrictive lung disease
5	Uncontrolled diabetes	Musculoskeletal diseases
6	Severe cognitive impairment that makes it difficult to follow orders	Heart failure
7	Progressive neuromuscular disease	
8	Lack of motivation	
9	Severe uncontrolled anemia	
10	Limited life expectancy	
11	Severe debilitating fatigue	
12	Severe visual impairment	
13	Inability to perform Training due to other diseases such as severe arthritis and severe peripheral vascular disease	

Pneumoconiosis and pulmonary rehabilitation

PR has been extensively utilized in the treatment of pulmonary disorders and has been shown to effectively result in sustained improvements in functional capacity and decreased requirements for clinical care. However, past investigations have typically included fewer patients with pneumoconiosis (16). Some recent RCTs of PR for the treatment of pneumoconiosis have been published (54, 79, 80) (Table 3), and a meta-analysis (65) considered 1307 participants from 16 randomized controlled trials. The results showed that PR is beneficial for individuals with pneumoconiosis, as changes in the 6-minute walk distance, St. George's Respiratory Questionnaire, modified Medical Research Council dyspnea scale, 36-item Short Form Health Survey, and pulmonary function were the most telling indicators. No negative side effects were identified in any of the investigations (65). These findings suggest that PR can enhance the exercise capacity and quality of life of people with pneumoconiosis. Subgroup research revealed that increasing the time spent in PR or combining exercise training with other forms of rehabilitation, such as nutritional intervention and psychosocial support, may increase pulmonary function (65). Since patients with pneumoconiosis have a poor quality of life, and the condition is still regarded as incurable and irreversible, the present guidelines should include PR as a routine treatment to alleviate symptoms and slow the disease's progression (81, 82).

Table 3: Randomized controlled trials (RCTs) studies investigating the effectiveness of pulmonary rehabilitation (PR) in treating pneumoconiosis.

Study	*Country*	*Year*	*Case*	*PR intervention*	*Period of treatment*	*Ref*
Ma et al	Japan	2023	15	Health education Exercise training Respiratory training	> 1 month	(83)
Chen et al	China	2020	38	Health education Exercise training Respiratory training	2 month	(54)
Xiao et al	China	2019	74	Health education Exercise training Respiratory training	6 month	(84)
Pan et al	China	2017	60	Health education Exercise training Respiratory training	2 month	(85)
Wang et al	China	2017	51	Health education Exercise training	2 month	(86)
Qu et al	China	2017	82	Health education Exercise training	3 month	(87)
Yun et al	China	2015	100	Health education Exercise training	12 month	(88)
Liu et al	China	2015	82	Health education Exercise training	3 month	(89)
Li et al	China	2015	80	Health education Exercise training Respiratory training Psychological counseling Nutritional guidance	6 month	(90)
Li et al	China	2014	200	Health education Exercise training	2 month	(91)
Liu et al	China	2014	60	Health education Exercise training Respiratory training	6 month	(92)
Ma et al	China	2014	60	Exercise training Respiratory training Psychological counseling Nutritional guidance	1.5 month	(93)
Dale et al	Australia	2014	10	Exercise training	4 month	(94)
Jin et al	China	2014	102	Health education Exercise training Respiratory training Psychological counseling	6 month	(95)
Zhang et al	China	2012	160	Health education Exercise training Respiratory training	2 month	(96)
Cao et al	China	2010	62	Health education Exercise training Respiratory training	2 month	(97)
Liu et al	China	2009	70	Health education Exercise training Psychological counseling Nutritional guidance	3 month	(98)
Dong et al	China	2009	62	Health education Exercise training Respiratory training	3 month	(99)

Benefits and perspective of pulmonary rehabilitation

PR is now widely recognized as an integral part of the post-exacerbation care plan for patients with chronic respiratory disorders. It has evolved from being primarily a field of study and inquiry to its current status as a robust subspecialty within respiratory medicine. The widespread acceptance of rehabilitation in the field of respiratory medicine is further evidenced by the incorporation of PR as a scientific working group or assembly in the social structure of major respiratory societies. The guidelines widely acknowledge the effectiveness of PR, and the Global Initiative for Chronic Obstructive Lung Disease (GOLD) method for rehabilitating COPD specifically focuses on patients with symptoms and exacerbations (100). Exercise training is one of the few interventions that has been shown to improve exercise tolerance, symptoms, and health-related quality of life in patients with pneumoconiosis. PR is widely acknowledged as a multimodal approach to treating patients with lung disease (38). However, gaining conceptual clarity and widespread agreement around the terminology for PR is a key step toward the future of the field. Numerous treatments fall under the umbrella phrase "pulmonary rehabilitation" today. Although some alternatives to traditional PR have been proposed, such as internet-based self-management program (101)s, home-based minimally supervised rehabilitation (102), tai chi exercises (103), and yoga (104). Some patients with chronic respiratory disorders may benefit from these procedures, and in some areas, they may be the only option, but it should be made clear that these methods are not intended to replace PR. Despite the growing body of research on rehabilitation and potential methods of delivery, many open questions persist. These include emphasizing fitness or physical activity instead, creating reliable biomarkers to predict whether a given patient will benefit from a given PR approach, tailoring PR programs to the needs of individual patients, evaluating the risks associated with various PR approaches effectively, and comparing new PR approaches against established ones in terms of their short- and long-term costs and benefits (105, 106).

Conclusion

PR strategies have been increasingly utilized as a multimodal program for the treatment of pneumoconiosis. Studies have shown that PR not only improve the management of patients' symptom and quality of life but also saves healthcare costs. In individuals with pneumoconiosis, a gradual increase in daily activity through exercise training has been demonstrated to improve quality of life more than medication alone. Despite these apparent benefits, PR is still not widely employed, which can be attributed to various issues such as doctors' lack of awareness of PR's benefits, patients' failure to follow their exercise plans, and inadequate health insurance coverage. Pneumoconiosis is becoming more prevalent in many parts of the world; therefore, preventive measures like PR should be widely disseminated and implemented. PR is an effective and cost-saving approach for managing pneumoconiosis, and healthcare providers should consider incorporating it into the standard care plan for patients with this condition.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of Interests

There is no conflict interest to be declared.

References

1. Austin ED, Loyd JE (2014). The genetics of pulmonary arterial hypertension. *Circ Res*, 115(1):189-202.
2. Perret JL, Plush B, Lachapelle P, et al (2017). Coal mine dust lung disease in the modern era. *Respirology*, 22(4):662-70.
3. Shen CH, Chen HJ, Lin TY, et al (2015). Association between pneumoconiosis and pulmonary emboli. *Thromb Haemost*, 113(5):952-7.
4. Zhang L, Zhu L, Li Z, et al (2014). Analysis on the disease burden and its impact factors of coal worker's pneumoconiosis inpatients. *Beijing Da Xue Xue Bao Yi Xue Ban,* 46(2):226-31.
5. Li Y, Cheng Z, Fan H, et al (2022). Epigenetic Changes and Functions in Pneumoconiosis. *Oxid Med Cell Longev*, 2022: 2523066.
6. Ye M, Wang Y, WAN R (2011). Research on Disease Burden of Pneumoconiosis Patients in Chongqing City. Mod. *Prev Med*, 38:840-2.
7. Liang Y, Wong O, Fu H, et al (2003). The economic burden of pneumoconiosis in China. *Occup Environ Med*, 60(6): 383–384.
8. Gupta M, Mehrara V, Singh T, et al (2022). Pneumoconiosis-an ignored occupational lung disease and Pulmonary Rehabilitation to improve the health related quality of life. *J Compr Health*, 10(1):37-9.
9. Nici L, Donner C, Wouters E, et al (2006). American thoracic society/European respiratory society statement on pulmonary rehabilitation. *Am J Respir Crit Care Med*, 173(12):1390-413.
10. Tsang EW, Kwok H, Chan AK, et al (2018). Outcomes of community-based and home-based pulmonary rehabilitation for pneumoconiosis patients: a retrospective study. *BMC Pulm Med*, 18(1):113.
11. Jenkins AR, Gowler H, Curtis F, et al (2018). Efficacy of supervised maintenance exercise following pulmonary rehabilitation on health care use: a systematic review and meta-analysis. *Int J Chronic Obstruct Pulm Dis*, 13:257-273.
12. Ryrsø CK, Godtfredsen NS, Kofod LM, et al (2018). Lower mortality after early supervised pulmonary rehabilitation following COPD-exacerbations: a systematic review and meta-analysis. *BMC Pulm Med*, 18(1):154.
13. Nici L, ZuWallack RL (2014). Pulmonary rehabilitation: definition, concept, and history. *Clin Chest Med*, 35(2):279-82.
14. Hill NS (2006). Pulmonary rehabilitation. *Proc Am Thorac Soc*, 3(1):66-74.
15. McCarthy B, Casey D, Devane D, et al (2015). Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev*, 2015(2):CD003793.
16. Dale MT, McKeough ZJ, Troosters T, et al (2015). Exercise training to improve exercise capacity and quality of life in people with non-malignant dust-related respiratory diseases. *Cochrane Database Syst Rev*, 2015(11):CD009385.
17. Hoy RF, Chambers DC (2020). Silica-related diseases in the modern world. *Allergy*, 75(11):2805-17.
18. Rosengarten D, Fox BD, Fireman E, et al (2017). Survival following lung transplantation for artificial stone silicosis relative to idiopathic pulmonary fibrosis. *Am J Ind Med*, 60(3):248-54.
19. Cockcroft A, Saunders M, Berry G (1981). Randomised controlled trial of rehabilitation in chronic respiratory disability. *Thorax*, 36(3):200-3.
20. Dowman LM, McDonald CF, Hill CJ, et al (2017). The evidence of benefits of exercise training in interstitial lung disease: a randomised controlled trial. *Thorax*, 72(7):610-9.
21. Baudouin S, Waterhouse J, Tahtamouni T, et al (1990). Long term domiciliary oxygen treatment for chronic respiratory failure reviewed. *Thorax*, 45(3):195-8.
22. Litow FK, Petsonk EL, Bohnker BK, et al (2015). Occupational interstitial lung diseases. *J Occup Environ Med*, 57(11):1250-4.
23. Odintseva O, Semenikhin V, Lee G (2015). Total broncho-alveolar lavage in respiratory diseases among coal mining workers. *Med Tr Prom Ekol*, 2015(5):25-9.
24. Burmeister R, Rhoderick JF, Holian A (2019). Prevention of crystalline silica-induced inflammation by the anti-malarial hydroxychloroquine. *Inhal Toxicol*, 31(7):274-84.

25. Zhang H, Sui J-N, Gao L, et al (2018). Subcutaneous administration of infliximab-attenuated silica-induced lung fibrosis. *Int J Occup Med Environ Health*, 31(4):503-15.
26. Huang H, Chen M, Liu F, et al (2019). N-acetylcysteine tiherapeutically protects against pulmonary fibrosis in a mouse model of silicosis. *Biosci Rep*, 39(7):BSR20190681.
27. Helal MG, Said E (2019). Carvedilol attenuates experimentally induced silicosis in rats via modulation of P-AKT/mTOR/TGFβ1 signaling. *Int Immunopharmacol*, 70:47-55.
28. El-Kashef DH (2018). Nicorandil ameliorates pulmonary inflammation and fibrosis in a rat model of silicosis. *Int Immunopharmacol*, 64:289-97.
29. Mroz MM, Ferguson JH, Faino AV, et al (2018). Effect of inhaled corticosteroids on lung function in chronic beryllium disease. *Respir Med*, 138 Suppl:S14-S9.
30. Du S, Li C, Lu Y, et al (2019). Dioscin alleviates crystalline silica-induced pulmonary inflammation and fibrosis through promoting alveolar macrophage autophagy. *Theranostics*, 9(7):1878-92.
31. Li N, Feng F, Wu K, et al (2019). Inhibitory effects of astragaloside IV on silica-induced pulmonary fibrosis via inactivating TGF-β1/Smad3 signaling. *Biomed Pharmacother*, 119:109387.
32. Liu H, Yu H, Cao Z, et al (2019). Kaempferol modulates autophagy and alleviates silica-induced pulmonary fibrosis. *DNA Cell Biol*, 38(12):1418-26.
33. Feng F, Cheng P, Zhang H, et al (2019). The protective role of tanshinone IIA in silicosis rat model via TGF-β1/Smad signaling suppression, NOX4 inhibition and Nrf2/ARE signaling activation. *Drug Des Devel Ther*, 13:4275-4290.
34. Zhang Y, Li C, Li S, et al (2019). Dihydrotanshinone I alleviates crystalline silica-induced pulmonary inflammation by regulation of the Th immune response and inhibition of STAT1/STAT3. *Mediators Inflamm*, 9:2019:3427053.
35. Bandeira E, Oliveira H, Silva JD, et al (2018). Therapeutic effects of adipose-tissue-derived mesenchymal stromal cells and their extracellular vesicles in experimental silicosis. *Respir Res*, 19(1):1-10.
36. Chen S, Cui G, Peng C, et al (2018). Transplantation of adipose-derived mesenchymal stem cells attenuates pulmonary fibrosis of silicosis via anti-inflammatory and anti-apoptosis effects in rats. *Stem Cell Rese Ther*, 9(1):110.
37. Qi XM, Luo Y, Song MY, et al (2021). Pneumoconiosis: current status and future prospects. *Chin Med J(Engl)*, 134(8):898-907.
38. Spruit M, Singh S, Garvey C, et al (2013). ATS/ERS task force on pulmonary rehabilitation. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med*, 188(8):e13-64.
39. Spruit M, Pitta F, Garvey C, et al (2014). ERS Rehabilitation and Chronic Care, and Physiotherapists Scientific Groups; American Association of Cardiovascular and Pulmonary Rehabilitation; ATS Pulmonary Rehabilitation Assembly and the ERS COPD Audit team. Differences in content and organisational aspects of pulmonary rehabilitation programmes. *Eur Respir J*, 43(5):1326-37.
40. Rochester CL, Vogiatzis I, Holland AE, et al (2015). An official American Thoracic Society/European Respiratory Society policy statement: enhancing implementation, use, and delivery of pulmonary rehabilitation. *Am J Respir Crit Care Med*, 192(11):1373-86.
41. Girdhar A, Agarwal P, Singh A (2020). Pulmonary Rehabilitation in Chronic Obstructive Pulmonary. *Cardiorespiratory Fitness*:1. DOI: 10.5772/intechopen.81742
42. Morgan M, Calverley P, Clark C, et al (2001). Pulmonary rehabilitation: British Thoracic Society standards of care subcommittee on pulmonary rehabilitation. *Thorax*, 56(11):827-34.
43. Li PW, Yu DS, Tam SY (2021). The Lived Experience of Patients and Family Caregivers in Managing Pneumoconiosis. *Qual Health Res*, 31(9):1645-56.
44. Casaburi R, Porszasz J, Burns MR, et al (1997). Physiologic benefits of exercise training in rehabilitation of patients with severe chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*, 155(5):1541-51.
45. Maltais F, LeBlanc P, Jobin J, et al (1997). Intensity of training and physiologic

adaptation in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*, 155(2):555-61.
46. Ringbaek T, Broendum E, Hemmingsen L, et al (2000). Rehabilitation of patients with chronic obstructive pulmonary disease. Exercise twice a week is not sufficient! *Respir Med*, 94(2):150-4.
47. Troosters T, Gosselink R, Decramer M (2000). Short-and long-term effects of outpatient rehabilitation in patients with chronic obstructive pulmonary disease: a randomized trial. *Am J Med*, 109(3):207-12.
48. Higashimoto Y, Ando M, Sano A, et al (2020). Effect of pulmonary rehabilitation programs including lower limb endurance training on dyspnea in stable COPD: a systematic review and meta-analysis. *Respir Investig*, 58(5):355-66.
49. Lake FR, Henderson K, Briffa T, et al (1990). Upper-limb and lower-limb exercise training in patients with chronic airflow obstruction. *Chest*, 97(5):1077-82.
50. Suhas KM, Alaparthi GK, Krishnan SK, et al (2020). Upper Limb Extremity Muscle-Dysfunction in Chronic Obstructive Pulmonary Disease: A Narrative Review. *Curr Respir Med Rev*, 16(1):11-20.
51. José A, Holland AE, Selman JP, et al (2021). Home-based pulmonary rehabilitation in people with bronchiectasis: a randomised controlled trial. *ERJ Open Res*, 7(2): 00021-2021.
52. Society AT (1999). Pulmonary rehabilitation-1999. *Am J Respir Crit Care Med*, 159(5 Pt 1):1666-82.
53. Horowitz MB, Littenberg B, Mahler DA (1996). Dyspnea ratings for prescribing exercise intensity in patients with COPD. *Chest*, 109(5):1169-75.
54. Chen L, Xu W, Ma X, et al (2020). The Effect of Respiratory Rehabilitation Training on the Life Quality of Pneumoconiosis Patients. *J Clin Nurs Res*, 4(4):5-8.
55. Jimborean G, Ianosi E, Croitoru A, et al (2017). Respiratory muscle training in chronic obstructive pulmonary disease. *Pneumologia*, 66(3):128-30.
56. Franklin E, Anjum F (2021). Incentive spirometer and inspiratory muscle training. StatPearls [Internet]: StatPearls Publishing.Available from: https://www.ncbi.nlm.nih.gov/books/NBK572114/
57. Kuhajda D, Obradović D, Ciobanu LD (2022). Non Invasive Ventilation, Pulmonary Rehabilitation and Chest Physiotherapy-1. *Teaching Pearls in Noninvasive Mechanical Ventilation*[Book]. *Springe*r, p. 435-43.
58. Postolache P, Săndulache Ş, Ghimuş C, et al (2022). Assessment of Exercise Capacity: A Key Element in Pulmonary Rehabilitation. DOI: 10.5772/intechopen.106211
59. Bhammar DM, Jones HN, Lang JE (2022). Inspiratory Muscle Rehabilitation Training in Pediatrics: What Is the Evidence? *Can Respir J*, 2022:5680311.
60. Troosters T, Casaburi R, Gosselink R, et al (2005). Pulmonary rehabilitation in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*, 172(1):19-38.
61. Vanfleteren LE, Gloeckl R (2019). Add-on interventions during pulmonary rehabilitation. *Respirology*, 24(9):899-908.
62. Emtner M, Porszasz J, Burns M, et al (2003). Benefits of supplemental oxygen in exercise training in nonhypoxemic chronic obstructive pulmonary disease patients. *Am J Respir Crit Care Med*, 168(9):1034-42.
63. Palange P, Crimi E, Pellegrino R, et al (2005). Supplemental oxygen and heliox:'new'tools for exercise training in chronic obstructive pulmonary disease. *Curr Opin Pulm Med*, 11(2):145-8.
64. McDonald CF (2022). Home oxygen therapy. *Aust Prescr*, 45(1):21-24.
65. Zhao H, Xie Y, Wang J, et al (2020). Pulmonary Rehabilitation Can Improve the Functional Capacity and Quality of Life for Pneumoconiosis Patients: A Systematic Review and Meta-Analysis. *BioMed Res Int*, 2020: 6174936.
66. Neish CM, Hopp JW (1988). The role of education in pulmonary rehabilitation. *J Cardiopulm Rehabil Prev*, 8(11):439-41.
67. Coventry PA, Hind D (2007). Comprehensive pulmonary rehabilitation for anxiety and depression in adults with chronic obstructive pulmonary disease: systematic review and meta-analysis. *J Psychosom Res,* 63(5):551-65.
68. Cornelison SD, Pascual RM (2019). Pulmonary rehabilitation in the management of chronic

lung disease. *Med Clin North Am* , 103(3):577-84.
69. Renfroe K (1988). Effect of progressive relaxation on dyspnea and state anxiety in patients with chronic obstructive pulmonary disease. *Heart Lung*, 17(4):408-13.
70. Celli BR, Cote CG, Marin JM, et al (2004). The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N Engl J Med*, 350(10):1005-12.
71. Ferreira IM, Brooks D, Lacasse Y, et al (2000). Nutritional support for individuals with COPD. *Chest*, 117(3):672-8.
72. Weekes C, Emery P, Elia M (2009). Dietary counselling and food fortification in stable COPD: a randomised trial. *Thorax*, 64(4):326-31.
73. Rochester CL (2019). Patient assessment and selection for pulmonary rehabilitation. *Respirology*, 24(9):844-53.
74. Vaishali K, Sinha MK, Maiya AG, Bhat A (2019). The initial steps in pulmonary rehabilitation: How it all began? *Lung India,* 36(2):139-141.
75. Kawaji T, Hasegawa T, Uchiyama Y (2022). Dyspnea and outcome expectations are associated with physical activity in persons with pneumoconiosis: a cross-sectional study. *BMC Pulm Med*, 22(1):335.
76. Bolton CE, Bevan-Smith EF, Blakey JD, et al (2013). British Thoracic Society guideline on pulmonary rehabilitation in adults: accredited by NICE. *Thorax*, 68 Suppl 2:ii1-ii30.
77. Evans R, Singh S, Collier R, et al (2009). Pulmonary rehabilitation is successful for COPD irrespective of MRC dyspnoea grade. *Respir Med*, 103(7):1070-5.
78. Kalamara EI, Ballas ET, Pitsiou G, et al (2021). Pulmonary rehabilitation for cystic fibrosis: A narrative review of current literature. *Monaldi Arch Chest Dis* 91(2).
79. Xiao K, Liu J, Ding X, et al (2019). Comprehensive rehabilitation of individualized exercise program for coal workers pneumoconiosis in Huaibei Coal Mine Group. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi*, 37(5):357-61.
80. Dale MT, McKeough ZJ, Munoz PA, et al (2014). Exercise training for asbestos-related and other dust-related respiratory diseases: a randomised controlled trial. *BMC Pulm Med*, 14:180.
81. Huang X, Chen H, Long R, et al (2019). Development and validation of the quality of life scale for Chinese coal miners with pneumoconiosis (QOL-CMP): Measurement method and empirical study. *J Clean Prod*, 232:1062-75.
82. Han B, Yan B, Zhao N, et al (2013). The influence of the functional capacity on subjective well-being and quality of life of patients with silicosis. *Aging Ment Health*, 17(6):707-13.
83. Ma P, Nagamatsu Y (2023). The impact of community-based pulmonary rehabilitation on the health and lives of migrant workers with pneumoconiosis in China: a qualitative study exploring patient experience. *J Global Health Rep*, 7:e2023026.
84. XIAO S, GAO J, HUA Z, et al (2019). Effect of exercise-based short-term rehabilitation therapy on pulmonary function of coal workers' pneumoconiosis. *China Occup Med*, 46(1):67-70. [In Chinease]
85. Pan W, Chen JL (2017). Effect of rehabilitation exercise training on pulmonary function and exercise endurance of patients with pneumoconiosis. *Chin J Rehabil Med*, 32:465–7. [In Chinease]
86. Wang F (2017). Effect of comprehensive treatment on exercise endurance of patients with coal worker's pneumoconiosis. *For all Health*, 5:48-53. [In Chinease]
87. Qu WJ (2017). Application of health education and exercise training in improving pulmonary function of pneumoconiosis patients. *Chin J Convalescent Med*, 26:331–4.
88. Yun X (2015). Therapeutic effect of rehabilitation therapy based on one year movement in patients with coal worker's pneumoconiosis in Datong Coal Mine Group. *North China Univ Sci Technol.* 8:15-24. [In Chinease]
89. Liu J, Wang JY, Li DH (2015). Application of heath education with sports training on pulmonary function among pneumoconiosis patients. *Chin J Modern Nurs*, 21:1241–4. [In Chinease]
90. F. Li JSG, Han Y, Chen L (2015). Effect evaluation of comprehensive pulmonary rehabilitation on patients with coal workers

pneumoconiosis. *Clin Med*, 35:30–2. [In Chinease]
91. Li XY, Hu W, Zhang ZH, et al (2015). Effect of comprehensive lung rehabilitation on respiratory function in patients with pneumoconiosis. *Chin J Rehabil Med*, 29:123-4. [In Chinease]
92. Liu CZ (2014). Effect of health education combined with respiratory muscle training on quality of life in patients with coal workers' pneumoconiosis. *Occup Health*, 30:2392–4. [In Chinease]
93. Ma LL (2014). Effect of pulmonary rehabilitation therapy on pulmonary ventilation function in patients with stable silicosis. *Occup Health*, 30:2395-9. [In Chinease]
94. Dale MT, McKeough ZJ, Munoz PA, et al (2014). Exercise training for asbestos-related and other dust-related respiratory diseases: a randomised controlled trial. *BMC Pulm Med*, 14:180.
95. Jin Y, Yao M, Wenjing L, et al (2014). Pulmonary rehabilitation therapy of pneumoconiosis patients. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi*, 32(11):849-50. [In Chinease]
96. Zhang ZH, Shang B, Li XY, et al (2012). Observation on the curative effect of pulmonary rehabilitation therapy in patients with pneumoconiosis. *Chin J Ind Hyg Occup Dis*, 30:612- 3. [In Chinease]
97. Cao DF, Zhang ZH, Gao P, et al (2010). Observation on curative effect of comprehensive pulmonary rehabilitation therapy on pneumoconiosis. *Chin J Ind Med*, 23:271-2. [In Chinease]
98. Liu QG, Zhao SY, Zheng X, et al (2009). Observation on the effect of multidisciplinary cooperative respiratory rehabilitation in patients with pneumoconiosis. *Chin J Ind Hyg Occup Dis*, 27:670–2. [In Chinease]
99. Dong AQ, Li KC, Tang D, et al (2009). The effect of systematic rehabilitation on QOL of patients with stage II pneumoconiosis. *Chin J Rehabil Med*, 24:927–9. [In Chinease]
100. Vogelmeier CF, Criner GJ, Martinez FJ, et al (2017). Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. GOLD executive summary. *Am J Respir Crit Care Med*, 195(5):557-82.
101. Chaplin E, Hewitt S, Apps L, et al (2017). Interactive web-based pulmonary rehabilitation programme: a randomised controlled feasibility trial. *BMJ Open*, 7(3):e013682.
102. Horton EJ, Mitchell KE, Johnson-Warrington V, et al (2018). Comparison of a structured home-based rehabilitation programme with conventional supervised pulmonary rehabilitation: a randomised non-inferiority trial. *Thorax*, 73(1):29-36.
103. Polkey MI, Qiu ZH, Zhou L, et al (2018). Tai Chi and pulmonary rehabilitation compared for treatment-naive patients with COPD: a randomized controlled trial. *Chest*, 153(5):1116-24.
104. Papp ME, Wändell PE, Lindfors P, et al (2017). Effects of yogic exercises on functional capacity, lung function and quality of life in participants with obstructive pulmonary disease: a randomized controlled study. *Eur J Phys Rehabil Med*, 53(3):447-61.
105. Troosters T, Blondeel A, Janssens W, et al (2019). The past, present and future of pulmonary rehabilitation. *Respirology*, 24(9):830-7.
106. Holland AE, Cox NS, Houchen-Wolloff L, et al (2021). Defining modern pulmonary rehabilitation. An official American thoracic Society workshop report. *Ann Ame Thorac Soc*, 18(5):e12-e29.