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EFFECTIVENESS OF PULMONARY AND MULTICOMPONENT REHABILITATION IN OCCUPATIONAL DUST-RELATED DISEASES OF THE BRONCHOPULMONARY SYSTEM

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Abstract

Background. Occupational dust-related lung diseases are associated with reduced exercise tolerance, dyspnea, limitations in daily activities, and impaired quality of life. Evidence on the effectiveness of pulmonary and multicomponent rehabilitation in these patients remains limited and heterogeneous.

Aim. To systematize the evidence on the effectiveness of pulmonary and multicomponent rehabilitation in adult patients with occupational dust-related lung diseases, with a focus on exercise tolerance, dyspnea, pulmonary function, quality of life, and occupational outcomes.

Materials and methods. This systematic review was conducted in accordance with PRISMA 2020. The literature search was performed in PubMed/MEDLINE, Scopus, Web of Science Core Collection, and the Cochrane Library from inception to November 30, 2025, with additional manual searching. A total of 348 records were identified; after duplicate removal and study selection, 12 primary studies were included in the qualitative synthesis. Studies involving adult patients with pneumoconiosis, silicosis, occupational COPD, and other chronic occupational dust-related lung diseases were eligible if they evaluated a rehabilitation intervention and reported at least one relevant outcome.

Results. The included studies generally indicate a beneficial effect of pulmonary and multicomponent rehabilitation on exercise tolerance and quality of life. Several studies also reported reductions in dyspnea and improvements in selected pulmonary function parameters, although these findings were less consistent. The most pronounced effects were observed in programs that included inspiratory muscle training. Occupational outcomes were rarely assessed in the available studies.

Conclusions. Pulmonary and multicomponent rehabilitation in patients with occupational dust-related lung diseases is primarily associated with improved exercise capacity and quality of life. The main limitations of the current evidence base are clinical and methodological heterogeneity, the small number of studies, and the lack of data on long-term occupational prognosis.

Key words: pulmonary rehabilitation, multicomponent rehabilitation, occupational dust-related lung diseases, occupational COPD, inspiratory muscle training, quality of life.

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Introduction. Occupational dust-related lung diseases continue to impose a substantial clinical and social burden on workers employed in the mining, cement, textile, and agricultural industries [1-6]. These conditions are characterized by persistent reductions in exercise tolerance, dyspnea, limitations in daily activity, and impaired quality of life [5-8]. At the same time, standard management is more often focused on pharmacological therapy, symptom control, and reduction of exposure, whereas rehabilitative interventions are described inconsistently and are rarely considered as an independent subject of evidence synthesis [9-12].

In contrast to the classical model of chronic obstructive pulmonary disease, occupational dust-related lung disorders often combine restrictive, obstructive, and fibrotic components [2, 3, 13]. This makes the transfer of results from general pulmonary rehabilitation to the occupational context not entirely straightforward [10, 12, 14]. In some studies, programs of classical respiratory and physical rehabilitation predominate, whereas in others narrower interventions are emphasized, such as inspiratory muscle training, behavioral modules aimed at maintaining physical activity, home-based and outpatient formats of pulmonary rehabilitation, as well as multicomponent programs for maintaining physical functioning [12, 15].

Available publications suggest probable improvements in exercise capacity and patients' subjective status; however, the structure of interventions, the composition of populations, and the set of outcomes vary considerably across studies [16]. In addition, even in studies directly related to occupational diseases, occupational prognosis is rarely analyzed, although it is precisely this outcome that is of greatest importance for real clinical and occupational practice [17].

In this regard, a systematic review was conducted to summarize and critically compare the available evidence on the effectiveness of pulmonary and multicomponent rehabilitation in adult patients with occupational dust-related diseases of the bronchopulmonary system, as well as to determine which effect domains are supported most consistently and which gaps remain in the current evidence base.

Materials and Methods.

Review design

This systematic review was conducted in accordance with the PRISMA 2020 recommendations [18] and was devoted to evaluating the effectiveness of pulmonary and multicomponent rehabilitation in adult patients with occupational dust-related diseases of the bronchopulmonary system. The research question was formulated according to the PICO framework. The population consisted of adult patients with pneumoconiosis, coal workers' pneumoconiosis, silicosis, occupational chronic obstructive pulmonary disease, and other chronic lung diseases associated with occupational dust exposure. The interventions of interest included pulmonary rehabilitation programs and other multicomponent restorative interventions, including physical training, breathing exercises, inspiratory muscle training, educational, and behavioral components. The comparison groups included standard treatment, usual care, no rehabilitation, or alternative lower-intensity programs. The main outcomes of interest were exercise tolerance, dyspnea severity, pulmonary function, quality of life, and occupational outcomes.

Search strategy and information sources

A systematic literature search was conducted in the PubMed/MEDLINE, Scopus, Web of Science Core Collection, and Cochrane Library databases for the period from inception to November 30, 2025. Search strategies were adapted for each database according to its search capabilities. The search was based on two key concepts: occupational dust-related lung diseases and rehabilitation interventions. To increase search sensitivity, both controlled terms and free-text words were used, including synonyms for diseases and components of pulmonary

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rehabilitation. Detailed examples of the search queries are presented in Table 1. In addition, a manual search of the reference lists of included studies and relevant review publications was carried out, as well as direct citation tracking of key papers. An additional manual search of the reference lists of included studies and relevant review publications was also performed to identify potentially missed sources.

Table 1. Examples of database-specific search strategies

Database	Search string
PubMed/MEDLINE	(("Pneumoconiosis"[Mesh] OR pneumoconiosis[tiab] OR silicosis[tiab] OR "coal workers' pneumoconiosis"[tiab] OR "coal worker* pneumoconiosis"[tiab] OR "coal mine dust lung disease"[tiab] OR "dust-related lung disease*"[tiab] OR "occupational lung disease*"[tiab] OR "occupational interstitial lung disease*"[tiab]) AND ("Rehabilitation"[Mesh] OR "Exercise Therapy"[Mesh] OR "Physical Therapy Modalities"[Mesh] OR "pulmonary rehabilitation"[tiab] OR "pulmonary rehab*"[tiab] OR "respiratory rehabilitation"[tiab] OR "lung rehabilitation"[tiab] OR "exercise therap*"[tiab] OR "exercise training"[tiab] OR "physical training"[tiab] OR "aerobic training"[tiab] OR "resistance training"[tiab] OR "respiratory muscle training"[tiab] OR "inspiratory muscle training"[tiab] OR IMT[tiab] OR "breathing exercise*"[tiab] OR "breathing retraining"[tiab] OR "diaphragmatic breathing"[tiab] OR "pursed-lip breathing"[tiab] OR "chest physiotherapy"[tiab])) NOT (animals[mh] NOT humans[mh])
Scopus	TITLE-ABS-KEY((pneumoconiosis OR silicosis OR "coal workers' pneumoconiosis" OR "coal worker* pneumoconiosis" OR "coal mine dust lung disease" OR "dust-related lung disease*" OR "occupational lung disease*" OR "occupational interstitial lung disease*") AND ("pulmonary rehabilitation" OR "pulmonary rehab*" OR "respiratory rehabilitation" OR "lung rehabilitation" OR "exercise therap*" OR "exercise training" OR "physical training" OR "aerobic training" OR "resistance training" OR "respiratory muscle training" OR "inspiratory muscle training" OR IMT OR "breathing exercise*" OR "breathing retraining" OR "diaphragmatic breathing" OR "pursed-lip breathing" OR "chest physiotherapy"))
Web of Science Core Collection	TS=((pneumoconiosis OR silicosis OR "coal workers' pneumoconiosis" OR "coal worker* pneumoconiosis" OR "coal mine dust lung disease" OR "dust-related lung disease*" OR "occupational lung disease*" OR "occupational interstitial lung disease*") AND ("pulmonary rehabilitation" OR "pulmonary rehab*" OR "respiratory rehabilitation" OR "lung rehabilitation" OR "exercise therap*" OR "exercise training" OR "physical training" OR "aerobic training" OR "resistance training" OR "respiratory muscle training" OR "inspiratory muscle training" OR IMT OR "breathing exercise*" OR "breathing retraining" OR

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	"diaphragmatic breathing" OR "pursed-lip breathing" OR "chest physiotherapy"))
Cochrane Library	((pneumoconiosis OR silicosis OR "coal workers' pneumoconiosis" OR "coal mine dust lung disease" OR "dust-related lung disease*" OR "occupational lung disease*") AND ("pulmonary rehabilitation" OR "exercise therapy" OR "exercise training" OR "respiratory rehabilitation" OR "respiratory muscle training" OR "inspiratory muscle training" OR IMT OR "breathing exercise*" OR "breathing retraining"))
Manual search	Screening of the reference lists of included studies and relevant review articles, as well as forward citation tracking of key eligible studies.

Inclusion and exclusion criteria

Primary studies were included in the review if they met the following criteria: adult patients aged 18 years and older; the presence of an occupational dust-related lung disease; evaluation of a rehabilitation intervention; the presence of a control or comparison group; and reporting of data on at least one of the pre-specified outcomes.

Randomized controlled trials, controlled clinical studies, and quasi-experimental studies were eligible for inclusion. Published systematic reviews and meta-analyses were not included in the main synthesis of results and were used only to verify the completeness of the search, compare conclusions, and provide contextual discussion. Publications focused exclusively on pharmacotherapy, surgical treatment, diagnostics, or emergency care without a rehabilitation component, as well as studies that did not contain data suitable for meaningful synthesis, were excluded.

Study selection

Study selection was carried out independently by two reviewers in two stages. At the first stage, the titles and abstracts of the identified publications were assessed; at the second stage, the full texts of potentially relevant articles were reviewed. All disagreements were resolved through discussion; in the absence of consensus, a third reviewer was involved. Duplicates were removed before the title and abstract screening stage.

The systematic search identified 348 records: 115 in PubMed/MEDLINE, 102 in Scopus, 94 in Web of Science Core Collection, 2 in the Cochrane Library, and 35 through manual searching. After removal of duplicates (n = 116), 232 publications remained for screening. At the initial screening stage, 127 records were excluded, after which 105 full-text articles were assessed for eligibility. All selected full-text publications were available for analysis. After full-text assessment, 93 studies were excluded, including those due to the absence of a rehabilitation intervention or an exclusive focus on pharmacotherapy, diagnostics, surgical treatment, or emergency care (n = 49), a population not meeting the review criteria (n = 16), and the absence of an appropriate comparison group and/or data suitable for synthesis (n = 28). Twelve primary studies were included in the qualitative synthesis. Published systematic reviews and meta-analyses were not included in the main synthesis as independent units of analysis and were used only for contextual discussion.

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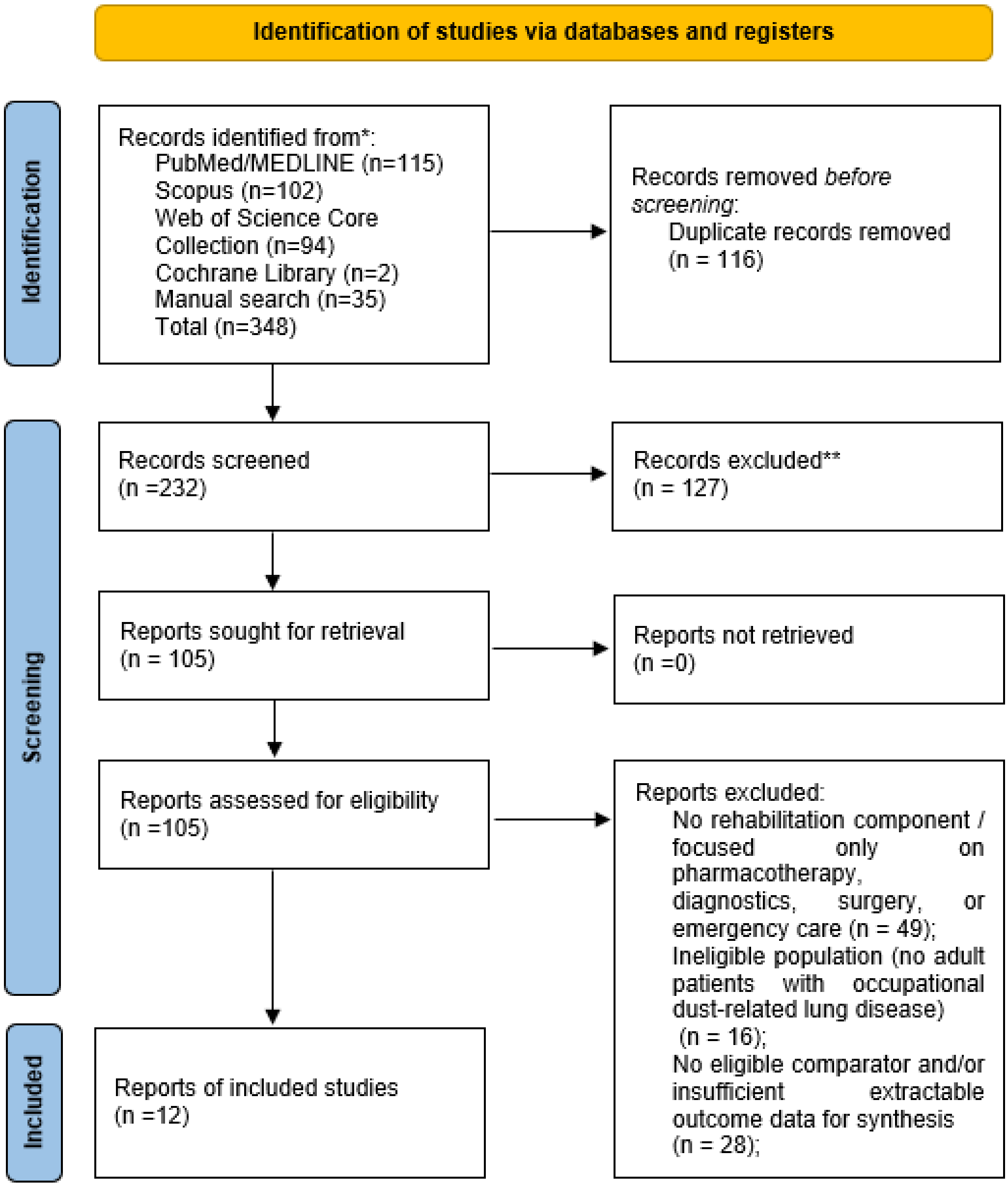

Figure 1. PRISMA 2020 flow diagram of study selection

Data extraction

Data extraction was performed using a standardized matrix. For each study, information was collected on population characteristics, study design, sample size, type and duration of the intervention, characteristics of the control group, format of rehabilitation delivery, and results for the predefined outcomes. In addition, specific features of program implementation were recorded, including the presence of inspiratory muscle training, behavioral components, and other constituent elements of the intervention. The extracted data were subjected to cross-checking and subsequent narrative verification.

Variables and outcomes

The key variables included disease category, sample size, type of rehabilitation program, duration of the intervention, format of implementation, and composition of the control group. Indicators of exercise tolerance and quality of life were considered primary outcomes.

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Secondary outcomes included dyspnea severity, pulmonary function parameters, and occupational outcomes. If multiple follow-up time points were reported in a study, both immediate post-intervention results and delayed follow-up data, when available, were taken into account in the qualitative synthesis.

Assessment of risk of bias

The risk of bias was assessed separately for each included primary study, taking its design into account. For randomized studies, an approach based on the RoB 2 domains was used, including assessment of the randomization process, deviations from the intended intervention, missing outcome data, outcome measurement, and selective reporting of results. For non-randomized and quasi-experimental studies, an approach conceptually close to ROBINS-I was applied, with emphasis on group comparability, risk of confounding, appropriateness of intervention classification, completeness of follow-up, outcome measurement, and selective reporting. The assessment was performed in a descriptive format, since some publications were available only as brief reports or conference abstracts, which limited the possibility of a full domain-based analysis. In such cases, the risk of bias was assessed conservatively, based on the availability of information on group formation, randomization, blinding, completeness of outcome data, and detail of result reporting. Published systematic reviews and meta-analyses were not included in the main risk-of-bias assessment, as they were not units of the primary synthesis.

Data synthesis

Given the pronounced clinical and methodological heterogeneity of the included primary studies, conducting a de novo meta-analysis was not considered justified. Differences between studies concerned population characteristics, the structure of rehabilitation programs, duration of interventions, formats of implementation, composition of control groups, and the set of assessed outcomes. Therefore, narrative analysis was chosen as the main method of synthesis. The results were grouped into five predefined domains: exercise tolerance; dyspnea severity; pulmonary function; quality of life; and occupational outcomes. For each study, the direction of effect, the clinical interpretation of the result, and the key methodological limitations were assessed. If published systematic reviews or meta-analyses on the topic were available, their results were used only for comparison with the authors' own qualitative synthesis and for discussion of the consistency of the evidence base, but were not included in the synthesis as independent units of analysis.

Results.

General characteristics of the included studies

Twelve sources with completed results were included in the main qualitative synthesis. Among them, randomized controlled trials predominated; however, the corpus also included controlled clinical studies, quasi-experimental studies, and propensity-matched case-control studies (Table 2).

Table 2. Characteristics of studies included in the main qualitative synthesis

Author, year	Design	Population	n	Intervention	Control	Duration
Chen et al., 2020 [19]	Controlled study	Pneumoconiosis stages I–III	76	Respiratory rehabilitation	Education + standard treatment	2 months
Kwan et al., 2019 [20]	Propensity-matched case-control	Pneumoconiosis	30	24 outpatient PR sessions	Matched group of COPD patients undergoing similar PR	24 sessions

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Xiao et al., 2019 [21]	RCT	Coal workers' pneumoconiosis	80	Individualized PR	Not specified	Not specified
Basha et al., 2024 [22]	Quasi-experimental study	Silicosis in cement workers	160	Pranayama + nutrition education	Not specified	24 weeks
Ju et al., 2019 [23]	RCT	Occupational pneumoconiosis + exacerbation of COPD	120	Holistic nursing	Conventional nursing	Not specified
Choi & Park, 2019 [24]	Quasi-experimental study	Pneumoconiosis	40	Laughter + exercise	Exercise-only program	5 weeks
Khant et al., 2023 [25]	Single-blinded interventional study	Pneumoconiosis in cotton industry workers	100	IMT + aerobic exercise	Aerobic exercise alone	4 weeks + 1 year
Kim, 2016 [26]	RCT	Occupational COPD in dust-exposed workers	28 (25 completed)	Workplace/home PR	No rehabilitation	7 weeks
Mueller et al., 2016 [27]	RCT	Occupational lung diseases	121	Behavioral exercise + inpatient rehabilitation	Standard inpatient rehabilitation	12-month follow-up
Eleawa et al., 2023 [28]	Single-blinded RCT	Occupational COPD GOLD II–III in farmers	60	Threshold IMT	Diaphragmatic + pursed-lip breathing	3 months
Wang et al., 2018 [29]	RCT	Silicosis + stable COPD	60	Respiratory exercise nursing	Standard treatment	2 months
Zhang et al., 2025 [30]	Blinded placebo-controlled RCT (pilot)	Chronic occupational lung diseases	60	IHHE + standard rehabilitation	Placebo + standard rehabilitation	3 weeks

In terms of intervention structure, the body of evidence was markedly heterogeneous, ranging from classical pulmonary rehabilitation and respiratory rehabilitation to inspiratory muscle training, behaviorally oriented programs, holistic nursing, as well as intermittent hypoxic-hyperoxic exposure (Table 3).

Table 3. Structure of rehabilitation interventions in studies with completed results

Author, year	Program type	Key components	Format	Frequency / intensity	Duration
Chen et al., 2020 [19]	Respiratory rehabilitation	Lip contraction, diaphragmatic, vertical, lunge breathing	Outpatient/home-based	15–20 min, 3 times/day	2 months
Kwan et al., 2019 [20]	Outpatient PR	Supervised exercise-based PR	Outpatient	24 supervised sessions	24 sessions
Xiao et al., 2019 [21]	Individualized PR	Individualized exercise program	Not specified	Not detailed	Not specified

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Basha et al., 2024 [22]	Pranayama + education	Pranayama + nutritional education	Group program	Assessments at 12, 18, and 24 weeks	24 weeks
Ju et al., 2019 [23]	Holistic nursing	Education + self-management + emotion management	Not specified	Not detailed	Not specified
Choi & Park, 2019 [24]	Laughter + exercise	Laughter therapy + exercise	Center-/group-based	50 min, 3 times/week	5 weeks
Khant et al., 2023 [25]	IMT + aerobic exercise	IMT + aerobic exercise	Outpatient	4 times/week	4 weeks + follow-up
Kim, 2016 [26]	Workplace/home PR	Exercise, breathing training, smoking cessation, nutrition, dust assessment	Home/workplace	Visits every 2 weeks	7 weeks
Mueller et al., 2016 [27]	Behavioral exercise + inpatient rehabilitation	Behavioral module to maintain activity	Inpatient + follow-up	Behavioral module + rehabilitation	12-month follow-up
Eleawa et al., 2023 [28]	Threshold IMT	Threshold IMT vs DB+PLB	Outpatient	2 times/day, 7 days/week	3 months
Wang et al., 2018 [29]	Respiratory exercise nursing	Respiratory function exercise	Not specified	Not detailed	2 months
Zhang et al., 2025 [30]	IHHE + standard rehabilitation	IHHE as an adjunct to standard rehabilitation	Rehabilitation center	12 sessions / 3 weeks	3 weeks

Exercise tolerance

The most consistent positive signal was observed for exercise tolerance (Table 4). For example, in the primary studies: an individualized rehabilitation program in patients with coal workers' pneumoconiosis improved exercise capacity [21], in patients with silicosis and stable COPD, respiratory exercise nursing was associated with higher 6MWD values [29], and in farmers with occupational COPD, the advantage in 6MWT was more pronounced in the threshold IMT group [11]. In the pilot blinded placebo-controlled trial by Zhang et al. [30] the addition of IHHE was accompanied by an 11.9% increase in exercise tolerance from baseline. In addition, a behaviorally oriented intervention after inpatient rehabilitation contributed to maintaining a higher level of physical activity at 2, 6, and 12 months of follow-up [27].

Table 4. Main results of studies with completed data

Author, year	Exercise capacity / 6MWT	Dyspnea	Pulmonary function	Quality of life	Work-related outcomes	Key conclusion
Chen et al., 2020 [19]	Not reported as a primary outcome	Not reported separately	FEV1, FVC, and FEV1/FVC were significantly better after the intervention	GQOLI-74: improvement in several domains	Not assessed	Improvement in pulmonary function and several QoL domains
Kwan et al.,	Significant improvement in 6MWT	Not reported separately	Not a primary outcome	CRQ improved	Not assessed	PR improved functional status

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2019 [20]						
Xiao et al., 2019 [21]	6MWD was higher than in the control group	Positive changes in the symptom domain of SGRQ	FVC, FEV1, and MEF improved	SF-36 ↑, SGRQ ↓	Not assessed	Comprehensive PR improved 6MWD, QoL, and some spirometric parameters
Basha et al., 2024 [22]	6MWT improved significantly	Not reported separately	Spirometric parameters and lung capacity improved	Described to a limited extent	Not assessed	A prolonged program improved endurance and pulmonary function
Ju et al., 2019 [23]	Not reported	Not reported	FEV1 and FEV1/FVC were higher in the intervention group	Not reported	Not assessed	Holistic nursing was associated with better spirometric parameters
Choi & Park, 2019 [24]	Between-group superiority was limited	Both groups improved; no between-group differences	No differences in FEV1/FVC; SpO2 ↑ in the experimental group	Quality of life improved more in the experimental group	Not assessed	The laughter component enhanced QoL, but not all physiological effects
Khant et al., 2023 [25]	Not a primary outcome	Not reported	FVC, FEV1, FEV1/FVC, and PEFR were better in the IMT group	SGRQ improved after the course; part of the effect weakened after 1 year	Not assessed	IMT enhanced the effect of aerobic rehabilitation
Kim, 2016 [26]	Shuttle walking test improved, but without significant superiority	Not reported	No significant improvement in PFTs	No significant improvement in SGRQ	Not assessed	Short workplace-based PR had a limited effect
Mueller et al., 2016 [27]	Physical activity was higher at 2, 6, and 12 months	Not reported	Not a primary outcome	Not a primary outcome	Not assessed	The behavioral intervention helped maintain physical activity
Eleawa et al., 2023 [28]	6MWT: marked advantage with IMT	mMRC and Borg were better with IMT	FEV1, FVC, and FEV1/FVC improved	Not a primary outcome	Not assessed	IMT produced the most pronounced effect
Wang et al., 2018 [29]	6MWD was higher in the intervention group	Not reported separately	FEV1, FVC, and PaO2 ↑; FEV1/FVC showed no significant differences	Not reported	Not assessed	Benefit in absolute lung volumes and PaO2, but not in FEV1/FVC
Zhang et al., 2025 [30]	6MWT +11.9% from baseline	Reduction in Borg severity score	Positive pilot changes	Not a primary outcome	Not assessed	IHHE appears promising, but requires confirmation

Dyspnea

Data on dyspnea were less homogeneous; however, overall, they also indicated favorable dynamics with respiratory and multicomponent rehabilitation programs (Table 4). In the blinded pilot trial by Zhang et al. [30] a reduction in symptom severity according to the Borg

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scale was observed with IHHE. In the single-blinded RCT by Eleawa et al. [28] the IMT group showed a more pronounced improvement in dyspnea outcomes compared with diaphragmatic plus pursed-lip breathing. In the quasi-experimental study by Choi and Park [24], dyspnea decreased in both groups; however, between-group differences were limited.

Pulmonary function

The results for pulmonary function were positive, but less consistent than those for exercise capacity (Table 4). In the controlled study by Chen et al. [19], two months of respiratory rehabilitation improved FEV1, FVC, and FEV1/FVC. In the RCT by Xiao et al. [21], FVC, FEV1, and MEF were higher after individualized pulmonary rehabilitation. In patients with silicosis and stable COPD in the study by Wang et al. [29], respiratory exercise nursing was associated with higher FEV1, FVC, and PaO2, but without significant differences in FEV1/FVC. In the study by Eleawa et al. [28], the threshold IMT group outperformed the control group in FEV1, FVC, and FEV1/FVC, and in the study by Khant et al. [25], IMT combined with aerobic exercise also enhanced the effect of rehabilitation on spirometric parameters.

Quality of life

Improvement in quality of life is among the most reproducible findings of the included body of evidence (Table 4). In the study by Chen et al. [19], several GQOLI-74 domains improved after two months of respiratory rehabilitation. In the study by Xiao et al. [21], positive changes were recorded in both SF-36 and the symptom domains of the SGRQ. In the quasi-experimental study by Choi and Park [24], the addition of a laughter component enhanced the effect on quality of life compared with the exercise-only program. In the single-blinded interventional study by Khant et al. [25], improvement in SGRQ was also observed after a course of IMT and aerobic exercise, although part of the effect weakened during longer follow-up.

Occupational outcomes

Despite the occupationally oriented profile of the included populations, formal work-related outcomes were scarcely represented in the studies as an independent domain (Table 4). The main focus of the publications was shifted toward 6MWT/6MWD, dyspnea, spirometry, blood gases, and quality of life. The outcome closest to occupational activity was the maintenance of a higher level of physical activity after inpatient rehabilitation in the study by Mueller et al. [27], however, return-to-work rates, work ability preservation, or absenteeism were not systematically analyzed.

Methodological profile and risk of bias

According to the risk of bias assessment, the methodologically strongest studies by design were the single-blinded RCT by Eleawa et al. [28] and the blinded placebo-controlled pilot RCT by Zhang et al. [30], although even these studies retained limitations related to sample size and the narrow clinical population (Table 5). A substantial proportion of the RCTs were characterized by incomplete reporting of randomization and blinding procedures, whereas the main limitations of quasi-experimental and non-randomized studies were the absence of randomization, small sample sizes, and limited detail regarding control conditions. Taken together, this means that the overall direction of effect in favor of pulmonary rehabilitation is traced quite consistently, but the exact magnitude of effect is only limitedly comparable across studies.

Overall, the included studies show that pulmonary rehabilitation programs in patients with pneumoconiosis, silicosis, and occupational COPD are most consistently associated with improved exercise capacity and quality of life, as well as with a probable reduction in dyspnea severity and improvement in selected pulmonary function parameters. The strongest overall

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support was obtained for the 6MWD/6MWT and quality of life domains, whereas data on spirometry and symptom burden appear positive but more variable, and work-related outcomes remain insufficiently studied.

Table 5. Risk of bias in studies included in the synthesis of results

Author, year	Design	Randomization / comparability	Blinding	Key limitations	Overall risk
Chen et al., 2020 [19]	Controlled study	Coin-toss	No/unclear	Lack of blinding; limited methodological detail	Moderately high
Kwan et al., 2019 [20]	Propensity-matched case-control study	No randomization	No/unclear	Non-randomized design; small sample size	Moderately high
Xiao et al., 2019 [21]	RCT	Reported, but incompletely described	No/unclear	Insufficient data on blinding and follow-up duration	Moderate
Basha et al., 2024 [22]	Quasi-experimental study	No randomization	No/unclear	Non-randomized design and incomplete reporting of control procedures	High
Ju et al., 2019 [23]	RCT	Reported, details limited	No/unclear	Limited reporting of outcomes and follow-up periods	Moderate
Choi & Park, 2019 [24]	Quasi-experimental study	No randomization	No/unclear	No randomization; small sample size	High
Khant et al., 2023 [25]	Single-blinded interventional study	Computer-generated randomization	Partial	Men only; ongoing dust exposure	Moderate
Kim, 2016 [26]	RCT	Reported, but incompletely described	No/unclear	Small sample size; incomplete reporting	Moderately high
Mueller et al., 2016 [27]	RCT	Reported, details limited	No/unclear	Outcomes were predominantly behavioral rather than clinical-functional	Moderate
Eleawa et al., 2023 [28]	Single-blinded RCT	Reported	Partial	Small sample size; single clinical population	Low to moderate
Wang et al., 2018 [29]	RCT	Reported, details limited	No/unclear	Blinding not described; limited detail on control procedures	Moderate
Zhang et al., 2025 [30]	Blinded placebo-controlled RCT	Reported	Yes	Pilot nature and mixed population	Moderate

Discussion. The obtained results form a sufficiently consistent picture: the most stable positive effect of rehabilitation programs in patients with occupational dust-related lung diseases is observed in relation to exercise tolerance and quality of life, whereas the effect on dyspnea severity and pulmonary function parameters appears less homogeneous. This pattern of effect seems clinically plausible. Most of the included interventions were aimed primarily at correcting physical deconditioning, reduced exercise tolerance, disturbed breathing pattern, and

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limitations in daily activity, rather than at reversing irreversible fibrotic or mixed fibrotic-obstructive changes in the lung tissue. It is for this reason that the most reproducible signals were obtained for physical performance tests and quality-of-life scales, which is consistent both with the meta-analytic data [9], and with the results of primary studies [20, 21, 25, 30].

Particular attention should be paid to the fact that the most pronounced effects in a number of studies were observed in programs that included inspiratory muscle training. It was specifically in studies using IMT that the most notable improvements were recorded in the 6MWT, dyspnea scales, and a number of spirometric parameters [25, 28]. This probably reflects an important feature of this population: functional impairment in occupational dust-related lung diseases is sustained not only by structural damage to the respiratory system, but also by secondary weakness of the respiratory musculature, reduced ventilatory reserve, and general deconditioning. From this perspective, IMT may be regarded not simply as an additional program component, but as a potentially clinically significant rehabilitation module, especially in patients with marked dyspnea and limited exercise tolerance.

No less indicative is the pattern of effects on pulmonary function. The body of included data suggests that rehabilitation interventions more often lead to improvement in absolute volume-based parameters such as FEV1 and FVC than to changes in the FEV1/FVC ratio. A similar tendency is seen both in the meta-analysis [9], and in a number of primary studies [19, 21, 28, 29]. This indirectly indicates that rehabilitation most likely improves the efficiency of respiratory mechanics, enhances tidal volume recruitment, and promotes the patient's functional adaptation, but does not have a substantial effect on the fixed morphological substrate of the disease. Therefore, expecting pulmonary rehabilitation to reverse pneumoconiosis or silicosis would be methodologically incorrect; its clinical value lies primarily in improving functioning rather than in the regression of structural damage.

An important observation is that, despite the occupationally oriented nature of the included populations, occupational outcomes were in fact not presented as an independent assessment domain. None of the included studies systematically analyzed return to work, job retention, work productivity, temporary disability, changes in working conditions, or the relationship between rehabilitation and occupational prognosis. Even in those studies in which physical activity was assessed during longer follow-up, there was no direct consideration of occupational endpoints [27]. For a review devoted to occupational pathology, this is a major gap, because without such data it is difficult to answer the main applied question: does improvement in functional status translate into a more favorable occupational and social prognosis?

No less important is the question of the durability of the achieved effect. Long-term data in the available body of evidence remain limited. In some studies, the effect was accompanied by maintenance of a higher level of activity during subsequent follow-up [27], whereas in others part of the achieved improvement weakened over time, especially in the presence of continued exposure to adverse occupational factors or in the absence of a maintenance training regimen [25]. This has important practical implications. For patients who continue to work under dusty conditions, rehabilitation apparently should not be regarded as a short isolated course, but rather as part of a longer-term management strategy combining training programs, exposure control, and measures aimed at modifying working conditions.

A strength of the present review is that it covers not only classical pulmonary rehabilitation programs, but also a broader range of multicomponent interventions, including respiratory rehabilitation, inspiratory muscle training, behavior-oriented approaches, comprehensive nursing support, and additional respiratory technologies [19, 23, 25, 27, 30]. This made it possible to identify not only an overall positive pattern, but also differences

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between types of programs. At the same time, the limitations of the review are also evident: the body of studies remains small and clinically heterogeneous; the design of the included studies ranges from meta-analysis and RCTs to quasi-experimental studies; in a number of publications, the procedures of randomization, blinding, the composition of the control group, and details of the intervention are described incompletely; and the set of outcomes differs across studies, which limits the direct comparability of the results. Therefore, the presented conclusions should be interpreted as a careful qualitative synthesis rather than as a definitive quantitative assessment of effectiveness.

From a practical point of view, the obtained data support the feasibility of incorporating pulmonary and multicomponent rehabilitation into the comprehensive management of patients with pneumoconiosis, silicosis, and occupational COPD. Most likely, the greatest clinical benefit is provided by programs combining physical training, breathing techniques, education and self-management elements, and, in some cases, targeted inspiratory muscle training. However, the next stage in the development of the evidence base should involve not so much confirming the general fact of benefit as clarifying the structure of the optimal program. First and foremost, comparative studies are needed with standardized outcomes, stratification by disease entity and severity, sufficient follow-up duration, and mandatory inclusion of occupational endpoints. Without this, the evidence base will remain clinically useful, but incomplete.

Conclusions. Pulmonary and multicomponent rehabilitation in patients with occupational dust-related lung diseases is most consistently associated with improvements in exercise tolerance and quality of life. The effects of rehabilitation programs on dyspnea severity and pulmonary function parameters are also generally favorable, although they are less homogeneous overall; the most pronounced results were observed in studies that included inspiratory muscle training. At the same time, a major limitation of the current evidence base remains the lack of data on occupational outcomes, as well as the limited number of studies with long-term follow-up, standardized design, and comparable endpoints.

Conflict of interest. The authors declare no conflict of interest.

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БРОНХ-ӨКПЕ ЖҮЙЕСІНІҢ КӘСІБИ ШАҢДЫ АУРУЛАРЫ КЕЗІНДЕ ӨКПЕЛІК ЖӘНЕ КӨПКОМПОНЕНТТІ ОҢАЛТУДЫҢ ТИІМДІЛІГІ

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Түйіндеме

Кіріспе. Өкпенің кәсіби шаңды аурулары физикалық жүктемеге төзімділіктің төмендеуімен, ентігумен, күнделікті белсенділіктің шектелуімен және өмір сапасының нашарлауымен астасады. Мұндай пациенттерде өкпелік және көпкомпонентті оңалтудың тиімділігі туралы деректер шектеулі және біркелкі емес.

Мақсаты. Өкпенің кәсіби шаңды аурулары бар ересек пациенттерде өкпелік және көпкомпонентті оңалтудың тиімділігі туралы деректерді физикалық жүктемеге төзімділікке, ентігуге, сыртқы тыныс алу функциясына, өмір сапасына және кәсіби-еңбек нәтижелеріне баса назар аудара отырып жүйелеу.

Материалдар мен әдістер. Жүйелі шолу PRISMA 2020 ұсынымдарына сәйкес орындалды. Іздеу PubMed/MEDLINE, Scopus, Web of Science Core Collection және Cochrane Library дерекқорларында олардың құрылған сәтінен бастап 2025 жылғы 30 қарашаға дейін қосымша қолмен іздеумен бірге жүргізілді. Барлығы 348 жазба анықталды; қайталанатын жазбаларды алып тастағаннан және іріктеу критерийлері бойынша сұрыптаудан кейін сапалық синтезге 12 бастапқы зерттеу енгізілді. Егер ересек пациенттердегі пневмокониоз, силикоз, кәсіптік ӨСОА және өкпенің басқа да созылмалы кәсіби шаңды аурулары бар науқастар зерттеліп, оңалту араласуы бағаланса және кемінде бір релевантты нәтиже бойынша деректер ұсынылса, мұндай зерттеулер енгізілді.

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Нәтижелер. Енгізілген зерттеулер тұтастай алғанда өкпелік және көпкомпонентті оңалтудың физикалық жүктемеге төзімділік пен өмір сапасына қолайлы әсерін көрсетеді. Бірқатар жұмыстарда ентігудің азаюы және сыртқы тыныс алу функциясының жекелеген көрсеткіштерінің жақсаруы да байқалды, алайда бұл нәтижелер біркелкі болмады. Ең айқын әсерлер инспираторлық бұлшықеттерді жаттықтыруды қамтитын бағдарламаларда байқалды. Қолда бар зерттеулерде кәсіби-еңбек нәтижелері іс жүзінде бағаланбаған.

Қорытынды. Өкпенің кәсіби шаңды аурулары бар пациенттерде өкпелік және көпкомпонентті оңалту негізінен физикалық жүктемеге төзімділіктің және өмір сапасының жақсаруымен астасады. Дәлелдемелік базаның негізгі шектеулері зерттеулердің клиникалық және әдіснамалық біркелкі еместігі, жұмыстар санының аздығы және ұзақ мерзімді еңбек болжамы туралы деректердің жеткіліксіздігі болып табылады.

Түйінді сөздер: өкпелік оңалту, көпкомпонентті оңалту, өкпенің кәсіби шаңды аурулары, кәсіптік ӨСОА, инспираторлық бұлшықеттерді жаттықтыру, өмір сапасы.

ЭФФЕКТИВНОСТЬ ЛЕГОЧНОЙ И МНОГОКОМПОНЕНТНОЙ РЕАБИЛИТАЦИИ ПРИ ПРОФЕССИОНАЛЬНЫХ ПЫЛЕВЫХ ЗАБОЛЕВАНИЯХ БРОНХОЛЕГОЧНОЙ СИСТЕМЫ

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Аннотация

Актуальность. Профессиональные пылевые заболевания лёгких ассоциированы со снижением переносимости физической нагрузки, одышкой, ограничением повседневной активности и ухудшением качества жизни. Данные об эффективности лёгочной и многокомпонентной реабилитации у таких пациентов остаются ограниченными и неоднородными.

Цель. Систематизировать данные об эффективности лёгочной и многокомпонентной реабилитации у взрослых пациентов с профессиональными пылевыми заболеваниями лёгких с акцентом на переносимость физической нагрузки, одышку, функцию внешнего дыхания, качество жизни и профессионально-трудовые исходы.

Материалы и методы. Систематический обзор выполнен в соответствии с PRISMA 2020. Поиск проведён в PubMed/MEDLINE, Scopus, Web of Science Core Collection и Cochrane Library от inception до 30 ноября 2025 года с дополнительным ручным поиском. Выявлено 348 записей; после удаления дубликатов и отбора по критериям включения в качественный синтез вошли 12 первичных исследований. Включались исследования взрослых пациентов с пневмокониозом, силикозом,

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профессиональной ХОБЛ и другими хроническими пылевыми заболеваниями лёгких, если оценивалось реабилитационное вмешательство и представлялись данные хотя бы по одному релевантному исходу.

Результаты. Включённые исследования в целом указывают на благоприятное влияние лёгочной и многокомпонентной реабилитации на переносимость физической нагрузки и качество жизни. В ряде работ отмечалось также уменьшение выраженности одышки и улучшение отдельных показателей функции внешнего дыхания, однако эти результаты были менее однородными. Наиболее выраженные эффекты наблюдались в программах, включавших тренировку инспираторных мышц. Профессионально-трудовые исходы в доступных исследованиях практически не оценивались.

Выводы. Лёгочная и многокомпонентная реабилитация у пациентов с профессиональными пылевыми заболеваниями лёгких ассоциирована преимущественно с улучшением переносимости физической нагрузки и качества жизни. Основными ограничениями доказательной базы остаются клиническая и методологическая неоднородность исследований, малое число работ и недостаток данных о долгосрочном трудовом прогнозе.

Ключевые слова: легочная реабилитация, многокомпонентная реабилитация, профессиональные пылевые заболевания легких, профессиональная ХОБЛ, тренировка инспираторных мышц, качество жизни.