REVIEW

Pulmonary Rehabilitation in Romania: From Pioneering Stages to the Horizons of Digital Technologies

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Abstract. This paper presents an overview of pulmonary rehabilitation in Romania, tracing its evolution from initial implementation to current integration with digital technologies. Pulmonary rehabilitation is now recognized as a cornerstone in the management of chronic lung diseases, aiming to enhance patients' quality of life and functionality through tailored, multidimensional interventions. The development of pulmonary rehabilitation in Romania began in the 1970s and was significantly advanced by the establishment of the Pulmonary Rehabilitation Working Group (PRWG) in 2006. The key components of pulmonary rehabilitation programs include physical training, education, psychological support, nutritional counseling, occupational therapy, and strategies for managing secretions. Current pulmonary rehabilitation practices are enhanced by telemedicine, digital health platforms, virtual reality, robotics and artitifical intelligence. These innovations enable remote monitoring, personalized exercises, and enhanced patient engagement, promising a transformative impact on pulmonary care. Future directions emphasize ongoing research to optimize technology integration, improve protocols, and ensure equitable access, thereby maximizing the benefits of pulmonary rehabilitation for diverse patient populations.

Keywords: *pulmonary rehabilitation, telerehabilitation, virtual reality, robots, artificial intelligence.*

Abbreviations: COPD = Chronic Obstructive Pulmonary Disease; ACCP = American College of Chest Physicians; ATS = American Thoracic Society, ERS = European Respiratory Society; RSP = Romanian Society of Pulmonolgy; PRWG = Pulmonary Rehabilitation Working Group, CT = Computed Tomography; AI = Artificial Intelligence; ML = Machine Learning; NLP = Natural Language Processing; WHO = World Health Organisation.

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INTRODUCTION

Integrated pulmonary rehabilitation is a fundamental pillar in the modern paradigm of chronic lung disease management. Its primary objective is to substantially improve patients' quality of life and overall functionality. Defined according to the 2023 American Thoracic Society (ATS) guidelines, pulmonary rehabilitation 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, designed to improve the physical and psychological condition of people with chronic pulmonary diseases and to promote the long-term adherence to health-enhancing behaviors".

The effectiveness of pulmonary rehabilitation translates into remarkable

clinical results, including increased skeletal muscle strength, improved exercise tolerance, reduced symptoms of underlying disease, prevention of exacerbations, and reduced risk of hospitalization. Furthermore, it has been shown that, in patients with chronic obstructive pulmonary disease (COPD), pulmonary rehabilitation can lead to a decrease in mortality of more than 30% at 1 year, while improving the patients' quality of life and autonomy [1].

PULMONARY REHABILITATION IN AN INTERNATIONAL AND NATIONAL CONTEXT

The development of pulmonary rehabilitation as a distinct medical discipline within the specialty Rehabilitation, Physical Medicine, and Balneology began in the 1970s. This field integrates physical exercises, education, and psychological support into the management of patients with chronic pulmonary diseases. A defining milestone was in 1974, when the American College of Chest Physicians (ACCP) issued a definition of pulmonary rehabilitation, describing it as an individually tailored art of medical practice. Evidence-based consolidation took place in 1997 with the publication of the first guidelines under the auspices of the American Association of Cardiovascular and Pulmonary Rehabilitation [2].

In Romania, the history of pulmonary rehabilitation is marked by the initiatives of the medical university center in Iasi. The cardiopulmonary rehabilitation clinic at the Iasi Rehabilitation Clinical Hospital was founded in 1977 by Prof. Dr. Ioan Lungu, initially with an impressive 144 beds out of a total of 500. Subsequently, in 2008, the number of beds dedicated to pulmonary rehabilitation was adjusted to 25.

The key moment for the recognition and integration of pulmonary rehabilitation into modern Romanian medicine came in 2006. This moment coincided with the publication of the joint statement on pulmonary rehabilitation by the ATS/European Respiratory Society (ERS). This recognition catalyzed the establishment of the Pulmonary Rehabilitation Working Group (PRWG) of the Romanian Society of Pneumology (RSP) which I founded with the support of the RSP management, represented by Prof. Dr. Florin Mihaltan and Prof. Dr. Paul Stoicescu. Since its founding, the PRWG has actively contributed to the development of the pulmonary rehabilitation by organizing courses and practical workshops at the national level, leading to a significant increase in the number of members and pulmonary rehabilitation departments throughout the country. PRWG members include pulmonologists and medical rehabilitation physicians, as well as key health experts such as physical therapists, nutritionists, psychologists, occupational therapists, and functional exploration technicians, etc.

The first major scientific event dedicated to pulmonary rehabilitation, highlighted by its multidisciplinary approach (involving rehabilitation medicine, pulmonology, cardiology, pediatrics, emergency medicine, and intensive care), was hosted in Iasi in 2010, followed by another in 2012 and many mores, aiming to bringing together specialists in both pulmonology and rehabilitation, as well as related specialties such as cardiology, pediatrics, emergency medicine, intensive care, and thoracic surgery. The conferences were organized under the auspices of prestigious Romanian medical societies—the Romanian Society of Pulmonology, the Romanian Society of Cardiology, the Romanian Society of Anesthesia and Intensive Care, the Romanian Society of Emergency Medicine, and the Romanian Society of Pediatrics—and under the patronage of the ACCP [3].

Editing the book “Handbook of Pulmonary Rehabilitation”, for which I had as co-editor Prof. Dr. Darcy D. Marciniuk from Canada, published by Nova Science Publishers, New York, at the beginning of 2021, played a

significant role in the international specialized literature. This book, published in English, the first of its kind in Romania, brought together renowned specialists from countries such as the USA, Canada, Italy, Germany and Romania. The book comprehensively addresses pulmonary rehabilitation, from fundamentals to practical aspects and particularities of each disease and is structured in 24 chapters across 400 pages. At the national level, under the auspices of the University of Medicine and Pharmacy in Iasi, I have published together with the members of the Pulmonary Rehabilitation Working Group of the RSP, two fundamental treatises on pulmonary rehabilitation, in 2022 and 2023. The first book, "Treatise on Pulmonary Rehabilitation," comprehensively describes the complexity of pulmonary rehabilitation intervention and details its components and applicability. The second book, "Treatise on Pulmonary Rehabilitation: Particular Aspects", places particular emphasis on the specific aspects of assessment and management of the most common pulmonary pathologies.

THE CURRENT LEVEL OF PULMONARY REHABILITATION IN ROMANIA: A MULTIDISCIPLINARY APPROACH

The pulmonary rehabilitation center in Iasi, through the Rehabilitation Clinical Hospital, Pulmonary Medical Rehabilitation Clinic, remains a reference center in the field. Annually, this center integrates over 1,000 patients into pulmonary rehabilitation programs, of which over 700 are diagnosed with COPD. The center contributes to the development of this discipline by promoting pulmonary rehabilitation in other national centers, including through the organization of courses and conferences with international participation. The Pulmonary Rehabilitation Clinic of the Rehabilitation Clinical Hospital in Iasi currently operates with 25 beds.

During their stay, patients undergo a comprehensive assessment from a clinical point of view, of lung function, physical capacity, quality of life, emotional state, nutrition, and occupational status, etc. and then they are integrated into an appropriate pulmonary rehabilitation program in accordance with current guidelines. After discharge, patients are encouraged to continue the rehabilitation program at home and to return periodically for reassessment, adjustment of medication and rehabilitation treatment. The complexity of pulmonary rehabilitation intervention requires a multidisciplinary team, coordinated by a specialist doctor in physical medicine and rehabilitation, alongside whom work pulmonologists and specialists in functional assessments, physical therapists, nutritionists, psychotherapists, nurses, occupational therapists, and social workers. The rehabilitation program is guided by close collaboration between the physician, nurse, physical therapist, dietitian, and psychologist and aims to provide an integrated approach to patients with compromised pulmonary function due to obstructive lung diseases (asthma, bronchiectasis, COPD, cystic fibrosis), restrictive lung diseases [interstitial diseases (pulmonary fibrosis, sarcoidosis, lymphangioleiomyomatosis), chest wall diseases, neuromuscular diseases, post-tuberculosis], bronchopulmonary cancer, post-COVID-19 syndrome, before and after lung surgery/lung transplantation [4]. The nationally implemented pulmonary rehabilitation program integrates six major components:

1. Physical training: This is the foundation of the programs, aiming to improve lung function and reduce dyspnea by increasing endurance, muscle strength, and exercise capacity. The exercises, which are personalized and adapted, include endurance and strength training for the respiratory and peripheral muscles. Sessions are conducted under the supervision of a physical therapist, with progressive intensity. Breathing exercises, focused on specific techniques and training of the inspiratory and

expiratory muscles, reduce exertional dyspnea and increase the strength and endurance of the respiratory muscles.

2. Educational counseling: Plays an essential role in improving symptom self-management and increasing treatment adherence. It covers crucial topics such as proper inhalation techniques, the importance of quitting smoking, and adapting to a new lifestyle. Studies indicate that education supported by informational materials and mobile applications reduces the frequency of exacerbations and hospitalization rates by actively involving the patient in their own care.
3. Psychological and social support: Addresses the psychological impact of dyspnea, the main symptom, which can cause fear and anxiety, limiting daily activities and social interactions. The psychosocial component provides a framework for addressing these issues through individual and group sessions, where patients learn stress management techniques and how to adapt to physical changes.
4. Nutritional counseling: This is an important component, given that nutritional status, body weight, body composition, and body mass index are independent determinants of therapeutic success in chronic pulmonary diseases. A healthy diet reduces the risk of metabolic and cardiovascular diseases, supports the effectiveness of physical exercise, and can reduce fatigue.
5. Occupational therapy: Intervenes to optimize the ability to perform daily activities (occupations) that are limited by the impact of pulmonary disease. Occupational therapy interventions focus on conserving energy by optimizing the energy costs associated with daily activities, anxiety, and physical exercise. The objectives of energy conservation are summarized by the 3 Ps: planning, prioritizing, pacing. Occupational therapists are essential to ensure that functional improvements translate into tangible benefits in maintaining or regaining independence.
6. Cough and expectoration stimulation: This is fundamental for patients with bronchiectasis and other conditions associated with secretion accumulation. This component includes postural drainage techniques, assisted coughing maneuvers, and breathing exercises that help keep the airways open and eliminate secretions [5].

FUTURE DIRECTIONS: INTEGRATION OF DIGITAL TECHNOLOGIES, ROBOTS, VIRTUAL REALITY AND ARTIFICIAL INTELLIGENCE

In recent years, accelerated by the COVID-19 pandemic, the delivery of pulmonary rehabilitation through telerehabilitation and the accelerated adoption of digital technologies, which increase the accessibility and personalization of interventions, are attractive alternatives to hospital/center-based pulmonary rehabilitation. New trends in the field focus on digital health and telerehabilitation to increase patient access and adherence to the program, with the aim of maintaining the long-term benefits of rehabilitation and cost reduction.

Telemedicine and telerehabilitation

Telemedicine, according to the World Health Organization (WHO), involves the provision of medical services through means of communication (telephone, mass media), especially when geographical distance is an obstacle. The major benefits of telemedicine include real-time audio and video communication between doctor and patient, collection and transmission of specific data (messages, recommendations, videos), remote monitoring of vital parameters using portable devices such as sensors, smart watches or tracking devices, and financial benefits through reduced hospitalization costs. Patients enrolled in the telerehabilitation program receive training for home exercises,

telemonitoring, and self-management. The implementation of pulmonary telerehabilitation considers the following biotic aspects: description of the intervention and ensuring the quality standard of care in accordance with the legal provisions and regulations in the field, patient confidentiality and informed consent expressed in writing, including regarding the recording and storage of sessions, information, and reports [6].

Telerehabilitation is classified according to provider and beneficiary into three categories:

- At the center level: Connecting an expert center to smaller centers via videoconferencing, facilitating the transfer of knowledge and experience in the field of pulmonary rehabilitation.
- At home: Patients follow supervised exercise programs in their own homes, using videoconferencing, sometimes monitoring oxygen saturation, respiratory and heart rate. This strategy can be complementary to hospital rehabilitation or can replace outpatient pulmonary rehabilitation.
- On the web: This refers to digital platforms that deliver pulmonary rehabilitation programs, primarily aimed at patients with COPD. These digital technologies include at least one of the essential components: physical exercise, educational, psychological, nutritional, or behavioral counseling [7].

Multiple applications and platforms have been identified, integrating physical exercise programs, breathing exercises, or educational components:

- Active+me REMOTE (Aspetika): A platform that delivers pulmonary rehabilitation through interactive videos with physical exercises and short educational lessons. The difficulty of the physical training increases as the patient's muscle strength increases. This application collects data provided by a pulse oximeter, spirometer, and smart inhaler device.
- Clinitouch: Provides a 6-week pulmonary rehabilitation program and supports remote monitoring of COPD.
- Kaia Health COPD: Offers a personalized program, including educational modules, customizable daily physical exercises, and meditation exercises, also providing an integrated communication component with medical staff.
- MyCOPD: A platform for education, self-monitoring, and pulmonary rehabilitation, with a 6-week PR program.
- Rehab Guru: Allows healthcare professionals to digitally prescribe personalized exercise programs, delivered through videos, with the possibility of user feedback to adjust the rehabilitation program.
- SPACE for COPD: A digital self-management program that contains educational topics on medicine, breath control, physical exercise, and nutritional counseling.
- Wellinks: An online platform that provides a pulmonary rehabilitation program and supports remote COPD control in adult patients by storing data from pulse oximeters and spirometers.
- MyBreath app: Provides information and videos focusing on breathing exercises, mindfulness, and stress reduction.
- Datos Health: Provides a pulmonary rehabilitation platform with data analytics and automation for both patients and providers [8].
- Live better with Pulmonary rehab: Started as a pilot project at the ATS, its mission is to inform and educate patients with chronic lung disease about the benefits of pulmonary rehabilitation and to provide access to pulmonary rehabilitation programs [9].

Virtual reality

Virtual reality is an innovative technology that offers new opportunities for personalization and self-control of pulmonary rehabilitation, increasing patient involvement. Its immersive, personalized, and interactive nature brings a new dimension to traditional rehabilitation protocols. The challenges of integrating virtual reality into RR are identifying the most effective programs and their duration, developing standardized protocols for optimizing care, and conducting studies to evaluate the long-term benefits of virtual reality-based pulmonary rehabilitation.

The implementation of all types of virtual reality technologies (non-immersive, semi-immersive, and fully immersive) has been adapted to the field of pulmonary rehabilitation, bringing significant benefits, improving dyspnea, exercise capacity and mobility, lung function, and patients' quality of life. The interfaces are designed to include breathing exercises, biofeedback systems, virtual environments for physical exercise, and educational modules [10].

The use of virtual reality combined with mindfulness techniques can serve as a distraction, helping to reduce stress and anxiety. Virtual reality programs enhanced with biofeedback software allow both the patient and the physician to track the effectiveness and progress of the training. Biofeedback enhances the sensory experience and enthusiasm of patients, thus playing a crucial role in program adherence.

A meta-analysis and systematic review showed that a virtual reality-based program can boost patients' therapeutic effort, having a positive effect on exercise capacity and lung function. Virtual reality is considered a safe and well-tolerated intervention, offering an appropriate and personalized exercise program compared to traditional programs. The use of games in virtual reality introduces a fun dimension and creates a competitive spirit, supporting long-term patient involvement [11].

The integration of robots into pulmonary rehabilitation programs

Robots are integrated into hospital or home-based pulmonary rehabilitation programs to provide assistance and guidance during physical training programs, to monitor patients, provide educational support, and even perform breathing exercises. The use of robots in rehabilitation is correlated with an increase in treatment adherence among patients with cognitive impairments or affective disorders.

The benefits of integrating robots include improved functional capacity and quality of life, increased adherence and reduced hospitalization rates, as well as objective monitoring of progress by providing a consistent, integrated, comprehensive, and effective pulmonary rehabilitation program integrated with biofeedback systems (EMG, arterial blood oxygen saturation, heart rate, spirometry) that allows for automatic adjustment of exercises. The challenges of effective robot use are high costs, lack of clinically validated protocols, and training medical staff to use them correctly. Integrating robots into pulmonary rehabilitation requires multicenter clinical studies and collaboration between engineers, physicians, and psychologists [12].

Types of robots used in pulmonary rehabilitation:

- Assisting robots (Robot-Assisted Gait Training-RAGT, Pulmonary training robots) can guide and assist walking, standing, and breathing exercises, providing real-time visual and auditory feedback [13].
- Interactive social robots (e.g., PARO, NAO) can increase the involvement of elderly or anxious patients by using alarms to remind them to take their medication and encourage them to follow their rehabilitation program.

- Mobile follower robots such as the Mobile Follower Robot for Home Oxygen Therapy-HOT, are useful for patients who need oxygen therapy, carrying the portable oxygen equipment according to the patient's needs. Robots like O2matic provide automatic, personalized oxygen therapy by continuously measuring blood oxygen saturation (SpO2) with a pulse oximeter. The robot's advanced software then automatically adjusts the oxygen dosage to keep patients within their optimal oxygen range [14].
- Exoskeleton robots: improve balance and functional capacity through interventions such as walking assistance and guidance for training, significantly contributing to reducing the risk of patient falls [15].
- "Rehabilitation Robot BreathCoach" and "PneumoRehabBot" are experimental devices for assisted diaphragmatic training.

Integrating artificial intelligence in pulmonary rehabilitation

Artificial intelligence (AI) is rapidly transforming healthcare, and pulmonary rehabilitation is no exception. By leveraging advanced analytics, machine learning, and natural language processing, AI is enabling a new era of personalized and proactive care for individuals with chronic respiratory diseases. This paper explores the multifaceted applications of AI in pulmonary rehabilitation, highlighting its potential to improve patient engagement, enhance treatment adherence, and ultimately lead to better clinical outcomes [16].

Key applications of AI in pulmonary rehabilitation:

- Predictive analytics and early intervention: One of the most promising applications of AI is its ability to predict exacerbations of conditions like COPD. By analyzing data from wearable sensors, spirometers, and electronic health records, AI models can identify patterns and predict impending exacerbations days in advance.
- Personalized exercise regimens: Exercise is a crucial component of pulmonary rehabilitation, but developing effective and safe exercise programs can be challenging. Machine learning (ML) algorithms can tailor exercise regimens to a patient's specific physical capabilities, disease severity, and progression, maximizing their therapeutic benefits.
- Virtual coaching and support: Many patients, particularly those in rural areas or with mobility impairments, face barriers to accessing traditional pulmonary rehabilitation programs. AI-powered chatbots and virtual assistants can provide daily check-ins, personalized exercise and medication reminders, tailored education, and encouragement. Utilizing natural language processing (NLP), these virtual coaches can engage patients in meaningful conversations, address their concerns, and provide ongoing support to promote adherence to treatment plans.
- Enhanced patient monitoring: AI systems can collect and analyze a wide range of biosignals, including cough sounds, airflow patterns, and respiratory rate. By monitoring these parameters, AI can detect subtle changes in a patient's condition and provide real time feedback and guidance for self-management. This enhanced monitoring capability empowers patients to take an active role in their care and improves their ability to recognize and respond to early warning signs.
- Improved diagnosis and treatment: AI can also assist in the diagnosis of respiratory illnesses by analyzing medical images, such as chest X-rays and CT scans. By identifying subtle abnormalities that might be missed by the human eye, AI can improve diagnostic accuracy and speed up the

time to treatment, allowing clinicians to make more informed decisions and personalize therapy based on individual patient responses.

- Remote and home-based care: AI plays a crucial role in facilitating virtual rehabilitation, allowing patients to manage their conditions from the comfort of their own homes. By analyzing data from home-based exercise sessions and providing personalized feedback, AI enables patients to participate more actively and independently in their rehabilitation. This not only reduces the burden on caregivers but also improves patient access to care and enhances their overall quality of life [17].

Benefits of AI in pulmonary rehabilitation:

- Improved patient outcomes: By supporting personalized treatment and early detection of exacerbations, AI enhances overall respiratory health and improves patient quality of life.
- Increased patient engagement: Virtual coaching and personalized tools help patients actively participate in their rehabilitation, fostering a sense of ownership and promoting adherence to treatment plans.
- Greater efficiency: AI can automate many tasks traditionally performed by healthcare providers, reducing their workload and improving resource utilization [18].

Challenges and considerations

- Data privacy and security: The collection and analysis of sensitive patient data raise significant privacy and security concerns. Robust policies and safeguards are needed to protect patient information and ensure compliance with data protection regulations.
- Misinformation and reliability: AI systems are only as good as the data they are trained on. Continuous evaluation of AI models is crucial to ensure reliability, transparency, and accurate information delivery. Steps must be taken to mitigate the risk of biased or misleading information being disseminated to patients.
- Equitable access: Efforts are required to ensure that AI tools are accessible to all patients, regardless of their socioeconomic status, geographic location, or technological literacy. Without such efforts, AI could inadvertently widen existing healthcare disparities.
- Ethical concerns: The use of AI in healthcare raises a number of ethical considerations, including issues related to bias, transparency, and accountability. Responsible and ethical use of AI requires collaboration between developers, providers, and patients to shape effective and fair tools [19].

CONCLUSIONS

Integrated pulmonary rehabilitation has emerged as an essential element in the management of chronic lung diseases. From the academic and institutional pioneering of the center in Iasi, pulmonary rehabilitation in Romania has reached a level of development based on a holistic and multidisciplinary approach, encompassing physical training, educational counseling, psychological and nutritional support, and occupational therapy. Future directions are defined by the convergence of medicine and digital technology. The widespread implementation of telemedicine and digital rehabilitation platforms increases access to personalized interventions.

In addition, the use of innovative technologies, such as virtual reality and robots, maximizes patient involvement and adherence to the rehabilitation process. It is essential that these programs be continuously adapted to the individual needs of patients to ensure the effectiveness and success of interventions. It is also imperative to continue research in this field to develop even more effective strategies

for the treatment of pulmonary conditions and to quantify the impact of virtual reality on critical psychosocial variables such as depression, anxiety, cognition, and quality of life. Further studies are also needed to develop protocols for the effective and successful use of robots in pulmonary rehabilitation.

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P.P. conceived the original draft preparation and was responsible for conception and design of the review. P.P. was responsible for the data acquisition and assembly of the articles/published data, and their inclusion and interpretation in this review. The author contributed to data interpretation, final editing, and approved the final version.

Compliance with Ethics Requirements
The authors declare no conflict of interest regarding this article.

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REFERENCES

[1]. American Thoracic Society. Pulmonary Rehabilitation for Chronic Lung Disease: ATS/ERS Policy Statement. Am. J. Respir. Crit. Care Med. 2023; 207(3):290-299. doi:10.1164/rccm. 2023-0001ST

[2]. Vaishali K, Sinha MK, Maiya AG, Bhat A. The initial steps in pulmonary rehabilitation: How it all began? Lung India. 2019;36(2):139-141. doi:10.4103/lungindia.lungindia_101_18

[3]. Postolache P, Darcy D. Marciniuc. Handbook of Pulmonary Rehabilitation. Nova Publishers, 2021.

[4]. Postolache P, Ghimuș C, Oiegar V. Reference pillar in pulmonary rehabilitation: Iasi. Romanian Journal of Medical Rehabilitation, Physical Medicine and Balneoclimatology. 2025: 2(1):5-7. Available from: https://www.doi.org/10.59277/RJMRPMB.2025.1.02.

[5]. Holland A, Cox N. Telerehabilitation for people with chronic lung disease [Internet]. American Thoracic Society; [cited 2025 Sept 23]. Available from: https://www.thoracic.org/members/assemblies/assemblies/pr/quarterly-bite/telerehabilitation-for-people-with-chronic-lung-disease.php

[6]. World Health Organization Guide—Consolidated telemedicine implementation guide. 2022, License: CC BY-NC-SA 3.0 IGO

[7]. Tsai LL, McNamara RJ, Moddel C, Alison JA, McKenzie DK, McKeough ZJ. Home-based telerehabilitation via real-time videoconferencing improves endurance exercise capacity in patients with COPD: The randomized controlled TeleR Study. Respirology. 2017;22(4):699-707. doi:10.1111/resp.12966

[8]. National Institute for Health and Care Excellence.Digital technologies to deliver pulmonary rehabilitation programmes for adults with COPD: early value assessment [Internet].2024 April 30. [cited 2025 Sept 23]. Available from: https://www.nice.org.uk/guidance/hte18/resources/digital-technologies-to-deliver-pulmonary-rehabilitation-programmes-for-adults-with-copd-early-value-assessment-pdf-17334271969477

[9]. Holland AE, Cox NS, Houchen-Wolloff L, et al. Defining Modern Pulmonary Rehabilitation. An Official American Thoracic Society Workshop Report. Ann Am Thorac Soc. 2021;18(5):e12-e29. doi:10.1513/AnnalsATS.202102-146ST

[10]. Malpo P, Matsangidou M, Pattichid P, Virtual Reality for Pulmonary Rehabilitation: Comprehensive Review. JMIR Rehabil Assist Technol. 2023; 10: e471114. doi: 10.2196/47114. doi: 10.2196/47114

[11]. Patsaki I, Avgeri V, Rigoulia T, Zekis T, Koumantakis GA, Grammatopoulou E. Benefits from Incorporating Virtual Reality in Pulmonary Rehabilitation of COPD Patients: A Systematic Review and Meta-Analysis [published correction appears in Adv Respir Med. 2024 Feb 01;92(1):89-91. doi: 10.3390/arm92010011.]. Adv Respir Med. 2023;91(4):324-336. Published 2023 Aug 10. doi:10.3390/arm91040026

[12]. Lee J, Ahn J, Lee J, et al. Utilization of Robot-Assisted Gait Training in Pulmonary Rehabilitation for a Patient with Ambulatory Dysfunction Post-Severe COVID-19 Pneumonia: A Case Report. J Clin Med. 2024;13(20):6213. Published 2024 Oct 18. doi:10.3390/jcm13206213.

[13]. Zhu Z, Cong B, Liu F, et al. Design of pulmonary training robot in rehabilitation of chronic obstructive pulmonary disease. IEEE International Conference on Advanced Intelligent Mechatronics (AIM), Busan, Korea (South). 2015; pp. 866-870, doi: 10.1109/AIM.2015.7222647.

[14]. Breathe design. Medical O2matic [Internet]. [cited 2025 Sept 23]. Available from: https://www.brahe-design.dk/medical/o2matic.html

[15]. Cho H. The Benefits of Wearable Robotics for Balance Training in COPD Rehabilitation. Ann Cardiopulm Rehabil. 2024; 4(1):11-14. DOI: https://doi.org/10.53476/acpr.2024.4.1.11

[16]. Vaish H. Is Digital Technology the Solution for Pulmonary Rehabilitation in Developing Countries During the COVID-19 Pandemic? Turk Thorac J. 2021;22(2):186-187. doi:10.5152/TurkThoracJ.2021.20224

[17]. Drummond D, Adejumo I, Hansen K, et al. Artificial intelligence in respiratory care: perspectives on critical opportunities and challenges. Breathe. 2024; 20(3): 230189; DOI: https://doi.org/10.1183/20734735.0189-2023

[18]. Abedi A, Colella TJF, Pakosh M, Khan SS. Artificial intelligence-driven virtual rehabilitation for people living in the community: A scoping review. NPJ Digit Med. 2024;7(1):25. doi:10.1038/s41746-024-00998-w

[19]. Hong L, Cheang X, Zheng D. Application of Artificial Intelligence in Emergency Nursing of Patients with Chronic Obstructive Pulmonary Disease. Contrast Media & Molecular Imaging. 2021;2021(1): 6423398. https://doi.org/10.1155/2021/6423398.