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Review Article

Virtual reality for chronic obstructive pulmonary disease: insights from a scoping review

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ABSTRACT

Recent advances in virtual reality (VR) technology have made it possible to use VR in healthcare settings to improve patient care and rehabilitation, with promising results in various clinical applications. This study aims to review the existing literature exploring the applications and potential benefits of VR for individuals with chronic obstructive pulmonary disease (COPD). A search of six databases, including PubMed, Medline, ScienceDirect, Web of Science, Ebsco, and ProQuest, was conducted to identify different studies exploring various VR applications for COPD patients. The search, updated in November 2024, yielded 2835 results, from which 18 diverse studies on this topic were included. The 18 publications included in the qualitative analysis were published in 2019-2024. These studies included 6 systematic reviews and meta-analyses, 4 mixed-methods studies, 3 observational studies, 3 conference papers, and 2 clinical trials. Among these, 11 studies investigated the efficacy of VR-assisted training in enhancing lung function, exercise endurance, and physical activity levels in COPD patients. Additionally, 7 studies explored the impact of VR on depression, anxiety, and stress levels in patients with COPD. Lastly, 8 studies assessed the acceptability, usability, or feasibility of this technology for COPD patients. In conclusion, the studies revealed that VR interventions led to positive outcomes for COPD patients, improving physiotherapeutic parameters, quality of life, and psychological well-being. Patients found VR programs acceptable and easy to use, increasing motivation and adherence to treatment. Further research is needed to assess VR's long-term effectiveness in reducing exacerbation and hospitalization rates for compliant COPD patients.

Keywords: Virtual reality, Chronic obstructive pulmonary disease, Health technology, Digital health

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) constitutes a significant global health threat, ranking as the fourth leading cause of mortality worldwide.[1] COPD is a condition marked by a progressive decline in lung function and airflow limitation. Long-term treatment is necessary to manage symptoms, primarily chronic and worsening shortness of breath. Moreover, COPD is often characterized by acute exacerbations, periods of severe worsening of respiratory symptoms.[2] These exacerbations have far-reaching consequences, both clinically and economically. Individuals with acute COPD exacerbations experience a decline in quality of life and lung function. Additionally, the condition imposes a substantial financial burden on healthcare systems due to increased hospitalization costs.[3] Pulmonary rehabilitation programs can reduce hospitalization rates and improve symptoms, exercise capacity, and quality of life. However, these programs require patients' proper compliance to reach the best efficacy.[4,5]

Recent advancements in VR technology have facilitated its integration into healthcare settings, demonstrating promising potential for improving patient care and rehabilitation across various clinical applications.[6] VR is a

simulated three-dimensional environment that users can explore and interact with. It offers a range of advantages for rehabilitation, including immersive learning experiences, safe and realistic practice scenarios, and personalized treatment plans, increasing patient motivation and allowing objective performance tracking.[7] VR technology has been increasingly utilized in various medical applications, including the treatment of pulmonary diseases such as COPD. This is due to the potential of VR to capture and analyze physiological signals, enabling the development of comprehensive breathing guidance techniques that can offer significant respiratory benefits to users.[8]

VR technology offers a promising avenue for addressing the multifaceted challenges posed by COPD. VR technology offers a promising avenue for addressing the multifaceted challenges posed by COPD. This review aims to systematically explore the current research on VR applications for COPD patients. By gathering, summarizing, and qualitatively analyzing the findings of relevant studies, we aim to identify knowledge gaps and draw conclusions to guide future research and clinical practice.

STUDY GOALS AND DESIGN

This study aims to explore the existing evidence on VR clinical applications for patients with COPD. To achieve this, a scoping review methodology was employed. Scoping reviews are designed to map the breadth of available research within a specific field. Unlike systematic reviews, scoping reviews do not critically appraise the quality of included studies. Instead, they provide a comprehensive overview of the existing knowledge base, regardless of methodological rigor.[9]

This systematic scoping review followed the methodological steps outlined by Arksey and O'Malley, incorporating modifications proposed by Levac and colleagues.[10,11] A formal protocol registration was not undertaken in Prospero, as the platform does not accommodate scoping reviews. The review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses for scoping reviews (PRISMA-ScR) guidelines.[12]

Identifying the research question

To guide the scoping review process and formulate research questions, the JBI mnemonic PCC framework was employed.[9] This framework focuses on three key elements: Participants (COPD patients), concept (VR interventions), and context (clinical and healthcare settings). This scoping review was guided by three research questions: What is the nature of research investigating the application of virtual reality for individuals with COPD? What specific VR aspects have been explored in the context of COPD management? Which areas of research related to VR and COPD require further investigation, and what potential avenues of inquiry could yield valuable insights?

Identifying relevant studies

A comprehensive literature search was conducted to identify studies that met specific inclusion and exclusion criteria. No limitations were placed on the publication date or study design.

LITERATURE SEARCH

Studies involving adult patients diagnosed with COPD and studies that implemented VR interventions as a therapeutic modality for COPD patients were included.

Studies on patients with conditions other than COPD, studies that utilized interventions other than VR, study protocols and technical reports, studies published in languages other than English and retracted studies were excluded.

A literature search was performed between November and December 2024 utilizing six electronic databases: PubMed, Medline, ScienceDirect, Web of Science, Ebsco, and ProQuest. The search strategy employed Boolean operators to combine the following keywords: ("Virtual reality" OR "VR" OR "Virtual" OR "Digital") AND ("COPD" OR "Chronic obstructive pulmonary disease" OR "lung disease" OR "pulmonary rehabilitation.") Reference Manager software was used to manage and organize the retrieved articles. Additionally, reference lists of relevant articles were hand-searched for additional studies.

STUDY SELECTION

A stepwise selection process was employed. Initially, titles were screened. Subsequently, abstracts were reviewed. Finally, full texts were evaluated. Inclusion and exclusion criteria were applied consistently at each stage of the selection process. Given the inclusion of systematic reviews encompassing a significant number of clinical trials, the direct inclusion of individual trials was restricted to those not previously evaluated in these reviews.

CHARTING THE DATA

The following information was extracted for each article: authors, publication type and study design, publication year, sample population, technology employed, and result. Data were organized in an Excel spreadsheet and arranged based on common themes.

SUMMARIZING AND REPORTING RESULTS

Descriptive qualitative content analysis was used to synthesize and analyze the data. A preliminary overview of key information from the studies was conducted. Three primary themes emerged, directly addressing the research

questions. These themes served as the foundation for presenting the results. The results were reported in line with the PRISMA-ScR guidelines for scoping reviews.

SELECTION OF SOURCES OF EVIDENCE

An initial database search yielded 2,835 studies. After removing duplicates, 1,572 studies remained for further review. A title and abstract screening process narrowed down the pool to 56 studies. Subsequently, a full-text review was conducted, resulting in the exclusion of studies that did not meet inclusion criteria. Ultimately, 18 studies were selected for inclusion in this review, as they were deemed relevant to application of VR for COPD patients. Figure 1 provides a visual representation of this study selection process using PRISMA flow diagram (Figure 1).

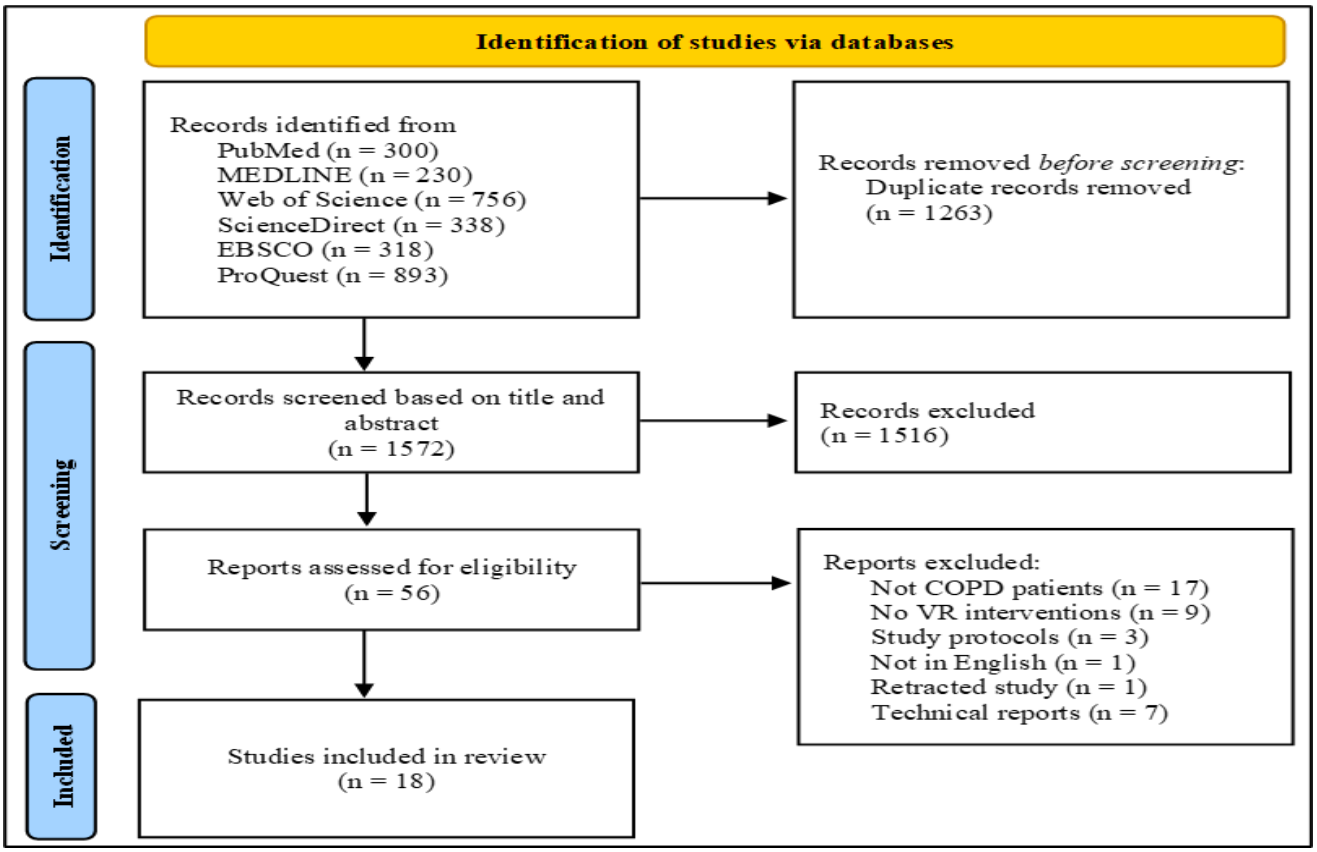

Figure 1: Detailing the study selection process for the review on VR applications for COPD patients.

CHARACTERISTICS OF INCLUDED STUDIES

Table 1 shows the types and outcomes of the chosen studies. Among the 18 included studies, six were systematic reviews and meta-analyses, four were mixed-methods studies, three were observational studies, three were conference papers, and two were clinical trials.[13-29] All studies were published between years 2019 and 2024, with majority (67%) being recent studies published in 2023/2024. The studies were carried out in 10 different countries: US, China, Italy, United Kingdom, Poland, Spain, Greece, Australia, Turkey, and Denmark.[13-30] Three main themes emerged in chosen studies: physiotherapeutic effect of VR for patients with COPD, Psychological benefits from VR for COPD patients, and acceptability and usability of VR by COPD patients (Table 1).

Table 1: Types and outcomes of studies exploring the application of VR for COPD patients.

Authors	Year	Study design	Assessed aspect	Conclusion
Condon et al[13]	2020	Systematic review and meta-analysis	Physical health	VR-based intervention can increase enjoyment, reduce symptoms (dyspnoea), and help maintenance of cardiovascular fitness.
Jung et al[14]	2020	Mixed methods	Physical and psychological health, quality of life, and usability	VR effectively improved physical ability (strength, mobility, and flexibility), psychological well-being, and quality of life (leaving the house and socializing more than before) and was easy to use.

Continued.

Authors	Year	Study design	Assessed aspect	Conclusion
Patsaki et al[15]	2023	Systematic review and meta-analysis	Physical and psychological health	VR is effective in increasing the therapeutic effect and improving lung function, but no significant effect on depression.
Curtis et al[16]	2024	Systematic review and meta-analysis	Physical health	VR is effective in improving aerobic endurance and lung function in individuals with COPD.
Obrero-Gaitán et al[17]	2024	Systematic review and meta-analysis	Physical health	VR is effective in increasing functional capacity, pulmonary function, and functional mobility in patients with COPD.
Chai et al[18]	2023	Systematic review and meta-analysis	Physical and psychological health	VR is effective in enhancing the therapeutic efficacy of pulmonary rehabilitation and improving lung function as well as reducing depression and anxiety.
Rutkowski et al[19]	2019	Conference paper	Physical health	VR is beneficial enhancing physical fitness parameters (mobility and exercise tolerance).
Liu et al[20]	2024	Systematic review and meta-analysis	Physical health	VR is effective in improving lung function in COPD patients and can improve exercise tolerance when combined with pulmonary rehabilitation.
Kizmaz et al[21]	2024	Randomized control trial	Physical and psychological health	VR is effective in reducing dyspnoea, improving physical well-being as well as reducing depression and anxiety.
Colombo et al[22]	2024	Observational study	Physical health and patient acceptability	Patients reported a positive experience and were highly engaged in the activity.
Finkelstein et al[23]	2023	Mixed methods	Patient acceptability and VR usability	VR received high user acceptance and participants had good ability to successfully operate the appliances.
Gabriel et al[24]	2023	Mixed methods	Patient acceptability and VR usability	VR received high acceptability and had good usability (participants were able to successfully operate the VR system with minimal assistance).
Gabriel et al[25]	2023	Observational study	Patient acceptability and VR usability	VR exercise app received high satisfaction and acceptance and was rated highly for usability and engagement.
Colombo et al[26]	2019	Conference paper	Patient acceptability and VR usability	VR showed excellent usability and received high acceptability after a single session of exercise.
Høeg et al[27]	2021	Conference paper	Patient acceptability and VR feasibility	VR-based training improved patient motivation and had no adverse effects.
Yin et al[28]	2024	Mixed methods	Psychological health	VR resulted in relaxation, stress reduction, and distraction, increased engagement and improved breathing exercise compliance.
Pancini et al[29]	2023	Randomized control trial	Psychological health	VR is effective in increasing emotional and psychological well-being, positive emotions, relaxation, and decreasing negative emotions.
Moorhouse et al[30]	2019	Observational study	Physical and psychological health, quality of life, and usability	VR was beneficial for improving physical (strength and mobility) and psychological (motivation, confidence and self-satisfaction) well-being as well as overall improvement in quality of life.

VR INTERVENTIONS FOR COPD PATIENTS

The VR interventions used in the studies included a range of activities designed to enhance physical and psychological well-being. Many studies incorporated endurance training combined with interactive VR components, such as pulmonary training with virtual scenes, cycling simulations, and somatosensory interactive game training.[17,18,26] Some interventions utilized video game systems like the Wii Fit for yoga, resistance, and aerobic exercises. Others employed fully immersive VR therapy with intense visual, auditory, and kinesthetic stimulation.[17] Relaxation-focused VR interventions included 10-minute virtual scenarios paired with narrative

audio to elicit positive emotions, followed by savouring exercises to consolidate the effects.[29] The virtual park application, developed in Unity 3D, provided supervised endurance training in a virtual park environment, with detailed performance reports tailored to individual patients.[26] Exergaming-based interventions further engaged participants by gamifying physical activities.[13] One unique intervention, the Virtual Therapeutic Garden, symbolized recovery by transforming from a grey, untidy garden to a vibrant, flourishing one as sessions progressed.[15]

PHYSIOTHERAPEUTIC EFFECT OF VR FOR PATIENTS WITH COPD

The 11 studies investigated the efficacy of VR-assisted training in enhancing physical health in COPD patients.[13-30] Studies were in favour of combined VR and pulmonary rehabilitation programs.[14,15,18,19-21] COPD patients undergoing these interventions reported improvements in strength, functional mobility, and flexibility.[14,17,30] The most common parameter used to assess physical effects was the 6-minutes-walking test, and it was consistently and significantly improved throughout the studies with $p<0.05$.[15-20,22,30] Another assessed parameter was the forced expiratory volume in 1 second (FEV1) which was also consistently and significantly improved throughout the studies, favouring the use of VR in training.[15,16,17,18,20] Shortness of breath was significantly improved in some studies while other studies reported minimal improvement with marginal statistical significance ($p=0.05$).[13-16,21,30]

PSYCHOLOGICAL BENEFITS FROM VR FOR COPD PATIENTS

Seven studies explored effectiveness of VR-assisted training in improving mental health and psychological well-being in COPD patients.[14,15,18,21,28-30] From a psychological perspective, studies were also in favour of combining VR training with pulmonary rehabilitation.[14,18,21,30] Patients reported a subjective sense of psychological well-being (feeling better, feeling joy, and feeling more confident).[14,27-30] Depression and anxiety were measured by five studies, with consistent reports of improvement and decrease in symptoms and negative emotion.[14,15,18,21,28] Furthermore, there was an improvement in the quality of life in COPD patients' who underwent VR sessions. Patients reported they are leaving the house more, socialising more and enjoying daily activities.[14,21,30] VR-based training also increased patient motivation and compliance to treatment session.[14,17,22,25,27,28,30]

ACCEPTABILITY AND USABILITY OF VR FOR COPD PATIENTS

Eight studies assessed the acceptability and usability of VR-assisted technologies for COPD patients.[14,22-30] Generally, VR-based interventions received high acceptability from COPD patients.[22-26] patients enjoyed the program and were engaged in the activities. As for the usability of VR technology for patients, they reported that it was easy to use and operate independently.[23-30] However, some minor improvements were suggested by some studies. Some patients reported technical glitches in the camera and visual dimensions. In addition, some patients found it difficult to find the starting point initially but managed to find it later. Some also suggested that the VR training should have the option to pause. Lastly, the headset was found to be heavy by some patients and they believed it needed to be lighter for it to be more comfortable.[14,23,25,30]

DISCUSSION

This scoping review aimed to explore the current evidence on use of VR as an intervention for COPD patients, focusing on its physiotherapeutic effects, psychological benefits, acceptability, and usability. The included studies demonstrated that VR-assisted interventions hold promise in improving both physical and psychological outcomes, with most studies supporting its integration into pulmonary rehabilitation programs. Additionally, VR was generally well-accepted by patients, with very few usability concerns and technical challenges.

The results revealed significant improvements in physical health, particularly in parameters such as the 6-minute walking test and forced expiratory volume in 1 second (FEV1). These findings suggest that VR-based interventions are effective in enhancing endurance, strength, and overall lung function in COPD patients. Importantly, VR's interactive and gamified nature likely played a role in increasing patient engagement, which is crucial for adherence to rehabilitation programs. However, while shortness of breath showed improvement in some studies, its minimal or marginal statistical significance in others suggests that the impact may vary depending on the intervention type or duration.

From a psychological perspective, VR interventions demonstrated consistent benefits, including reductions in anxiety and depression, increased motivation, and enhanced quality of life. Patients reported improved socialization and enjoyment of daily activities, highlighting VR's ability to positively impact mental well-being. These results are particularly relevant for COPD patients, who often suffer from social isolation and psychological distress due to the chronic nature of their disease.[31]

The acceptability and usability of VR interventions were also assessed in several studies, with most reporting high levels of patient satisfaction and engagement. Patients found VR-based rehabilitation enjoyable and easy to use, which likely contributed to improved compliance and motivation to participate in treatment. However, some studies highlighted minor usability challenges. While many patients were able to operate a VR program on their own, some occasionally experienced difficulties with

navigation at the beginning of VR sessions but were able to overcome these with practice. Additionally, few technical issues such as glitches in cameras or visual components were noted but have not disrupted the intervention experience.

Technical considerations regarding the VR equipment also emerged as an area for improvement. Some patients reported discomfort due to the weight of VR headsets, suggesting that lighter, more ergonomic designs are needed to optimize comfort and usability, especially for prolonged sessions. Moreover, the inability to pause VR sessions and the lack of flexibility in some programs were highlighted as areas that could enhance user control and satisfaction. Addressing these issues is essential to ensure that VR interventions are more user-friendly and accessible for COPD patients, particularly those with limited technological familiarity.

VR has been clinically applied to numerous health conditions beyond COPD. A 2024 study by Fereidooni et al investigating the effectiveness of VR for cancer patients, demonstrated positive impacts on both psychological and physiological aspects, as well as overall quality of life.[32] Patients experienced improvements in physical parameters and a decrease in anxiety. Similarly, a 2022 study by Chen et al examining VR for patients with heart disease, observed beneficial effects, including improved exercise capacity, reduced stress, and enhanced quality of life.[33] These findings align with our study's results, which also showed improvements in the physical and mental health of patients. However, a 2023 study by Yangöz et al evaluating the physical and psychological benefits of VR for chronic kidney disease patients, concluded that the intervention was not effective in reducing depression symptoms.[34] This contradicts our study's findings, which demonstrated a reduction in depression and improvements in mood and positive emotions.

Limitations and future directions

Despite promising findings, this review has some limitations. Firstly, the inclusion of only English-language publications may have excluded relevant research conducted in other languages. Secondly, the quality and heterogeneity of included studies posed challenges. This includes variations in study designs, intervention types, and outcome measures, making direct comparisons and generalizations difficult. Furthermore, the inclusion of conference papers, while permitted in a scoping review, may have introduced preliminary or incomplete data. Finally, many studies had small sample sizes and short intervention durations, limiting the assessment of long-term impact and the scalability of VR interventions.

Future research should focus on conducting large-scale, randomized controlled trials with standardized protocols to provide robust evidence for VR's effectiveness in COPD management. Long-term studies are needed to evaluate the sustainability of improvements in physical and psychological outcomes and its effects on exacerbation and hospitalization rates. Future work should also address the usability concerns identified, such as VR equipment weight, technical glitches, and user interface improvements, to ensure VR interventions are more patient friendly. Exploring the cost-effectiveness and accessibility of VR technologies will be essential for their widespread implementation in clinical practice.

CONCLUSION

This study demonstrates the potential of VR interventions for effective COPD management. Observed improvements in both physical and psychological well-being, coupled with positive patient feedback, suggest VR as a promising tool for enhancing care. Specifically, integrating VR into existing pulmonary rehabilitation programs may improve treatment adherence, optimize clinical outcomes, and provide a more engaging and motivating patient experience. While these initial findings are encouraging, further research is needed to improve VR technology, optimize treatment protocols, and confirm long-term efficacy and cost-effectiveness. Nonetheless, these findings indicate VR's significant potential to positively impact COPD care and warrant further investigation.

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