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Maitrayee Agrawal, BPT Intern, Department of Physiotherapy, School of Allied Health Sciences, Galgotias University, U.P, India, https://orcid.org/0009-0003-4939-4856

Dr. Tanya Gujral (PT), Assistant Professor, Department of Physiotherapy, School of Allied Health Sciences, Galgotias University, U.P, India, https://orcid.org/0000-0001-6288-5228

Dr. Chhavi Kumar Sharma (PT), Assistant Professor, Department of Physiotherapy, Mangalayatan University, Beswan Aligarh, U.P, India, https://orcid.org/0000-0002-0762-9990

Prof. (Dr.) Shahiduz Zafar, Professor, Department of Physiotherapy, School of Allied Health Sciences, Galgotias University, U.P, India, https://orcid.org/0000-0003-2764-7755

Mohammad Sidiq, Physiotherapy Department, Tishk International University, Erbil, Iraq, https://orcid.org/0000-0003-2448-8971

Effectiveness of Virtual Reality among Patients with Cardiopulmonary Disorders – A Narrative Review (Literature Review)

Abstract

Background. Cardiopulmonary disorders, including chronic obstructive pulmonary disease (COPD), heart failure, and post-cardiac surgery conditions, significantly impact patients' physical capabilities and quality of life. Traditional rehabilitation programs often face challenges such as low motivation and adherence. Virtual Reality (VR), with its immersive and interactive features, has emerged as a potential tool to enhance engagement and improve clinical outcomes in cardiopulmonary rehabilitation.

Aim. This narrative review aims to explore the effectiveness of VR-based interventions in the rehabilitation of patients with cardiopulmonary disorders by analyzing current evidence and clinical applications.

Materials and Methods. A comprehensive literature search was conducted using databases such as PubMed, Scopus, and Google Scholar. Studies focusing on the use of VR in patients with cardiopulmonary conditions were selected, including randomized controlled trials, observational studies, and pilot trials published in English. Key outcomes assessed included physical performance, respiratory function, psychological well-being, and adherence.

Results. The review indicates that VR-based rehabilitation programs can lead to improvements in exercise tolerance, pulmonary function, and mental health indicators such as anxiety and depression. VR also shows promise in enhancing motivation and compliance, especially in home-based and tele-rehabilitation settings. Despite positive trends, heterogeneity in study design, VR modalities, and outcome measures limit definitive conclusions.

Conclusions. VR represents a promising adjunct to conventional cardiopulmonary rehabilitation strategies. It offers a novel approach to patient engagement and functional improvement. However, more standardized, large-scale studies are necessary to validate its efficacy and establish clinical protocols for widespread use.

Keywords: *virtual reality, cardiopulmonary rehabilitation, COPD, heart failure, exercise training, patient engagement, telerehabilitation*

Introduction. Both cardiovascular diseases (CVDs) and chronic respiratory diseases (cardiopulmonary disorders) form a widely permeating and rapidly growing worldwide health issue with substantial effects on morbidity and mortality across the globe [1,2]. These disorders impact millions of people and create a huge economic burden to societies and health systems [3]. In order to counteract their widespread consequences, cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) have been viewed as irreplaceable parts of comprehensive patient care; they serve as the building blocks of secondary prevention. These multidisciplinary interventions aim to improve functional capacity, enhance pharmacological treatment, manage risk factors, and improve overall quality of life, with a notable reduction in hospital readmissions and mortality rates [4].

Conventional CR and PR programs typically include exercise training, counseling, education and dietary guidance [3]. However, traditional rehabilitation often encounters barriers that diminish its effectiveness, particularly with low levels of patient participation, motivation and adherence [5]. Socioeconomic disparities, geo-

graphic limitations, scheduling conflicts, transportation issues, and rigid program structures pose challenges [6]. Despite the proven benefits of CR in reducing morbidity and mortality, only about one-third of eligible patients enroll, with participation in some regions falling below 10%, and dropout rates ranging from 12 % to 56 % [7]. Similarly, PR faces significant personal and systemic barriers, with registration and attendance rates as low as 70 % and 40 %, respectively [8]. These concerns highlight the urgent need for innovative strategies to improve engagement.

To address these challenges, VR technology has emerged as a promising tool in healthcare, particularly in rehabilitation [9]. VR enables users to interact with immersive simulations that may enhance patient involvement and outcomes. It includes non-immersive, semi-immersive, and fully immersive systems, with head-mounted displays providing the highest level of immersion [10].

Research indicates that VR-based rehabilitation can significantly enhance physical performance. VR-integrated exercises have been shown to increase cardiovascular endurance, peak oxygen consumption, and exercise capacity in CR patients [11]. Improvements in 6-minute walk distance and heart rate recovery have also been reported. Similarly, VR benefits patients in PR by enhancing functional status and exercise ability [4]. VR-based breathing systems positively impact heart rate, respiratory rate, and SpO2 [12]. For patients with cystic fibrosis, VR helps achieve target heart rates and provides cardiovascular benefits [13]. It also induces hemodynamic and autonomic responses conducive to basic rehabilitation, allowing patients to reach their target heart rate reserve [14].

VR has further demonstrated benefits in reducing anxiety and depressive symptoms in cardiac patients [15]. Immersive VR helps distract patients from discomfort such as dyspnea and fatigue and provides a sense of disconnection from clinical settings, improving psychological well-being [16]. It can reduce peri-procedural anxiety and foster positive beliefs [17]. This is especially relevant for patients with COPD, who often experience depression, anxiety, and social isolation [18].

One of the critical advantages of VR in rehabilitation is enhanced motivation and adherence. By making sessions more enjoyable and engaging, VR increases satisfaction and compliance [16]. The immersive experience elevates user interest and enjoyment, while digital rewards have been found to significantly improve attendance and adherence [2]. Patients perceive VR as convenient, affordable, and effective, empowering them to adopt healthier lifestyles and better manage their conditions [19].

Materials and Methods. The research reported in this narrative review followed the checklist of the PRISMA (Figure 1). To fit the answer to the question on the effect of virtual reality (VR) on cardiopulmonary rehabilitation, a wide-ranging search in suppliers of electronic databases, including Scopus, ResearchGate, Google Scholar, and PubMed, was done. Each database was used with search strategies specific to the database but complemented by the manual checking of bibliography and the use of expert recommendation.

The research studies were included regardless of the research design, but they had to be published in the English language between 2014 and 2024. The human studies with VR in the cardiopulmonary rehabilitation area were searched; those related to animal studies and pathologies that do not belong to the cardiopulmonary field, neurological disorders, and so forth were not included.

The keywords that were used in searching included: Physical Rehabilitation, Virtual Reality, Cardiopulmonary disorders, Physiotherapy intervention, VRBT, Cardiac rehabilitation, Exercise therapy, CVD, Respiratory tract disease, Physiotherapy rehabilitation and Augmented Reality. In the case of PubMed, the Medical Subject Headings (MeSH) terms were used in pairs, that is, the pairs of keywords: technology-related and disease-related keywords.

The only works that were taken into consideration were original peer-reviewed research articles. Abstracts of conferences, opinion articles, study protocols, and non-original study articles were excluded. They removed duplicates and performed eligibility screening using titles and abstracts by a single reviewer, and full text in case of need. The reviewers could make a final decision concerning inclusion based on their consensus, and the extraction of the data was done by one reviewer with some advice given by the other.

Results. After the complete literature search, 278 articles were detected after eliminating duplicates. Titles and abstract screening excluded 180 articles, and the remaining 64 articles were reviewed for the full text. Of these, 57 were eligible to be included in the study. The resultant studies consisted of 14 randomized controlled trials (RCTs), 6 systematic reviews with meta-analyses, 5 systematic reviews, 12 clinical trials, 13 qualitative reviews, 2 scoping reviews, 2 observational studies and one mixed-methods, feasibility, and exploratory study.

Discussion. The major aim of this narrative review was to investigate how Virtual Reality (VR) is used in cardiac and pulmonary rehabilitation programs, and to evaluate how its implementation influences essential physical characteristics and health recovery outcomes. By summarizing recent research findings on the development of VR as a technological adjunct or alternative to conventional rehabilitation methods, this paper highlights key benefits of its application.

As demonstrated by a systematic review with meta-analysis by Rubia et al. [10], 812 participants from 7 studies indicate that non-immersive virtual reality (niVR) active videogames significantly enhance aerobic capacity and cardiovascular endurance during cardiac rehabilitation (SMD=0.65; 95 % CI: 0.11-1.18; p=0.019) and an average 49.32-meter gain in 6-Minute Walking Test distance (95 % CI: 41.9-56.7; p<0.001), both exceeding the minimally clinically important difference for this measure.

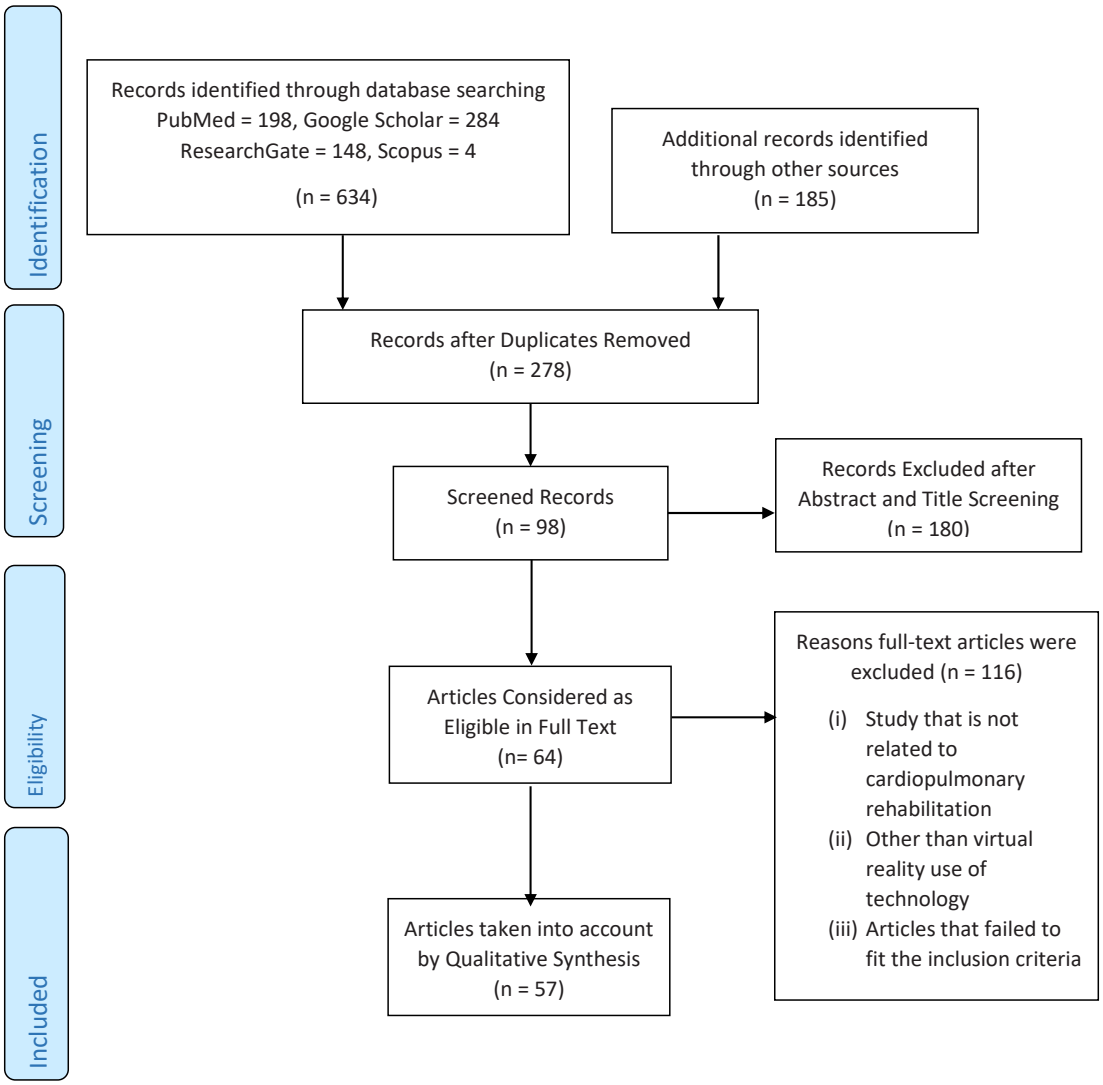

Figure 1. *PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the literature review [20]*

A randomized controlled trial by Gulick et al. [7], involving 72 cardiac rehabilitation patients, compared the impact of an intervention program with a control group using the 6-Minute Walk Test (6MWT) as the primary outcome. Both the intervention and control groups exhibited improvements in 6MWT distance following the rehabilitation period. The control group improved by an average of 298 feet, while the intervention group improved by 340 feet.

A feasibility cohort study by Groenveld et al. [21] of home-based VR rehabilitation in post-COVID-19 patients showed statistically significant improvements in 6-MWT distance (median +29.8 m, p=0.01), grip strength (+2 kg, p=0.02), 30-Second Chair Stand Test (+4 repetitions, p=0.03), lower extremity strength (+10-15 %) and reduced fatigue on the Borg scale (p=0.03).

According to a systematic review by Abrub et al. [22], exercise capacity improvements were noted across trials, with peak quadriceps force increasing more substantially in the intervention group (3-80 % range) compared to controls, and significant gains in gait speed ($p<0.001$), timed up-and-go test (p=0.004), knee extension (p=0.042) and improved Short Physical Performance Battery scores (p=0.004).

In a 12-week randomized controlled trial, Mologne et al. [23] showed substantially higher VO_2 max gains, and only the IVR group achieved significant systolic blood pressure reduction (~2.3 mmHg). Despite 31.8 % shorter session duration, IVR participants reported higher satisfaction (PACES 4.45±0.22) and perceived lower exertion while achieving superior results.

In a case-control study, Lacraru et al. [24] demonstrated that experimental and ambulatory intervention groups achieved significant VO_2max improvements in heart failure patients and ischemic heart disease patients. LDL-cholesterol decreased approximately 30 % in the experimental group. Quality of life improved, anxiety and depression decreased, and

nicotine use was reduced by 50 % in the intervention group.

A feasibility study of adaptive control of cardiorespiratory training in a VR hiking simulation by Lima et al. [25] demonstrated that adaptive VR maintained participants more effectively in target heart rate zones compared to non-adaptive VR. Adaptive VR achieved a significantly higher percentage of time in the target HR zone versus non-adaptive VR and showed a lower root mean square error from target HR, indicating superior exercise intensity control. Adaptive VR achieved greater time in light exercise with higher magnitude vector values, demonstrating an improved capacity to optimize and maintain appropriate cardiorespiratory training zones during VR-based rehabilitation.

A randomized controlled trial by Polat et al. [26] produced significantly greater improvements compared to aerobic training alone. The VR group showed statistically significant gains in 6-minute walk test distance, reduced fatigue severity (Fatigue Severity Scale), and improved quality of life (EQ-5D Index and EQ-5D-VAS Scale), with higher treatment satisfaction scores, suggesting that VR-augmented aerobic training is effective for managing fatigue and improving functional capacity in fibromyalgia patients.

A randomized controlled trial of Kinect-based mixed reality (VM) exercise training in Korean firefighters by Kim et al. [27] demonstrated significant improvements in cardiorespiratory and muscular function over 8 weeks. VO_2peak increased by approximately 9 % from 42.2 to 45.9 mL/kg/min, exceeding the recommended safety threshold of 45 mL/kg/min and achieving similar improvements to 12-week instructor-led programs within a shorter timeframe. In a pilot randomized controlled trial, Gieracha et al. [28] found that VR therapy effectively reduced symptoms of depression, anxiety, and stress in coronary artery disease patients.

A systematic review by Darabseh et al. [13] found that VR-based training produced similar improvements in FEV_1, forced breath techniques (FBT), and airway clearance when compared to traditional airway clearance techniques. Importantly, a greater duration of VR gameplay was significantly correlated with higher FEV_1 and vital capacity, suggesting that greater engagement with VR physiotherapy may enhance respiratory outcomes in individuals with cystic fibrosis.

A primary study by Azab et al. [5] found that combining virtual reality-based exercise with conventional chest physiotherapy significantly improved pulmonary function (FVC, FEV_1, FEV_1/FVC ratio), cardiopulmonary capacity (peak VO_2, lowest VE/VCO_2 slope), functional performance (6-MWT distance), and health-related quality of life compared to conventional therapy alone.

Despite encouraging results, limitations remain. Many studies have small sample sizes, heterogeneous designs, and a lack of long-term follow-up, limiting generalizability. Methodological concerns such as selection bias and limited blinding are also prevalent. There is insufficient evidence regarding VR's application in diverse or high-risk populations across various rehabilitation stages. Future research should focus on large-scale, multi-center randomized controlled trials with extended follow-up. Developing standardized VR protocols—including system types, duration, intensity, and outcome measures—is essential for cross-study comparisons. Moreover, comprehensive cost-effectiveness analyses are needed to evaluate the financial feasibility of VR interventions in rehabilitation settings.

Conclusions. Virtual reality (VR) treatment modalities have shown considerable potential to improve cardiovascular as well as pulmonary rehabilitation outcomes. Physical measures of improvement, including the 6-minute walk test (6MWT), metabolic equivalents (METs), and oxygen saturation (SpO_2), have been measured in studies. It is also quite remarkable that VR used during rehabilitation has helped reduce the deterioration of pulmonary functions and functional independence after coronary artery bypass surgery, and even improve symptoms such as fatigue and dyspnea in patients with COVID-19. Despite a speculative meta-analysis showing that VR does not always exhibit superior performance to standard cardiac rehabilitation in terms of enhancing exercise capacity, it can produce similar physiological effects. VR also sustains heart rate reactions within recommended exercise load levels and has practical advantages and faster recovery rates, not to mention a potentially decreased length of hospital stay. In patients with pulmonary problems, VR helps with breathing awareness and relaxation procedures by using biofeedback. In summary, VR has demonstrated the likelihood of enhancing quality of life (QoL) in different patient groups. To sum it up, this review highlights VR as an innovative, active, and more accessible method of supporting both the physical and psychological components of cardiopulmonary rehabilitation.

Final Statements

Prospects for Further Research- The future studies should focus on the creation of specific VR content targeting cardiac patients and the creation of effective models of VR implementation in common rehabilitation practices.

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Consent For Publication Yes, we want to publish our article.

Conflict of Interest-There is no conflict of interest.

Compliance with Ethical Standards. Since this is a narrative evaluation, neither direct human nor animal participation is necessary. As a result, neither formal ethical approval nor informed permission were necessary. Every process used in this evaluation complied with recognized guidelines for ethical research conduct, reporting accuracy, and academic integrity. Regarding the study's content, the authors declare that they have no conflicts of interest.

Use of Artificial Intelligence. Language models and other artificial intelligence methods were not utilized. They weren't utilized for data creation, extraction, analysis, interpretation, or conclusion-making. The authors created and confirmed all of the fundamental scientific information, search tactics, findings interpretation, and final conclusions.

Primary Data and Materials. No new primary data was created for this narrative review; it is solely based on already published literature. To guarantee transparent and organized reporting, it adhered to the PRISMA checklist. Several electronic databases, including Scopus, ResearchGate, Google Scholar, and PubMed, were thoroughly searched. In addition to manual reference checking and professional advice, each database was searched according to its own methodology. Research published in English between 2014 and 2024 was included. Included were only original, peer-reviewed studies that looked into the application of virtual reality in cardiac rehabilitation.

Excluded were studies using animals, research on neurological or non-cardiopulmonary conditions, abstracts, opinion papers, protocols, and other non-original works. A reviewer examined titles and abstracts for eligibility after eliminating duplicates, and full-texts were evaluated as needed. Final inclusion was decided by consensus, and data extraction was carried out by one reviewer and verified by another. The sources listed here make the materials used in this review publicly available.

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Ефективність віртуальної реальності у пацієнтів з кардіопульмональними розладами. (Огляд літератури)

Maitrayee Agrawal[1], Tanya Gujral[1], Chhavi Kumar Sharma[2], Shahiduz Zafar[1], Mohammad Sidiq[3]

[1]School of Allied Health Sciences, Galgotias University, Greater Noida, 203201, UP, India

[2]Mangalayatan University, Beswan Aligarh, U.P, India

[3]Tishk International University, Erbil, Iraq

Резюме

Вступ. Кардіопульмональні розлади, включаючи хронічне обструктивне захворювання легень (ХОЗЛ), серцеву недостатність та стани після кардіохірургічних втручань, суттєво впливають на фізичні можливості пацієнтів та якість їхнього життя. Традиційні програми реабілітації часто стикаються з проблемами, такими як низька мотивація та недостатнє дотримання рекомендацій. Віртуальна реальність (VR), завдяки своїм занурювальним та інтерактивним функціям, стала потенційним інструментом для підвищення залученості пацієнтів та покращення клінічних результатів у кардіопульмональній реабілітації.

Мета. Цей наративний огляд має на меті дослідити ефективність VR-інтервенцій у реабілітації пацієнтів із кардіопульмональними розладами шляхом аналізу сучасних доказів та клінічних застосувань.

Матеріали та методи. Було проведено комплексний пошук літератури у базах даних PubMed, Scopus та Google Scholar. Було відібрано дослідження, що зосереджуються на використанні VR у пацієнтів із кардіопульмональними станами, включаючи рандомізовані контрольовані дослідження, спостережні дослідження та пілотні випробування, опубліковані англійською мовою. Основними оцінюваними показниками були фізична працездатність, функція дихальної системи, психологічний стан та дотримання рекомендацій.

Результати. Огляд свідчить, що програми реабілітації на основі VR можуть покращувати толерантність до фізичного навантаження, функцію легень та психологічні показники, такі як тривога та депресія. VR також демонструє перспективи у підвищенні мотивації та дотриманні рекомендацій, особливо у домашній та дистанційній (телереабілітаційній) формах. Незважаючи на позитивні тенденції, різноманітність у дизайні досліджень, VR-модалях та показниках ефективності обмежує можливість остаточних висновків.

Висновки. VR є перспективним доповненням до традиційних стратегій кардіопульмональної реабілітації. Вона пропонує новий підхід до залучення пацієнтів та покращення функціонального стану. Проте необхідні більш стандартизовані, великомасштабні дослідження для підтвердження її ефективності та розробки клінічних протоколів для широкого застосування.

Ключові слова: *віртуальна реальність, кардіопульмональна реабілітація, ХОЗЛ, серцева недостатність, фізичне тренування, залученість пацієнтів, телереабілітація*

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