**Short Research Article**

# The Application of Immersive Virtual Reality in Occupational Therapy-based Pulmonary Rehabilitation Program: A Mixed-method Study


ABSTRACT

## Introduction

The management of chronic respiratory conditions critically relies on Pulmonary Rehabilitation (PR). Traditional PR programs often encounter obstacles in patient engagement and adherence. To overcome these issues, immersive virtual reality (VR) technology is being explored. Immersive VR, experienced through a head-mounted display, provides an interactive simulated environment. Its integration into occupational therapy (OT) PR programs holds the potential to boost the effectiveness of rehabilitationand patient experience.

## Objective

This study aimed to probe the effects of VR-based training on PR patients' psychological well-being, training engagement, adherence to breathing control exercises, and sense of security. The assessment of these outcomes is intended to ascertain the potential benefits of VR in augmenting PR efficacy.

## Method

A mixed-method, single-group design was adopted, involving a one-week trial with daily half-hour VR sessions. Pre-post assessments, incorporating qualitative and quantitative approaches, were conducted for data collection and analysis. Quantitative measures assessed functional capacity (Barthel Index-Dyspnea; BI-D), psychological well-being (Hospital Anxiety and Depression Scale; HADS), and symptom assessment (Shortness of Breath Questionnaire; SOBQ and Chronic Respiratory Disease Questionnaire; CRQ). Qualitative analysis hinged on semi-structured interviews, with thematic analysis used to discern underlying themes and patterns from participant experiences.

## Results

The study, conducted from August to November 2023, involved 10 in-patients of the PR program from a rehabilitation hospital, aged 67 to 91, and diagnosed with COPD, ~~Covid~~COVID-19, and lung cancer. Quantitative results showed significant improvements across all measures, including BI-D ($p<0.001$; MD -19.60), HADS-Anxiety ($p<0.001$; MD -4.60), HADS-Depression ($p<0.001$; MD-3.90), SOBQ ($p=0.002$; MD-19.85), CRQ-Dyspnea ($p=0.002$; MD+1.01), CRQ-Emotion ($p=0.004$; MD+0.89), CRQ-Management ($p=0.010$; MD+1.2), and CRQ-Fatigue ($p<0.001$; MD+1.16). In qualitative analysis, noteworthy enhancements in psychological well-being were reported by all participants. VR resulted in relaxation, stress reduction, and distraction, highlighting a positive mental health impact. The captivating and motivating nature of the simulated environment led to increased engagement and improved breathing exercise compliance. VR also offered a secured platform for practicing breathing control, contributing to a enhanced rehabilitation experience.




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**Conclusion**

Merging VR technology into OT services for PR yields positive results. VR enhances psychological well-being, training engagement, and exercise compliance, while also providing a secure virtual environment. Future research ~~could~~should explore ~~more~~a greater variety~~variability~~ of VR training programsto meet a wider range of therapeutic needs.

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Keywords: Virtual Reality, Rehabilitation, COPD, Occupational Therapy

# 1. INTRODUCTION

## 1.1 Development of Virtual Reality in Rehabilitation

The advent of Virtual Reality (VR) technology in the realm of rehabilitation has heralded a new epoch of therapeutic possibilities within healthcare. Tracing its roots back to the 1980s, VR initially made its mark with basic two-dimensional visuals and auditory cues, tailored primarily for hand function training through nascent hand gesture interfaces [1]. These early forays, despite their limitations, sparked a revolution that would profoundly shape the future of rehabilitative care.

Advancing through the decades, the field of VR has witnessed an extraordinary surge in technological advancement and clinical application. From the 1990s to the 2020s, a robust body of research—spanning from proof of concept to comprehensive reliability, validity studies [2], and the meticulous validation of VR-induced movement kinematics [3]—has established VR as a formidable instrument in the rehabilitation toolkit.

Today, the embodiment of VR in rehabilitation is both sophisticated and sensory-rich, offering an array of high-definition 3D visuals, immersive auditory environments, and nuanced haptic feedback [4]. Modern VR platforms, now more affordable and user-friendly, provide patients with engaging therapeutic experiences that were once beyond reach. Recognizing this advancement, the Occupational Therapy Practice Framework: Domain and Process—Fourth Edition has embraced VR as a recommended modality for occupational therapists [5].

The application of VR extends through a myriad of rehabilitation disciplines—from aiding children with developmental delays to enhancing cognitive functions in the elderly, and from supporting psychiatric treatment to facilitating neurological recovery [6]. Yet, its utilization within pulmonary rehabilitation remains surprisingly nascent. Despite VR's potential to transform various aspects of healthcare, its adoption in respiratory therapy has not been as widespread or deeply explored.

## 1.2 Current Challenges in Pulmonary Rehabilitation

The realm of pulmonary medicine is frequently tasked with addressing the complexities of Chronic Obstructive Pulmonary Disease (COPD), a condition with extensive global prevalence. Characterized by debilitating respiratory symptoms such as dyspnea, chronic coughing, and sputum production, COPD's impact is compounded by the psychological distress it engenders [7]. A significant proportion of patients experience comorbid anxiety and depression, with prevalence rates ranging from 21% to 96% for anxiety and 27% to 79% for depression [8]. These mental health challenges not only diminish the quality of life but also exacerbate the physical manifestations of the disease, underlining the importance of a holistic treatment paradigm that fuses psychological support with physical rehabilitation [9].

Pulmonary Rehabilitation (PR) has long been a fundamental component in managing chronic respiratory conditions. It has demonstrated efficacy in improving exercise tolerance and life quality. However, traditional PR's impact on mental ~~distresses~~distress remains unexplored, and it faces additional hurdles including sustaining patient motivation, ensuring adherence, and providing broad accessibility [10]. These challenges highlight the need for innovative and multifaceted strategies that address both the psychological aspects of COPD and enhance engagement in rehabilitation.

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VR emerges as a possible adjunct to traditional PR owing to its potential to overcome existing barriers [11, 12]. The immersive nature of VR can enhance patient motivation and engagement, offering a compelling and interactive therapeutic environment. Customizability is another strength of VR, allowing rehabilitation programs to be tailored to the individual needs and preferences of each patient, while also providing immediate feedback and facilitating progress tracking. Moreover, VR can overcome physical and geographic barriers to access, enabling patients to participate in rehabilitation exercises without the constraints of their physical condition.

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## 2. MATERIALS & METHODS

~~In an effort to~~To enhance in-patient pulmonary rehabilitation services, an innovative intervention involving the Oculus Quest 2, a VR device notable for its high-fidelity sound and high-resolution display, was introduced. This setup was further supported by a high-performance gaming laptop, a robust Wi-Fi network to ensure uninterrupted streaming~~,~~ and hygienic face covers to maintain sanitary conditions.

~~Prior to~~Before the VR sessions, participants received a comprehensive orientation regarding the VR equipment and were psychologically prepared for the immersive experience. The VR environments were designed to induce relaxation and included a variety of serene landscapes such as tranquil maple leaf forests, sunset safaris, and peaceful coastal vistas. Additional VR settings featured idyllic beaches, dawn-lit forests, and expansive galaxies, all curated to foster a calming atmosphere conducive to PR. The interactivity within the VR experience was a critical component; participants could interact dynamically with the environment by initiating the growth of flora, encountering lifelike wildlife, and customizing environmental variables such as time of day and weather. An integrated breathing guide prompted patients to align their breathing with the visual expansion and contraction of a virtual lotus, facilitating targeted respiratory exercises. Throughout the sessions, therapists monitored the VR content via a gaming laptop, providing real-time supervision and support.

The pilot study involved a cohort of 10 in-patients from the pulmonary rehabilitation program, characterized by a balanced gender distribution and ages ranging from 67 to 91 years, with an average age of 79. The majority of the participants were diagnosed with COPD, with the remainder comprising individuals diagnosed with COVID-19 and lung cancer who were suitable for rehabilitative care. Participants' characteristics ~~were~~ areprovided in **Table 1**. Each participant underwent 30-minute VR sessions daily over a span of five consecutive days. To evaluate the impact of the VR intervention, semi-structured interviews were conducted, and participants' responses were recorded alongside results from standardized assessments within the PR program.

**Table 1. Demographic profile of participants**

| Participant Code | Age | Gender | Diagnosis |
|---|---|---|---|
| P1 | 80 | M | Covid-19 |
| P2 | 84 | M | COPD |
| P3 | 82 | F | COPD |

| | | | |
|---|---|---|---|
| P4 | 80 | F | Lung Cancer |
| P5 | 70 | M | COPD |
| P6 | 67 | F | COPD |
| P7 | 77 | F | COPD |
| P8 | 88 | M | COPD |
| P9 | 91 | F | Covid-19 |
| P10 | 71 | M | COPD |

## 3. RESULTS

### 3.1 Psychological Well-being

*"I have been in a wheelchair for a long time and never expected that I would be able to walk around these beautiful scenes again." – P5*

One key aspect examined was the impact of VR on participants' psychological well-being. Data gathered from semi-structured interviews revealed that the VR experiencesignificantly enhanced participants' mental states, with many describing the sessions as extraordinary and unlike anything they had previously encountered. The immersive VR environments, which featured breathtaking landscapes and realistic animal interactions, evoked feelings of awe and joy. Moreover, VR allowed participants to transcend their physical limitations; testimonials highlighted the profound emotional impact, particularly noting the virtual ability to 'walk' again in picturesque settings. This aspect of the VR experience was crucial in not only improving mental well-being but also in reconnecting individuals with experiences they thought were lost, thereby enhancing their overall quality of life and providing substantial psychological relief.

### 3.2 Training Engagement

*"I am sick and constantly tired. I don't always manage to get out of my nursing bed and attend the gym session, but if I do, playing this is one of the biggest reasons." – P2*

This discussion underscores a prevalent challenge in pulmonary rehabilitation: maintaining consistent engagement with physical activity. The engaging nature of the VR experience effectively counteracted apathy and fatigue, emerging as a crucial motivator for participants to adhere to their exercise regime. Such engagement is critical, as regular training provided in PR is essential for managing pulmonary conditions. The interactive and gamified elements of VR transformed routine PR into enjoyable activities that patients anticipated eagerly, potentially enhancing their long-term commitment and, consequently, improving their health outcomes.

### 3.3 Breathing Control Exercise Adherence

*"You don't just do them by listening or reading (educational booklets)... but we could see it there (Guiding Lotus) and practice the techniques correctly." – P8*

This feedback highlights the distinct advantages of an immersive learning environment provided by VR over traditional instructional methods such as booklets or audio guides, which frequently fail to fully engage patients or ensure accurate practice of breathing techniques. VR's interactive visualizations serve as an effective and intuitive guide, enhancing patient engagement. By fostering an environment conducive to tranquility and concentration, VR significantly enhances the effectiveness of breathing exercises, which are fundamental to pulmonary rehabilitation. This adaptation not only improves the execution of these techniques but also potentially increases the overall efficacy of the rehabilitation process.

### 3.4 Sense of Security

*"I know I am safe in the virtual world and can practice freely within my own realm. I am also aware that my therapist is nearby… knowing that assistance is readily available makes me feel ~~secured~~secure." – P4*

Throughout the rehabilitation process, participants encountered no side effects, such as dizziness or nausea that are often associated with immersive technology. The virtual realm offered a secure setting for individuals to navigate and engage in breathing control exercises without the risk of physical harm. Additionally, therapists were readily available to provide support, ensuring a robust system of patient care. This holistic approach to safety and well-being is crucial in creating an optimal environment for rehabilitation, allowing patients to concentrate fully on their healing journey with confidence and comfort.

### 3.5 Quantitative Results

In addition to the subjective experiences reported by participants, a comprehensive set of clinical assessments demonstrated significant improvements across key metrics as shown in **Table 2**. Notably, the data revealed substantial progress in the Barthel Index-Dyspnea (BI-D) and the Hospital Anxiety and Depression Scale (HADS), indicating enhancements in both functional capabilities and psychological well-being. Furthermore, the positive trends observed in the Shortness of Breath Questionnaire (SOBQ) and the Chronic Respiratory Questionnaire (CRQ) substantiate the effectiveness of VR in improving the symptoms related to respiratory conditions. These findings provide robust support for the integration of VR technologies in therapeutic settings, affirming their benefit in enhancing overall treatment outcomes.

**Table 2.** Supplementary Assessment Results

| **Assessment** | **Pre-mean (S.D)** | **Post-mean (S.D)** | **P value** |
|---|---|---|---|
| BI-D | 43.40 (24.09) | 23.80 (16.90) | <0.001 |
| HADS-Anxiety | 9.70 (4.35) | 5.10 (2.85) | <0.001 |
| HADS-Depression | 9.20 (3.58) | 5.30 (3.27) | <0.001 |
| SOBQ | 59.60 (23.62) | 39.75 (18.74) | 0.002 |
| CRQ-Dypnea | 4.30 (0.84) | 5.30 (0.93) | 0.002 |
| CRQ-Emotion | 4.83 (0.83) | 5.72 (0.45) | 0.004 |
| CRQ-Management | 4.20 (1.35) | 5.41 (1.02) | 0.010 |

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|---|---|---|---|
| CRQ-Fatigue | 3.90 (0.76) | 5.06 (1.03) | <0.001 |

Note: Results of paired-t test were shown. Data tested for normal distribution with kolmogorov-smirnov&shapiro-wilk's test.

## 4. DISCUSSION

The integration of immersive VR technology within the PR program has yielded significant advancements. This innovative approach has led to notable improvements in patient well-being, increased engagement in training activities, enhanced adherence to breathing control exercises, and provided a sense of security during therapy sessions. As technology continues to evolve, it is anticipated that VR will play an increasingly crucial role in rehabilitation strategies, offering solutions that are specifically tailored to the unique needs of individual patients.

Additionally, the application of VR has shed light on a relatively unexplored aspect—its potential impact on psychological health and its influence on patient participation in PR. With limited research in this area, as evidenced by only two pertinent studies identified (Mazzoleni et al., 2014; Rutkowski et al., 2021), there appears to be substantial potential for VR to mitigate psychological barriers that frequently hinder patient engagement and ~~the~~ success of treatment. By disseminating the findings, this study contributes to a deeper understanding of the interplay between psychological health and PR, advocating for further research into how VR can help mitigate the adverse cycle of health deterioration associated with pulmonary conditions by simultaneously addressing physical and psychological well-being.

This endeavor not only underscores the viability of VR as an innovative therapeutic tool in pulmonary rehabilitation but also highlights its potential to revolutionize patient care. The insights gained from the deployment of VR technologies in clinical settings are intended to guide OTpractitionersin the effective utilization of digital tools. The knowledge and practical experiences derived from this integration encourage ongoing exploration and adoption of VR technology, potentially leading to more effective and personalized treatment modalities in healthcare.

This study has several limitations that future research should address to enhance its validity and generalizability. Firstly, the small sample size and absence of a control group limit the robustness of the findings. Future studies should expand participant numbers and include control groups to strengthen the inferential capabilities of the study. Secondly, the reliance on subjective reports for mental stress may introduce potential bias; incorporating objective measures such as heart rate variability would offer a more rigorous assessment. Lastly, the lack of long-term outcome data prevents evaluation of the sustained effects of VR interventions. It is recommended that future research includes longitudinal follow-ups to assess long-term benefits.

## 5. CONCLUSION

Suggestion:

The advent of virtual reality (VR) technology has opened new frontiers in various fields, including healthcare.The development and integration of VR in rehabilitation programs mark a pivotal advancement, offering new possibilities for patient care and setting the stage for further research to optimize and expand its applications.

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6. RECOMMENDATION

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**opportunities for Further Research**:

- The findings of this research could open up opportunities for further studies, such as exploring the use of VR in various types of occupational therapy or other health conditions.

7. CONSENT & ETHICAL CONCERN

Not applicable.

[Research involving the application of immersive virtual reality in an occupational therapy-based pulmonary rehabilitation program indeed requires ethical considerations].

1. **Informed Consent**: It is essential to ensure that all participants understand the purpose, procedures, potential benefits, and risks of the research. They must voluntarily give their consent after being fully informed about the study.
2. **Privacy and Confidentiality**: The personal and medical data of participants must be kept confidential.
3. **Participant Safety**: Ensure that the technology used is safe. (there are no harmful side effects from using VR devices, such as nausea or vertigo, and ensuring that the use of VR does not exacerbate the participants' health conditions).
4. **Potential Benefits and Risks**:Researchers must evaluate whether the potential benefits of the research outweigh the possible risks. All risks should be identified and minimized as much as possible.
5. **Involvement of Vulnerable Participants**:If the research involves vulnerable groups (e.g., patients with serious health conditions), special attention must be given to ensure that they are not exploited and that their participation is truly voluntary.
6. **Scientific Integrity and Reporting Results**:Data must be collected and reported honestly and transparently. Researchers should avoid data manipulation or misleading reporting.
7. **Conflict of Interest**:Researchers must disclose and manage potential conflicts of interest that might affect the design, outcomes, or interpretation of the research.
8. **Access to Technology**:Consideration should be given to equitable access to VR technology. Do all participants have equal access to the necessary equipment and support?

7. REFERENCES

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