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Virtual Reality as a Tool in Pulmonary Rehabilitation: A Narrative Review

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Abstract

Background and Objective: Pulmonary Rehabilitation (PR) has been widely accepted as a standard non-pharmacological intervention for the management of chronic lung diseases. The 21st century has ushered in the age of technology utilization in every field including healthcare. Virtual Reality (VR) is an emerging technology with several potential benefits in almost every aspect of PR, whether be it assessment or treatment. This narrative review aims to explore emerging evidence regarding the utilization of VR in PR, adding feathers to the emerging IR4.0.

Methods and Results: Literature related to the utilization of VR in PR was sourced from following electronic databases from inception until May 2020: Google Scholar, PubMed, PEDro, and Cochrane databases. A total of 14 articles that informed the content of the present review were identified. These articles were reviewed and summarized with an emphasis on how VR could be beneficial as an adjunct to the current practice of PR.

Conclusion: VR shows promising results as a beneficial intervention in the rehabilitation of patients with chronic lung diseases. However, further research with large, well-designed randomized controlled trials are needed to further support these shreds of evidence.

Keywords

Virtual Reality, Pulmonary Rehabilitation, Exergames

Introduction

Chronic respiratory conditions such as chronic obstructive pulomary disease (COPD), asthama and cystic fibrosis (CF) accounts for almost 7% of all deaths worldwide, and hence contribute to a significant global disease burden (Maio et al., 2006). Exercise based pulmonary rehabilitation (PR) is considered to be an effective management tool in wide range of patients suffering from various chronic respiratory diseases (Spruit et al., 2013). As part of integrated care, PR has shown to improve functional capacity and health related quality of life, while decreasing symptoms of fatigue, shortness of breath, and depression (McCarthy et al., 2015). Despite the strong evidences

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supporting exercise based PR for management of chronic respiratory conditions, the adherence to PR in patients is low. In COPD, PR has the adherence and completion rates of as low as 50% and 40%, respectively (Hogg et al., 2012). Some of the possible reasons for the low attendance and completion rates are identified as low motivation level, difficulties related to commute and lacking social support (Keating et al., 2011; Swisher et al., 2008).

Virtual reality (VR) technologies and active video games (AVG) have a potential to become a novel way of management and assessment in rehabilitation environment (Rizzo & Kim, 2005). VR is based on the application of three- dimensional camera or sensors placed on the body during exercise and a computer program which records the movement patterns. This is followed by the transfer of the data to a computer generated environment (Rutkowski et al., 2019). The unique attributes of VR technologies which provide increased levels of motivation through experiential and active learning among participants, provide a rationale for its use in rehabilitation (Rizzo & Kim, 2005). The use of VR and AVG have been shown to be an enjoyable form of intervention among various clinical conditions (Staiano & Flynn, 2014). Given the significant amount of evidence showing positive correlation between enjoyment and adherence to physical activity in healthy adults (Rhodes et al., 2009, 2015), it is likely that management tools that improve enjoyment of exercise can also improve the adherence to exercise.

In the current COVID-19 pandemic scenario, when a significant number of patients are not able to visit an outpatient PR program, VR technology can become an effective tool for home based rehabilitation and self care management among patients with chronic respiratory conditions. So, the objective of this narrative review is to shed some light on the potential role of VR and AVG as an adjunct to traditional PR in assessment and management of patients with chronic repiratory diseases. The primary aim of this review was to evaluate the effectiveness of VR and AVG for clinical outcomes, safety, patient enjoyment and adherence.

Methods

Electronic papers published from inception up to May 2020 were searched in Google Scholar, PubMed, PEDro, and Cochrane databases rigorously for Virtual Reality, Pulmonary Rehabilitation and Exergames. Randomized controlled and convenience trials were considered for evaluation that focussed on use of VR and AVG in PR. There was no restrictions on type of chronic respiratory condition and intervention protocols. Total 1020 articles were identified, retrieved, analyzed and interpreted and those which did not meet the above-stated criteria were excluded. Out of all, only 14 manuscripts met the inclusion criteria. The flowchart of the selection process is shown in Figure 1.

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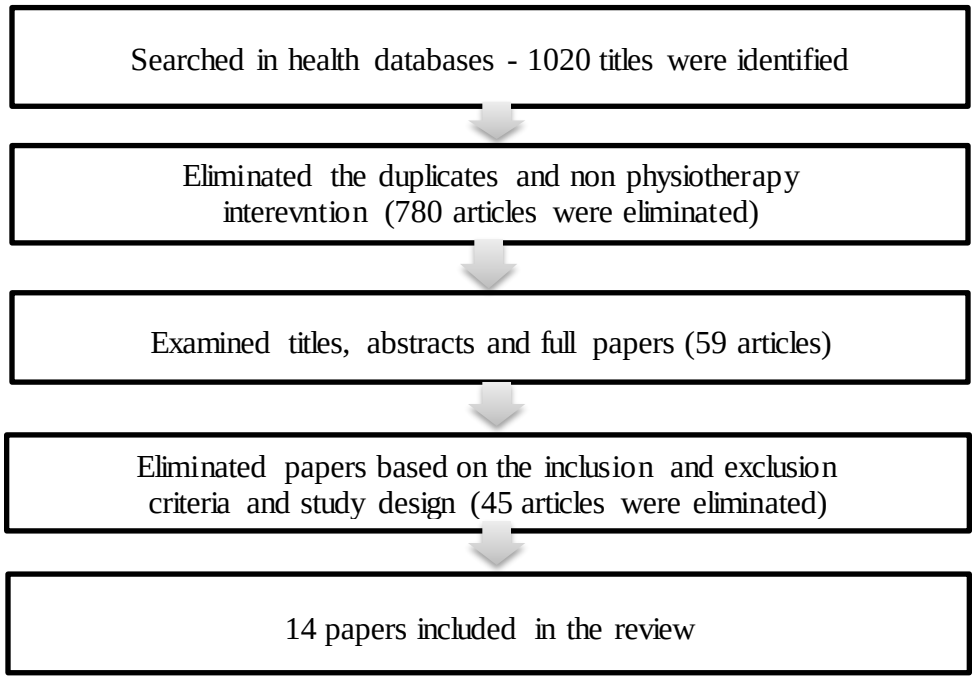
Figure 1. Selection process of articles for the review



Discussion

The studies included and analysed in this comprehensive narrative review supported the use of VR intervention in PR for patients with various respiratory conditions such as COPD, Duchenne muscular dystrophy (DMD), Non-small cell lung cancer **(**NSCLC), CF, Asthama, Interstitial Lung Disease (ILD) and Bronchiectasis (Freitas et al., 2019; Hoffman et al., 2017; Holmes et al., 2013; Mazzoleni et al., 2014; LeGear et al., 2016). Most studies included in this review used the Nintendo Wii (along with "Wii Fit" or "Wii Sports software") and Microsoft Xbox Kinect as VR technologies for PR.

The inculcation of novel technological trends in different areas of healthcare makes it possible to introduce adjuncts and alternatives to traditional medical treatments, an example of which is the increasing use of VR in management of various respiratory conditions. A study by Freitas et al (2019) conducted on 120 male individuals (60 with DMD and 60 without DMD) compared performance on a virtual task using interfaces with and without physical contact in order to identify functionality by using different devices in individuals with DMD. Participants were divided into three groups of 20 individuals each. All particiapnts performed a virtual task in all the three different interfaces: Kinect®, computer Touch Screen and Leap Motion. The results of this study showed that irrespective of the interface used, all participants improved performance through practice.

Two studies done by Hoffman et al. (2014; 2017), incorporated VR in management of patients with NSCLC. Out of these two studies, one study was a two-arm randomized controlled trial (RCT) used to examine the impact of a 6-week rehabilitative cancer related fatigue (CRF)

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self-management exercise intervention on 37 NSCLC participants compared with 35 control group participants receiving usual care from diagnosis to 6 weeks post-surgical hospital discharge. The results of this study showed that the particular exercise intervention (Wii walking and Wii balance exercises) for post-surgical NSCLC patients was feasible, safe, and highly acceptable showing positive changes in CRF self-management. Moreover, the exercise group's functional performance (physical and mental health scores) exceeded usual care and no adverse events were reported. Another study done on NSCLC patients was a single-arm design composed of 7 participants postthoracotomy performing light-intensity exercises using an efficacy-enhancing virtual-reality approach using the Nintendo Wii Fit Plus. The results of this study showed that the exercise intervention was feasible, safe, well tolerated, and highly acceptable showing positive changes in CRF self-management.

Another study included 10 patients with cystic fibrosis. They performed the Xbox Kinect™ exercise session involving repetitive cardiovascular-based interval training, comprising alternating sets of squat punches and jumping jacks using the Your Shape™ Fitness Evolved program. The results of the study concluded that training using the Xbox Kinect™ represents high intensity exercise for adults with CF and may be a suitable alternative to conventional exercise modalities used in PR (Holmes et al., 2013).

Mazzoleni et al (2014), included 40 participants with chronic respiratory conditions (COPD, ILD, restrictive chest wall disease, asthama and bronchiectasis) in their study. The Randomised Controlled Trial compared standard PR (20 patients, control group: CG), and PR + sessions of interactive videogame-aided exercises (20 patients, experimental group: EG). Lung and respiratory muscle function, arterial blood gases, exercise capacity, dyspnoea, health status and health-related quality of life (HRQL) and emotional response were measured before and after PR. The results of this study showed that exercise capacity, dyspnoea and HRQL significantly improved in both groups after the PR, whereas the EG showed a greater improvement in six-minute walk test and transitional dyspnoea index than the CG. No difference in psychological status or acceptability of PR was observed between the two groups.

A number of studies included in this review focussed on the COPD patients (Jung et al., 2020; Moorhouse et al., 2019; Liu et al., 2016; Rutkowski et al., 2019; Wardini et al., 2013; Colombo et al., 2019; LeGear et al., 2016). The overall results of these studies showed that VR and AVG improved the physical fitness and exercise tolerance, overall mobility, level of motivation and self confidence and decreased symptoms such as dyspnea in patients with COPD. The interventions using VR were safe, feasible and widely accepted among the participants and were also enjoyed by them as an adjunct to PR. The key characteristics of these studies are stated in table 1.

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Table 1. Key characteristics of included studies

Reference	Sample	Study design	Test	Intervention	Results
Freitas et al., 2019	120 male individuals took part in this study: 60 with DMD and 60 without DMD in the control group (CG)	Randomized controlled trial	A one-way ANOVA, Regression analysis	Participants were divided into three groups of 20 individuals each and they performed a virtual task in three different interfaces: Kinect®, computer Touch Screen and Leap Motion®. This was a cross over design in which all participants used all devices.	Regardless of the interface used , all participants improved performance through practice.
Tekerlek et al., 2017	7 patients with chronic respiratory disease	Convenience sampling	Students *t* test, Pearsons chi square	20 min ET session on cycle ergometer. 3 groups: ET only, ET with VR, ET with music	Higher satisfaction with ET+ music, dissatisfaction with VR
Hoffman et al., 2017	37 NSCLC participants compared with 35 control group participants	Randomized controlled trial	Effect sizes were calculated using Cohen's d mean difference methodology	Duration of walking started at 5 minutes each day for 5 days during week 1 and continued to increase by 5 minutes per day each week with the goal of walking with the Wii of 30 minutes per day during week 6.	Exceeded goals for recruitment , retention, adherence, and acceptability, reduced CRF severity and fatigability, improved functional performance
Hoffman et al., 2014	7 participants postthoracotomy for NSCLC	Convenience sampling	Trend lines were used to analyze data from baseline presurgery and postsurgery	Performed light-intensity exercises using an efficacy-enhancing virtual-reality approach using the Nintendo Wii Fit Plus	No adverse events, high acceptability scores on conclusion. CRF scores also improved
Holmes et al., 2013	10 Participants with CF	Convenience sample method	Wilcoxon tests.	20 min of exercise using the Xbox Kinect	Training using the Xbox Kinect™ may be a suitable alternative to conventional exercise modalities because it represents high intensity exercise for adults with CF

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Jung et al., 2020	10 elderly COPD patients	Purposive sampling	Thematic analysis	Eight-week patient trial using an innovative VR pulmonary rehabilitation programme	This study demonstrated that remotely supervised VR-based PR could help to overcome current issues and limitations
Mazzoleni et al., 2014	(20 patients, control group: CG), (20 patients, experimental group: EG)- chronic respiratory diseases.	Randomised controlled trial	A Student's t-test was used to evaluate differences between the two groups. A one-way Analysis of Variance (ANOVA) was used to evaluate changes of outcome measures before and after treatment.	In the last week of PRP patients of EG underwent 7 additional 1-h daily sessions of Wii Fit Plus_ exercises	VR training was more effective for improving some parameters of exercise tolerance and dyspnoea, did not result in better psychological status nor it was better accepted than the standard PRP in patients with chronic respiratory diseases.
Moorhouse et al., 2019	Ten elderly COPD patients	Convenience sampling, Qualitative study	Thematic analysis	themes identified were including seven benefits: increased strength and mobility, compliance, motivation, quality of life, improved self-management, satisfaction, and confidence,	The findings indicate patients using VR for PR are more compliant to conducting their exercises because VR motivates them and increases their confidence in physical activity and self-management of their condition.
Liu et al., 2016	Sixty-one patients with COPD and 48 healthy elderly	A cross-sectional observational study	independent t-tests or two independent samples tests; The intra-class correlation coefficient (ICC)	Patients performed two overground 6MWTs and healthy elderly performed one overground test.	The GRAIL is a promising system to assess the 6MWD in patients with COPD and healthy elderly.
Rutkowski et al., 2019	68 patients with COPD	Randomised controlled trial	Wilcoxon test for within-group analysis and the Mann–Whitney U test for between- group analysis	Group I included 34 patients – non-participants in Kinect training. Group II included 34 patients – participants in Kinect training. The Xbox 360 and Kinect motion sensor were used to carry out virtual reality training	VR training in patients with COPD seems to be a practical and beneficial intervention leading to improved mobility and physical fitness.

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Rutkowski et al., 2020	106 patients with COPD	Randomised controlled trial	Linear-mixed effects analysis	34 patients participated in a traditional PRP including endurance exercise training (ET), 38 patients participated in traditional PR, including both endurance exercise training and VR training (ET+VR) and 34 patients participated in PRP including VR training but no endurance exercise training (VR).	Results suggest that PRP supplemented with VR training is beneficial intervention to improve physical fitness in patients with COPD.
Wardini et al., 2013	Thirty-two patients with severe COPD	Purposive sampling	Means and SD were calculated and paired *t* tests were performed to determine differences	Patients were provided an opportunity to individually engage in VGS sessions three times weekly, varying with length of stay	Moderate exercise using a VGS was safe, feasible and enjoyed as an adjunct to inpatient PR. This modality may encourage patients to maintain physical activity after PR
Colombo et al., 2019	Nine stable patients with COPD or bronchial asthma	Purposive sampling	test of Kolmogorov-Smirnov	VR-based system for patients with respiratory diseases performing endurance exercise training on a cycle-ergometer	Excellent usability and high acceptability after a single session of exercise
LeGear et al., 2016	10 COPD patients	Randomized cross-over study	Mean difference and Confidence Interval	Participants completed two 15- min exercise interventions in a single session, with a washout period of 30 min in-between. The interventions were an experimental Wii intervention and a traditional treadmill intervention.	Gaming technology can provide an exercise program that has similar cardiovascular demands to traditional PR for patients with COPD

Conclusion

The present review demonstrated that VR and AVGs, as an adjunct to PR among patients suffering with chronic respiratory conditions, were relatively safe, could enhance exercise capacity and improve health related quality of life. The participants in these included studies generally enjoyed VR based exercises with improved levels of adherence to PR. VR can also serve as a useful clinical tool for assessment of outcome measures in PR, such as 6 minute walk distance. Future studies can explore the effects of different types of VR based exercises to create more effective interventions program for PR. Studies can also be done to analyse long term effects of VR based

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intervention on different outcome measures such as strength training or airway clearance in chronic respiratory diseases.

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