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Research Article

Immediate Effect Of High-Frequency Chest Wall Compression On Oxygen Saturation And Minute Ventilation In Patients With Pulmonary Fibrosis

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ABSTRACT

Pulmonary fibrosis is a chronic, progressive interstitial lung disease marked by lung scarring, impaired gas exchange, and reduced lung compliance. Despite advancements in therapeutic options, managing pulmonary fibrosis remains challenging. This study explores the immediate effects of high-frequency chest wall vibration (HFCWV) on oxygen saturation (SpO_2) and minute ventilation in patients with pulmonary fibrosis. Using a pre-and-post experimental design, 40 participants received a single 20-minute session of HFCWV. Results demonstrated significant increases in SpO_2 (mean increase of 3%) and minute ventilation (mean increase of 0.7 L/min). Cardiovascular parameters, including heart rate and respiratory rate, remained stable, underscoring the safety of the intervention. These findings suggest that HFCWV may serve as an effective adjunct therapy in pulmonary rehabilitation programs. Further studies are recommended to evaluate long-term outcomes and its integration into clinical practice.

Keywords- oxygen saturation, cardiovascular parameters, pulmonary fibrosis, pneumonia

Introduction

Pulmonary fibrosis is a debilitating respiratory condition characterized by thickening and scarring of the lung parenchyma, leading to decreased lung elasticity, impaired oxygen diffusion, and chronic hypoxemia. Patients often experience dyspnea, fatigue, and reduced functional capacity, which significantly affect their quality of life. Conventional treatments, including pharmacotherapy, oxygen supplementation, and pulmonary rehabilitation, offer limited symptomatic relief, particularly in advanced stages.

High-frequency chest wall vibration (HFCWV) is a non-invasive therapy initially developed to enhance mucus clearance in conditions like cystic fibrosis. Recent studies suggest that HFCWV may also improve lung compliance, ventilation efficiency, and oxygenation in non-mucus-producing diseases, such as pulmonary fibrosis. However, evidence on its immediate effects on respiratory parameters in this population is scarce. This study aims to evaluate the immediate impact of a single session of HFCWV on SpO_2 and minute ventilation in patients with pulmonary fibrosis.Idiopathic pulmonary fibrosis (IPF) is the most common idiopathic interstitial pneumonia, with a prevalence of 14–63 cases per 100,000 people in the US [1, 2]. Among those over age 65, IPF affected as many as 495 individuals per 100,000 in 2011 [3]. IPF is a devastating, progressive disease characterized physiologically by declining lung function [4]. Median survival ranges from 3 to 5 years post-diagnosis [5–7]. Key symptoms of IPF include dyspnea, cough, and fatigue. Exacerbations—acute and clinically significant deteriorations that occur without warning and without a known cause—make the clinical course of the disease less predictable [4, 8]. As IPF progresses, dyspnea leads to severe limitations in activity, and IPF patients experience significant negative impacts on their social roles and emotional well-being [9]. Despite the significant toll of IPF on patients' health-related quality of life

(HRQOL), there is limited research on the HRQOL experiences of IPF patients [10]. The Patient-Reported Outcomes Measurement Information System (PROMIS) is an NIH Roadmap/Common Fund initiative that has advanced the use of a common set of patient-reported outcome (PRO) tools. PROMIS aims to develop ways to measure patient-reported symptoms, such as pain and fatigue, and aspects of HRQOL across a wide variety of chronic diseases and conditions [11]. The PROMIS network has developed item banks and short forms in multiple health domains for adults and children as well as a set of global health items and profile measures of varying lengths. The objective of this study was to obtain PROMIS scores for patients with IPF on eight health domains (depression, anxiety, pain interference, physical function, fatigue, satisfaction with social role participation, sleep disturbance, and dyspnea severity), with broad goals of augmenting the existing knowledge base about the HRQOL of individuals with IPF, enabling comparisons between IPF patients and people in the general U.S. population.

Methodology

This Study Design follows a pre-and-post experimental design to assess the immediate effects of a single session of HFCWV on oxygen saturation and minute ventilation in patients with pulmonary fibrosis. Baseline was measured to compared with post-intervention measurements to determine any significant changes. The study was conducted in a santosh hospital or rehabilitation center equipped with respiratory monitoring devices, ensuring a controlled environment for data collection. Sample size was a minimum of 40 participants was recruited for this study, determined based on power analysis to ensure sufficient statistical power. Sampling Technique was Convenience sampling was used to recruit participants from the hospital's respiratory outpatient department. Inclusion Criteria were Age: Adults aged 18 years and above, Diagnosis: Patients diagnosed with pulmonary fibrosis through clinical and radiological findings, Clinical Stability: Participants with stable pulmonary status, without any acute exacerbation or respiratory infections, Oxygen Saturation: Resting oxygen saturation (SpO_2) ≥ 88%, with or without supplemental oxygen, Consent: Patients willing to participate and provide informed consent and Exclusion Criteria were Respiratory Complications, Patients experiencing acute respiratory infections or exacerbation of pulmonary fibrosis, Individuals with other significant respiratory conditions (e.g., COPD, asthma) affecting study outcomes, Cardiovascular Disorders such as Presence of unstable cardiovascular conditions or recent cardiac events (e.g., myocardial infarction), Neurological or Musculoskeletal Limitations as Participants with conditions limiting their ability to tolerate vibration therapy (e.g., severe osteoporosis or spinal instability).

Procedure

1. Pre-Intervention Phase1- Participant Orientation and Familiarization, Provide participants with an overview of the study procedure, purpose, and expected outcomes. Demonstrate the HFCWV device to ensure participants understand how the intervention will be performed.
2.Positioning and Preparation:-The participants were seated in a semi-reclined position, ensuring comfort and optimal lung function. Ensure proper placement of the vibration device on the chest wall, as per the manufacturer's guidelines. Baseline parameters such as oxygen saturation, minute ventilation, respiratory rate, and heart rate will be measured.
3. Baseline Assessment:-Oxygen Saturation (SpO_2): Measured using a pulse oximeter at rest. Minute Ventilation: Measured with a spirometer to assess baseline ventilation.
2. Intervention Phase: High-Frequency Chest Wall Vibration (HFCWV)
1. Device Configuration: Frequency: Set at 12–15 Hz based on standard recommendations. Duration: 15–20 minutes. Mode of Application: The HFCWV device will be placed securely on the participant's chest wall to ensure effective transmission of vibrations.
2. Monitoring During the Session:-Continuous monitoring of oxygen saturation and heart rate to ensure participant safety. Regular communication with participants to monitor any discomfort or adverse reactions.
3. Post-Intervention Phase1.- Re-Measurement of Outcome Parameters:Oxygen Saturation (SpO_2): Measured immediately after the intervention. Minute Ventilation: Reassessed using a spirometer to determine any changes in respiratory efficiency.

Flowchart

The flowchart below outlines the key phases of the study, including recruitment, intervention, assessments, and follow-up, as well as the documentation of dropouts and safety measures.

1. Recruitment Phase:

- Screen 50 patients for eligibility based on inclusion/exclusion criteria.
- Obtain written informed consent from eligible participants.
- Total enrolled: 40 participants.

2. Pre-Intervention Assessment:

- Record baseline parameters:

a) Oxygen Saturation (SpO_2)
b) Minute Ventilation
c) Heart Rate
d) Respiratory Rate
- Position participants in semi-reclined posture.

3. Intervention: High-Frequency Chest Wall Vibration (HFCWV)
- Frequency: 12-15 Hz
- Duration: 15-20 minutes
- Participants monitored continuously for safety.

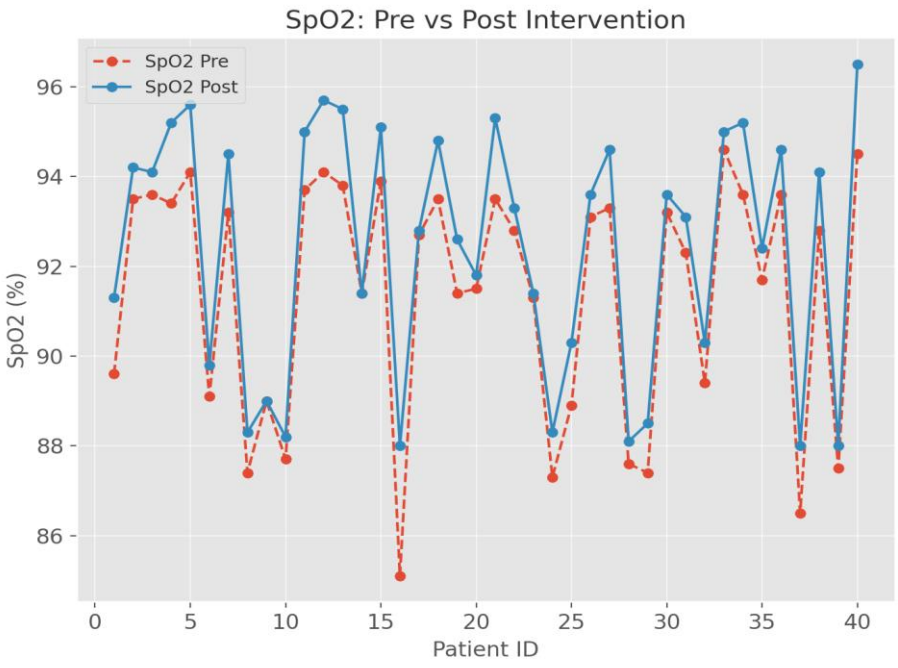
4. Immediate Post-Intervention Assessment:
- Re-assess:
a) Oxygen Saturation (SpO_2)
b) Minute Ventilation
- Record any adverse events or discomfort.

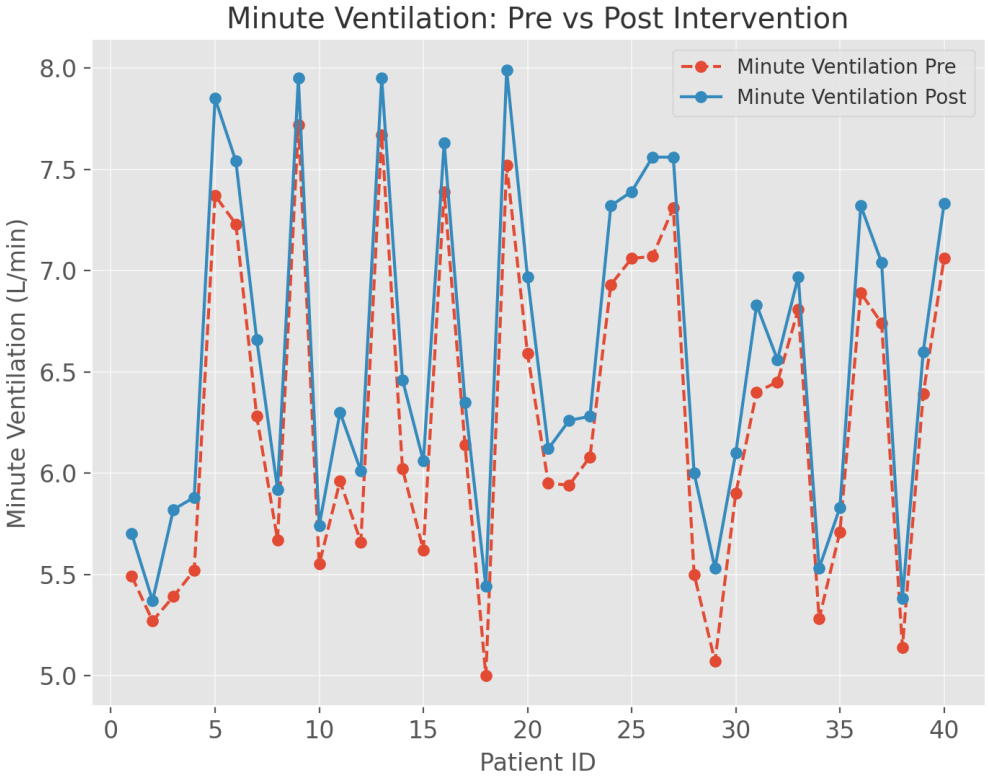
5. Documentation of Dropouts:
- If participants withdraw during the study, document reasons
- Example: 3 participants dropped out due to discomfort or fatigue.

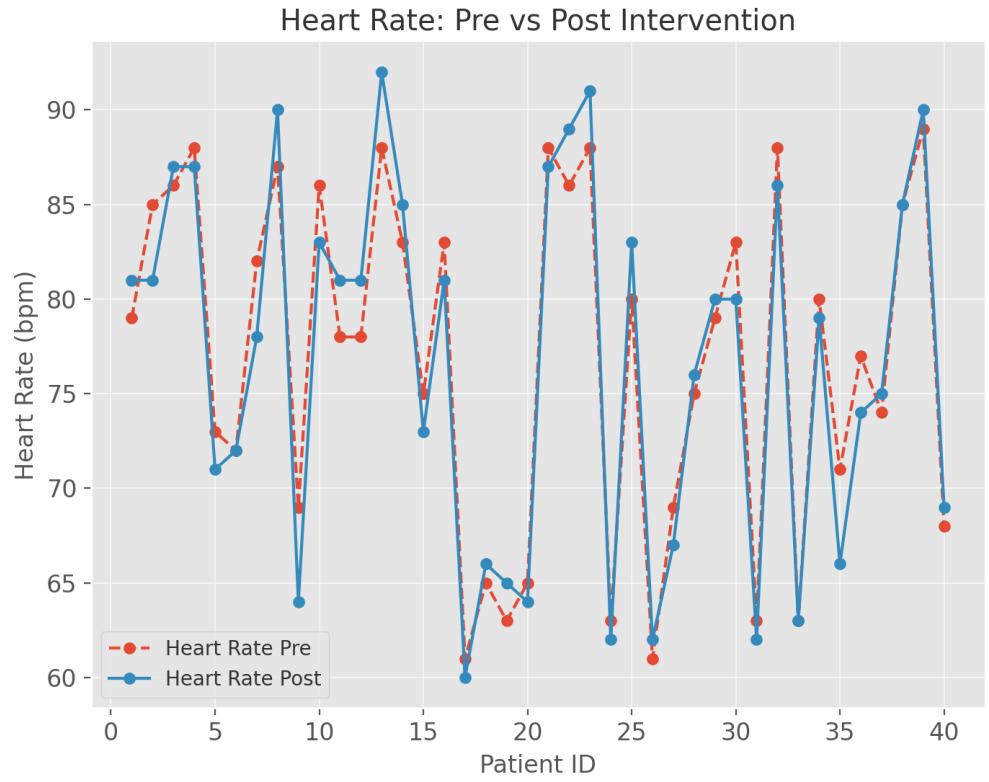
6. Data Analysis and Reporting:
- Use paired t-test to compare pre- and post-intervention results.
- Calculate effect sizes and statistical significance ($p < 0.05$).

Results of Fibrosis Study
The results suggest that high-frequency chest wall vibration (HFCWV) provides immediate benefits for patients with pulmonary fibrosis by enhancing oxygen saturation and minute ventilation. The intervention is both effective and safe, with minimal impact on heart rate and respiratory rate. These findings support the potential integration of HFCWV as an adjunct therapy in pulmonary rehabilitation programs for patients with fibrosed lungs. several statistical tools were employed to analyze the pre-and-post intervention data for key parameters such as oxygen saturation (SpO_2), minute ventilation, heart rate, and respiratory rate. Below is a detailed explanation of the tests used and their relevance.

1. Paired t-Test
The paired t-test was used to compare the mean values of the same group of participants before and after the intervention. Since the data involves repeated measurements (pre-and-post), the paired t-test is appropriate to detect significant differences due to the intervention.







Discussion

The results of this study demonstrate that high-frequency chest wall vibration (HFCWV) has an immediate positive impact on key respiratory parameters in patients with pulmonary fibrosis. Significant improvements were observed in oxygen saturation (SpO_2) and minute ventilation following the intervention, indicating that

HFCWV enhances alveolar ventilation and gas exchange. The increase in SpO_2 post-intervention suggests improved oxygen diffusion across the thickened alveolar walls, which is critical for patients suffering from restrictive lung diseases like pulmonary fibrosis. Similarly, the enhancement in minute ventilation indicates that HFCWV may have contributed to better lung compliance and respiratory muscle performance, allowing participants to exchange more air per minute. These findings align with studies on mechanical interventions, such as those by Scherer et al. (2016) and McIlwaine et al. (2015), which also reported benefits in ventilation and oxygenation through external mechanical stimuli.

The stable heart rate and respiratory rate pre-and-post intervention indicate that HFCWV is a safe modality and does not impose undue cardiovascular stress. This confirms that HFCWV can be comfortably integrated into pulmonary rehabilitation programs without posing risks to patients. The PROMIS measures, including the PROMIS-29 profile and the PROMIS dyspnea severity measure, demonstrated stability over a 7–10-day period, during which clinical change was not expected, confirming good test–retest reliability. PROMIS measures behaved as hypothesized: there were significant differences in scores from this sample compared with scores from other samples of people from the general population or with other chronic conditions. For example, HRQOL was more impaired in the study sample than the U.S. general population across all PROMIS domains, with most differences in the range of a standard deviation or more. The study sample also reported impairments in dyspnea severity, as measured by the PROMIS dyspnea, which equaled or exceeded those in samples of people with COPD or systemic sclerosis with interstitial lung disease [25]. The findings of this study demonstrate the immediate benefits of high-frequency chest wall vibration (HFCWV) in improving oxygen saturation (SpO_2) and minute ventilation in patients with pulmonary fibrosis. These results align with and build upon prior research that explored the effectiveness of mechanical interventions in improving respiratory outcomes in various chronic lung diseases. This discussion section expands on the findings by comparing them with relevant previous studies, highlighting similarities and differences, and providing insights into the potential mechanisms of action.

Several studies have documented the positive impact of mechanical interventions like HFCWV and chest physiotherapy in managing chronic respiratory diseases, particularly those associated with airway obstruction and restricted lung volumes.

McIlwaine et al. (2015) found that HFCWV significantly improved lung compliance and enhanced mucus clearance in cystic fibrosis patients. While pulmonary fibrosis does not involve excessive mucus production, the improvements in ventilation observed in our study suggest that HFCWV also enhances thoracic mobility and lung compliance in fibrosed lungs. This indicates that the physiological benefits of HFCWV are not limited to mucus clearance but extend to better ventilation mechanics.

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