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Research Article

A Randomized Case-Control Study on High-Frequency Chest Wall Oscillator Versus Conventional Chest Physical Therapy in Spinal Cord Injury Subjects

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Abstract

Study Design: This study is a randomized case-control trial.

Setting: Indian Spinal Injuries Centre, Vasant Kunj, New Delhi, India.

Background: Spinal cord injury (SCI) often results in severe respiratory dysfunction, leading to increased morbidity and mortality. Respiratory complications, including atelectasis and pneumonia, are prevalent and exacerbated by compromised lung function and ineffective cough. CCPT poses risks like hypoxemia and arrhythmias. HFCWO has emerged as a promising alternative, facilitating airway clearance and improving lung function without manual intervention. Despite its efficacy in other conditions, its specific benefits in SCI require further study.

Objective: To study the effect of High-Frequency Chest Wall Oscillator versus Conventional Chest Physical Therapy in candidates with Spinal Cord Injury.

Methodology: A sample of 78 SCI patients was selected, with 71 completing the study. Patients were divided into Group A (HFCWO) and Group B (CCPT). Baseline vital, clinical, and radiological parameters were recorded. Group A received HFCWO twice daily for 15 minutes over 5 days, while Group B received CCPT that included positioning, percussions on the affected lobe, and mechanical vibration for 5 days as indicated. Suctioning was performed post-intervention in both groups. Parameters were re-evaluated post-treatment and after 5 days by an intensivist.

Results: The median (IQR) age of participants was 32 (18 to 60). Wilcoxon signed- rank test was used for intragroup analysis. The intervention group (HFCWO) had a median age of 49, and the control group (CCPT) had a median age of 22. In the HFCWO group, RR significantly decreased and SpO2 significantly increased ($p<0.05$) from Day 1 to Day 5. No significant changes were observed in HR and MAP. PEEP, FiO2, and ROASSCI significantly decreased ($p<0.05$). In the CCPT group, RR, HR, and MAP significantly increased ($p<0.05$), with no significant change in SpO2. PEEP and FiO2 significantly decreased, but ROASSCI did not change. Both groups showed significant improvement in Chest X-ray scores ($p<0.05$).

Conclusion: This study compares High-Frequency Chest Wall Oscillator (HFCWO) with conventional chest physical therapy (CCPT) in spinal cord injury patients. HFCWO showed superior improvements in clinical and radiological parameters, facilitating earlier ventilator weaning. These findings suggest that HFCWO is a more effective alternative to CCPT for airway clearance in intubated SCI patients.

***Keywords:** Spinal Cord Injury, High-frequency chest wall oscillator, Conventional chest physical therapy.*

Introduction

Spinal cord injury (SCI) represents a significant global health challenge, often resulting in severe and lasting impairments, including respiratory dysfunction. The impact on respiratory muscles due to SCI, particularly in higher-level injuries, can lead to compromised lung function, ineffective cough, and a heightened risk of respiratory infections and other complications. (1)

Respiratory complications including atelectasis (36.4%), pneumonia (31.4%), and ventilatory failure (22.6%); cardiovascular problems such as sinus bradycardia, bradyarrhythmia, autonomic dysreflexia, orthostatic hypotension, and decreased cardiovascular reflex are common in spinal cord injury patients. (2–5) Other complications include osteoporosis and muscular atrophy, pressure ulcers, thrombosis, bladder dysfunction, and heterotopic ossification. (2,6)

Among the myriads of complications associated with SCI, respiratory dysfunction emerges as a major cause of concern as it raises the morbidity and mortality rates of those who are affected. (7) Typically, individuals with a complete injury above the C5 level experience compromised diaphragm function and are prone to necessitate endotracheal intubation and mechanical ventilation for a certain duration.(8) Mechanical ventilation and intratracheal intubation can worsen mucociliary clearance, retain secretions, worsen lung conditions, and ultimately result in reintubation if the patient survives the spontaneous breathing trial. (9)

To mitigate the risk of respiratory complications and optimize respiratory function in SCI individuals, chest physical therapy has emerged as a cornerstone in respiratory care. Chest physical therapy encompasses a range of techniques aimed at mobilizing pulmonary secretions, improving lung mechanics, enhancing gas exchange, and preventing respiratory complications. (10,11) Conventional chest physical therapy (CCPT) techniques include manual chest percussion and vibration, postural drainage, and assisted coughing, which are performed either independently or with the assistance of a trained healthcare provider. CCPT has been linked to a range of complications, such as hypoxemia, arrhythmias, and increased intracranial pressure. (12,13)

The existing clinical evidence does not advocate for the regular application of CCPT in typical scenarios, such as pneumonia, the postoperative period, and respiratory failure necessitating mechanical ventilation. (14,15) It may even cause occupational hazards like carpal tunnel syndrome among therapists or nurses administering the treatments. (16,17)

High-frequency chest wall oscillator (HFCWO) involves rapid external compressions of the thorax that can produce variations in flow and volume up to 1.6 L/s and 15–57 mL, respectively. It delivers oscillatory mechanical vibrations to the chest wall, facilitating the loosening and mobilization of pulmonary secretions, enhancing airway clearance, and improving lung function providing a standardized approach and getting rid of the need for hands-on treatments. (18,19) High-frequency chest Wall Oscillation proves to be more efficacious in augmenting mucociliary fluid clearance and mobilizing tracheobronchial secretions. (19)

In recent years, HFCWO devices have gained increasing attention as an alternative therapy to CCPT methods in various patient populations, including those with cystic fibrosis, bronchiectasis, lung transplantation, and chronic obstructive pulmonary disease which leads to improvement in pulmonary functions and quality of life. (20–23)

Despite the growing interest in HFCWO therapy, limited evidence exists regarding its efficacy and safety specifically in SCI populations. While studies have demonstrated the effectiveness of HFCWO in improving airway clearance and respiratory outcomes in other patient groups, the applicability of these findings to SCI individuals remains uncertain. (24) Therefore, there is a compelling need for well-designed, randomized control trials to evaluate the comparative effectiveness of HFCWO versus CCPT in SCI individuals.

Methodology

Design: A randomized case-control study was conducted after Institutional Ethical and Review Committee approval from the Indian Spinal Injuries Centre on candidates with Spinal cord injury.

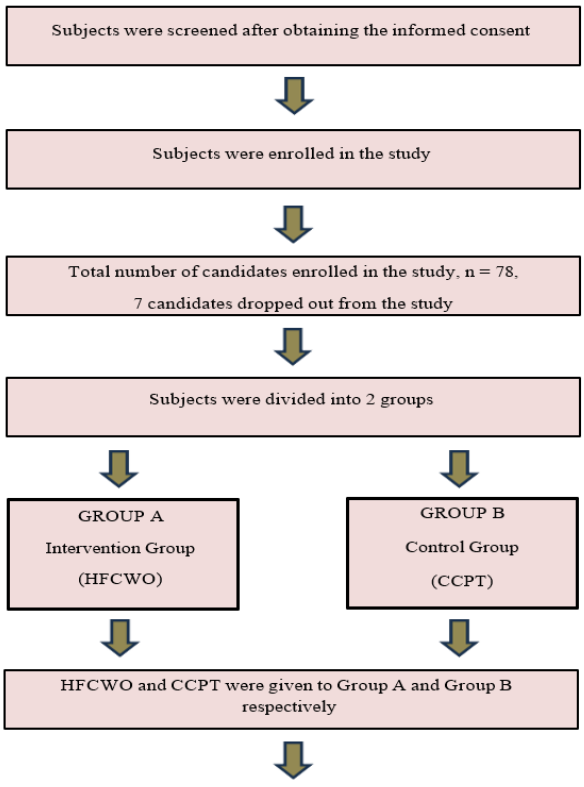
Sample & setting: A sample of 78 candidates with SCI were selected through convenience sampling from the Indian Spinal Injuries Centre, Vasant Kunj, New Delhi. 7 candidates dropped out from the study due to bronchoscopy, death, and loss of follow-up with some patients. Patients who met the following inclusion criteria were recruited: (1) age group from 18 to 60 years, (2) candidates with SCI who were intubated/tracheotomized, (3) candidates with stable spinal fractures but on the ventilator, and (4) diagnosed case of ventilator-associated pneumonia. Potential participants were excluded in case of (1) pregnancy, (2) arrhythmias, and (3) unstable spinal cord injury.

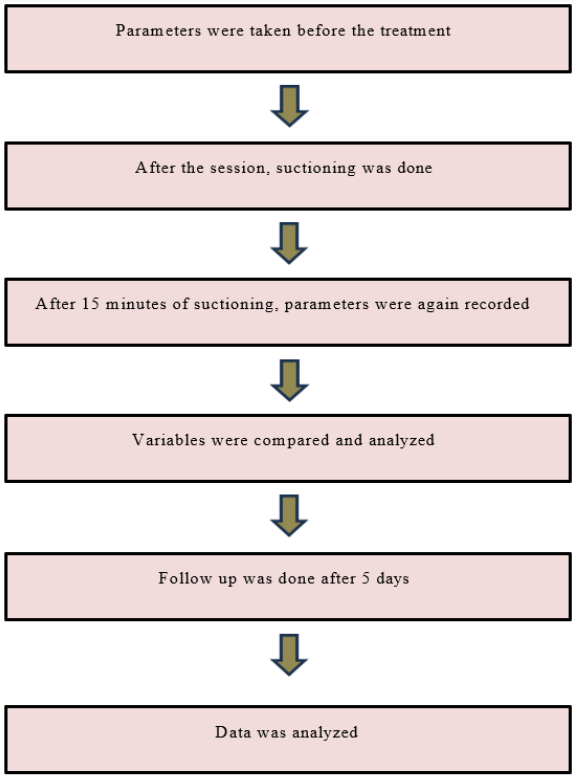
Data collection: The candidates were explained about the study, and a patient information sheet was shared with them. After receiving the signed consent, subjects were conveniently allocated into Group A (Intervention Group) and Group B (Control Group). Group A received High-frequency chest wall oscillation twice a day for 15 minutes for 5 days whereas Group B received Conventional chest physical therapy that included positioning, percussions on the affected lobe, and mechanical vibration for 5 days as indicated.

Outcome Measures: (1) Vital parameters: respiratory rate (RR), mean arterial pressure (MAP), heart rate (HR), and oxygen saturation (SpO2), (2) Clinical parameters: Positive end- expiratory pressure (PEEP) and fraction of oxygen (FiO2), (3) Radiological parameter: chest x-ray film, and (4) Respiratory objective assessment scale for spinal cord injury (ROASSCI).

Procedure: The baseline variables were recorded before the interventions including vital, clinical, and radiological parameters. All patients were given nasogastric tube feeding at least 2 hours before the intervention. Group A candidates received High-frequency chest wall oscillation for 15 minutes whereas Group B received conventional chest physical therapy that included positioning, percussions on the affected lobe, and mechanical vibration to mobilize secretion centrally. The frequency for both interventions was kept standard along with the nebulization schedule.

The HFCWO was applied to each subject at a frequency of 5 to 12 Hz selected from a scale ranging from 5-20 Hz and a pressure setting of 4 to 8 selected from a scale ranging from 1 to 10 (cm of H2O) for 15 minutes. The patients receiving HFCWO were placed in a supine position with cervical collars to stabilize the injured or surgical site whereas the candidates undergoing Conventional chest physical therapy received percussion with the hands, striking the chest with a waving movement while they were placed in the right and left decubitus positions for 10 minutes each and then application of mechanical vibrator. The suction was performed immediately via an endotracheal tube or tracheostomy tube in both groups post-intervention. The variables were recorded before and post-treatment (15 minutes) after suctioning. The radiological parameters and mechanical ventilator parameters were evaluated by the intensivist after 5 days.



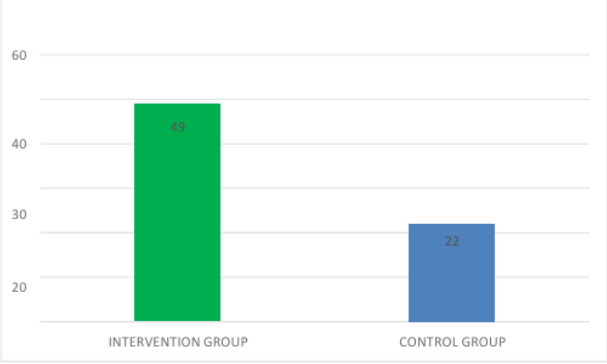


Statistical Analysis

The SPSS for Windows version 26 was used for data analysis. Median and interquartile ranges were computed for descriptive characteristics while percentages were provided for categorical data. Shapiro Wilk test was performed to check the normality of the data. Mann Whitney U test was used to compare the demographic characteristics of both the groups at baseline and for intergroup analysis. Wilcoxon signed-rank test was applied for intragroup analysis. Statistical significance was set at $p<0.05$.

Results

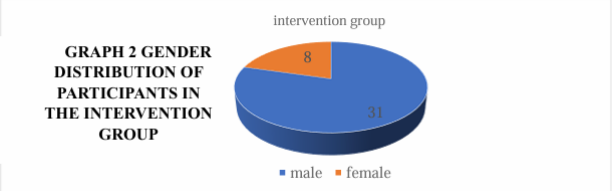
Participants' median (IQR) age was 32 (18 to 60). The median (IQR) age of the intervention group and control group was 49 (18 to 60) and 22 (18 to 59) respectively. Of the 71 subjects, 57 (80.28%) were male and 14 (19.72%) were female. In the intervention group, 31 (79.49%) were male and 8 (20.51%) were female. In the control group, 26 (81.25%) were male and 6 (18.75) were female. Gender distribution varied across groups with [$\chi 2 = 24.45$, p-value = 0.0001].



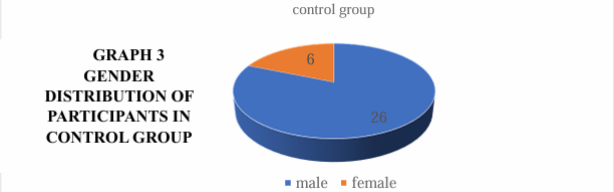
GRAPH 1 MEDIAN AGE OF PARTICIPANTS IN BOTH GROUPS

VARIABLES	TOTAL n=71 Median (IQR)	INTERVENTION GROUP n=39(%)	CONTROL GROUP n=32(%)	ANALYSIS	p-value
AGE					
Median (IQR)	32 (18 to 60)	49 (18 to 60)	22 (18 to 59)	Z = -3.70	0.0001*
GENDER				χ^2 = 24.45	0.0001*
Male	57 (80.28%)	31 (79.49%)	26 (81.25%)		
Female	14 (19.72%)	8 (20.51%)	6 (18.75)		

TABLE 1 THE DEMOGRAPHIC CHARACTERISTICS OF INTERVENTION AND CONTROL GROUP PARTICIPANTS



GRAPH 2 GENDER DISTRIBUTION OF PARTICIPANTS IN THE INTERVENTION GROUP



GRAPH 3 GENDER DISTRIBUTION OF PARTICIPANTS IN CONTROL GROUP

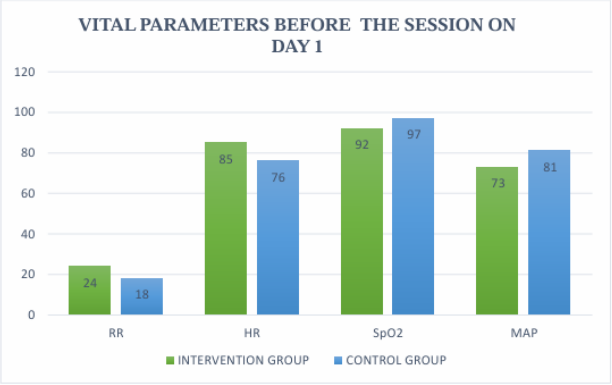
VITAL PARAMETERS

INTERGROUP COMPARISON OF VITAL PARAMETERS ON DAY 1

Before The Session: RR, HR, and SpO2 were significantly different between the two groups as p = 0.0001, p = 0.001, and p = 0.0001 respectively. MAP was not significantly different between the twogroups as p = 0.24.

VITAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
RR	24 (17 to 30)	18 (10 to 24)	-6.539	0.0001*
HR	85 (63 to 92)	76 (52 to 129)	-3.424	0.001*
SpO_2	92 (88 to 100)	97 (94 to 99)	-3.736	0.0001*
MAP	73 (70 to 110)	81 (65 to 103)	-1.182	0.24

TABLE 2 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF VITAL PARAMETERS BEFORE THE SESSION ON DAY 1

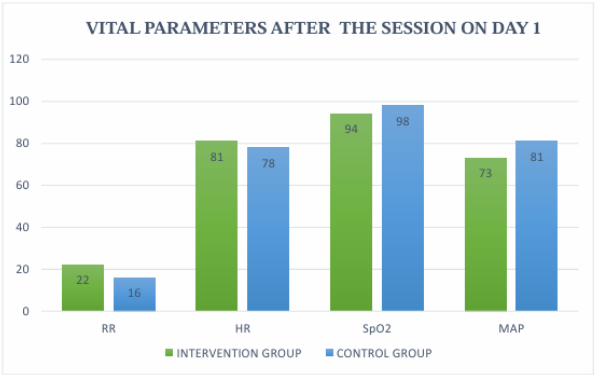


GRAPH 4 SHOWING INTERGROUP COMPARISON OF VITAL PARAMETERS BEFORE THE SESSION ON DAY 1

After the session: RR, HR, and SpO2 were significantly different between the two groups as p = 0.0001, p = 0.0001, and p = 0.03 respectively. MAP was not significantly different between the two groups as p = 0.712.

VITAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
RR	22 (16 to 28)	16 (10 to 19)	-6.535	0.0001*
HR	81 (60 to 93)	78 (52 to 119)	-4.076	0.0001*
SpO_2	94 (91 to 100)	98 (94 to 99)	-2.167	0.03*
MAP	73 (70 to 100)	81 (65 to 103)	-0.368	0.712

TABLE 3 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF VITAL PARAMETERS AFTER THE SESSION ON DAY 1



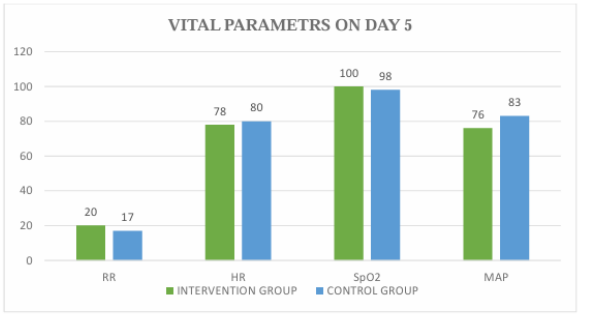
GRAPH 5 SHOWING INTERGROUP COMPARISON OF VITAL PARAMETERS BEFORE THE SESSION ON DAY 1

INTERGROUP COMPARISON OF VITAL PARAMETERS ON DAY 5

RR, HR, and SpO2 were significantly different between the two groups as p = 0.045, p = 0.003 and p = 0.023 respectively. MAP was not significantly different between the two groups as p = 0.096.

VITAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
RR	20 (16 to 26)	17 (16 to 22)	-4.501	0.045*
HR	78 (60 to 103)	80 (62 to 90)	-4.036	0.003*
SpO_2	100 (94 to 100)	98 (91 to 100)	2.168	0.023*
MAP	76 (67 to 100)	83 (70 to 95)	1.461	0.096

TABLE 4 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF VITAL PARAMETERS ON DAY 5



GRAPH 6 SHOWING INTERGROUP COMPARISON OF VITALPARAMETERS ON DAY 5

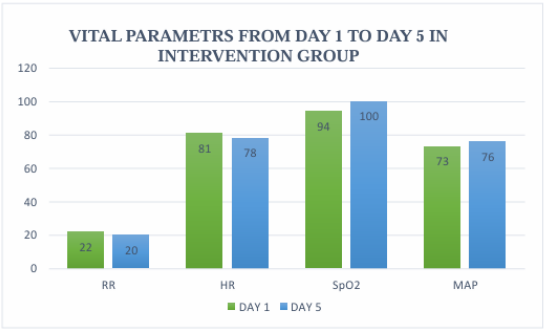
INTRAGROUP COMPARISON OF VITAL PARAMETRS

Change In Vital Parameters from Day1 to Day 5 in Intervention Group

There was a statistically significant decrease in RR as p = 0.0001 and a statistically significan increase in SpO2 as p = 0.001 from Day 1 to Day 5. There was no statistically significant differenc in HR and MAP from Day 1 to Day 5 as p > 0.05.

VITAL PARAMETER	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z- value	p-value
RR	22 (16 to 28)	20 (16 to 26)	-3.84	0.0001*
HR	81 (60 to 93)	78 (60 to 103)	-1.656	0.098
SpO2	94 (91 to 100)	100 (94 to 100)	-3.472	0.001*
MAP	73 (70 to 100)	76 (67 to 100)	-1.198	0.231

TABLE 5 WILCOXON SIGNED RANK TEST FOR INTRAGROUP COMPARISON OF THE CHANGE IN VITAL PARAMETERS FROM DAY 1 TO DAY 5 IN THE INTERVENTION GROUP



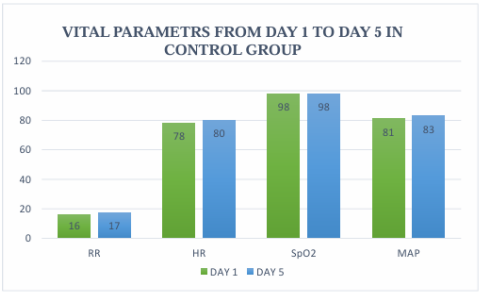
GRAPH 7 SHOWING INTRAGROUP COMPARISON OF VITALPARAMETERS FROM DAY 1 TO DAY 5 IN INTERVENTION GROUP

Change In Vital Parameters from Day1 To Day 5 in Control Group

RR, HR, and MAP were significantly increased from Day 1 to Day 5 as p = 0.0001, 0.025, and 0.028 respectively. There was no statistically significant difference in SpO_2 from day 1 to day 5 as p = 0.908.

VITAL PARAMETERS	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z- value	p-value
RR	16 (10 to 19)	17 (16 to 22)	-3.557	0.0001*
HR	78 (52 to 119)	80 (62 to 90)	-2.242	0.025*
SpO2	98 (94 to 99)	98 (91 to 100)	-0.115	0.908
MAP	81 (65 to 103)	83 (70 to 95)	-2.192	0.028*

TABLE 6 WILCOXON SIGNED RANK TEST FOR INTRAGROUP COMPARISON OF CHANGE IN VITAL PARAMETERS FROM DAY 1 TO DAY 5 IN CONTROL GROUP



GRAPH 8 SHOWING INTRAGROUP COMPARISON OF VITAL PARAMETERS FROM DAY 1 TO DAY 5 IN CONTROL GROUP

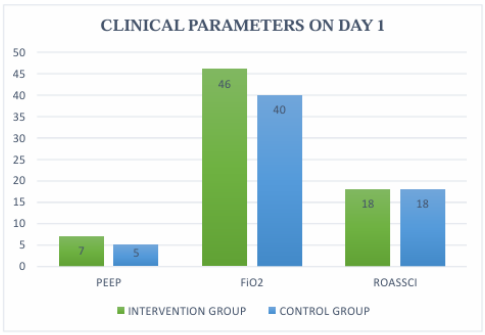
CLINICAL PARAMETERS (PEEP, FiO_2, ROASSCI)

INTERGROUP GROUP COMPARISON ON DAY 1

PEEP and FiO_2 were significantly different between the two groups as p = 0.0001 and 0.0001 respectively. ROASSCI was not significantly different between the two groups as p = 0.217.

CLINICAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
PEEP	7 (5 to 7)	5 (5 to 7)	-7.23	0.0001*
FiO2	46 (35 to 55)	40 (40 to 60)	-4.81	0.0001*
ROASSCI	18 (14 to 26)	18 (12 to 28)	-1.235	0.217

TABLE 7 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF CLINICAL PARAMETERS ON DAY 1



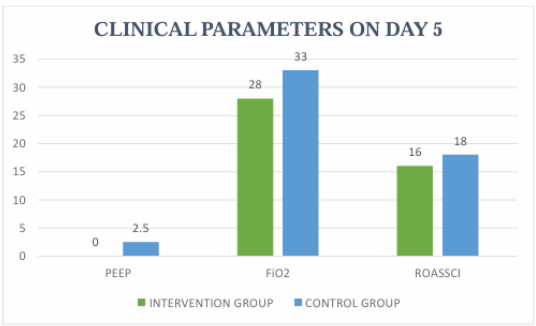
GRAPH 9 SHOWING INTERGROUP COMPARISON OF CLINICAL PARAMETERS ON DAY 1

INTERGROUP GROUP COMPARISON ON DAY 5

PEEP, FiO_2, and ROASSCI were significantly different between the twogroups as p < 0.05.

CLINICAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
PEEP	0 (0 to 6)	2.5 (0 to 6)	-3.532	0.0001*
FiO2	28 (21 to 36)	33 (21 to 50)	-4.276	0.0001*
ROASSCI	16 (14 to 22)	18 (15 to 28)	-2.17	0.0001*

TABLE 8 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF CLINICAL PARAMETERS ON DAY 5



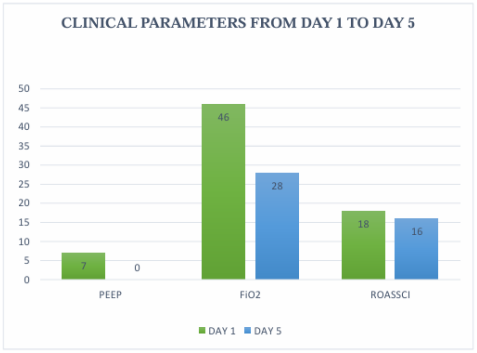
GRAPH 10 SHOWING INTERGROUP COMPARISON OF CLINICAL PARAMETERS ON DAY 5

INTRAGROUP COMPARISON FROMDAY 1 TO DAY 5

Intervention group: PEEP, FiO_2, and ROASSCI significantly decreased from Day 1 to Day 5 as $p < 0.05$.

CLINICAL PARAMETERS	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z-value	p-value
PEEP	7 (5 to 7)	0 (0 to 6)	-5.57	0.0001*
FiO2	46 (35 to 55)	28 (21 to 36)	-5.465	0.0001*
ROASSCI	18 (14 to 26)	16 (14 to 22)	-3.647	0.0001*

TABLE 9 WILCOXON SIGNED RANK TEST FOR INTRAGROUP COMPARISON OF THE CHANGE IN CLINICAL PARAMETERS FROM DAY 1 TO DAY 5 INTHE INTERVENTION GROUP

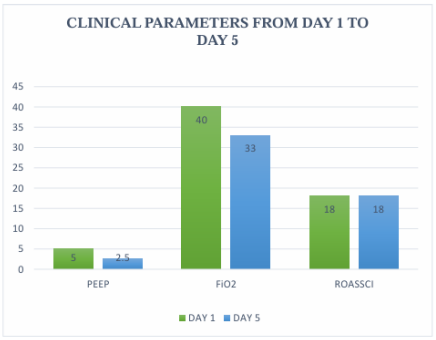


GRAPH 11 SHOWING INTRAGROUP COMPARISON OF CLINICAL PARAMETERS FROM DAY 1 TO DAY 5 IN INTERVENTION GROUP

Control group: PEEP and FiO2 significantly decreased from Day 1 toDay 5 as $p < 0.05$ but there was no significant change in ROASSCI from Day 1 and Day 5 as $p = 0.459$.

CLINICAL PARAMETERS	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z-value	p-value
PEEP	5 (5 to 7)	2.5 (0 to 6)	-3.7	0.0001*
FiO2	40 (40 to 60)	33 (21 to 50)	-4.708	0.0001*
ROASSCI	18 (12 to 28)	18 (15 to 28)	-0.749	0.459

TABLE 10 WILCOXON SIGNED RANK TEST FOR INTRAGROUP COMPARISON OF THE CHANGE IN CLINICAL PARAMETERS FROM DAY 1 TO DAY 5 INTHE CONTROL GROUP



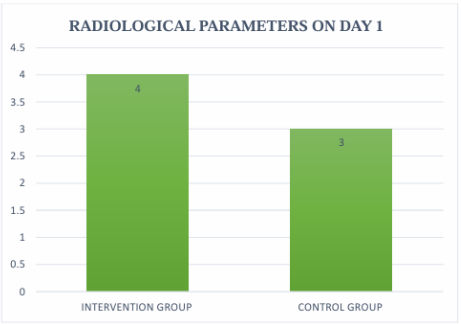
GRAPH 12 SHOWING INTRAGROUP COMPARISON OF CLINICAL PARAMETERS FROM DAY 1 TO DAY 5 IN CONTROL GROUP

RADIOLOGICAL PARAMETER (CHEST X-RAY)

INTERGROUP GROUP COMPARISON ON DAY 1: There was asignificant difference between the twogroups as $p = 0.0001$.

CLINICAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
X-RAY	4 (2 to 4)	3 (2 to 4)	-4.641	0.0001*

TABLE 11 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF CHEST X-RAY ON DAY 1

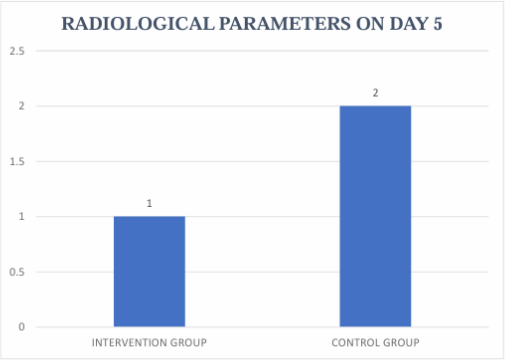


GRAPH 13 SHOWING INTERGROUP COMPARISON OF RADIOLOGICAL PARAMETERS ON DAY 1

INTERGROUP GROUP COMPARISON ON DAY 5: There was asignificant difference between the twogroups ($p = 0.000$).

CLINICAL PARAMETERS	INTERVENTION GROUP Median (IQR)	CONTROL GROUP Median (IQR)	Z-value	p-value
X-RAY	1 (1 to 3)	2 (1 to 3)	-4.84	0.0001*

TABLE 12 MANN WHITNEY U TEST FOR INTERGROUP COMPARISON OF CHEST X-RAY ON DAY 5



GRAPH 14 SHOWING INTERGROUP COMPARISON OF RADIOLOGICAL PARAMETERS ON DAY 5

INTRAGROUP COMPARISON FROM DAY 1 TO DAY 5

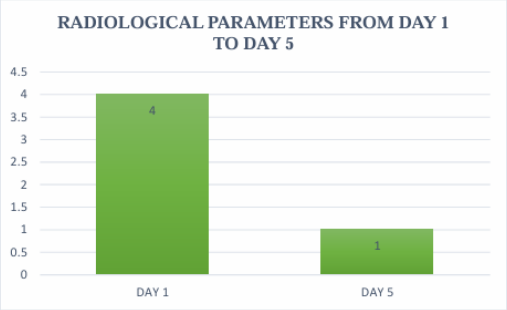
Both the groups showed a statistically significant decrease from day 1 to day 5 as $p < 0.05$.

CLINICAL PARAMETERS	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z-value	p-value
X-RAY	4 (2 to 4)	1 (1to 3)	-5.478	0.0001*

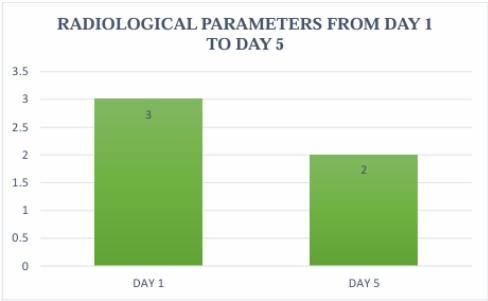
TABLE 13 WILCOXON SIGNED RANK TEST FORINTRAGROUP COMPARISON OF THE CHANGE IN CHEST X-RAY FROM DAY 1 TO DAY 5 IN THE INTERVENTION GROUP

CLINICAL PARAMETERS	DAY 1 Median (IQR)	DAY 5 Median (IQR)	Z-value	p-value
X-RAY	3 (2 to 4)	2 (1 to 3)	-3.499	0.0001*

TABLE 14 WILCOXON SIGNED RANK TEST FORINTRAGROUP COMPARISON OF THE CHANGE IN CHEST X-RAY FROM DAY 1 TO DAY 5 IN THE CONTROL GROUP



GRAPH 15 SHOWING INTRAGROUP COMPARISON OF RADIOLOGICAL PARAMETER FROM DAY 1 TO DAY 5 IN INTERVENTION GROUP



GRAPH 16 SHOWING INTRAGROUP COMPARISON OF RADIOLOGICAL PARAMETER FROM DAY 1 TO DAY 5 IN CONTROL GROUP

Discussion

This study aims to compare the effect of High-Frequency Chest Wall Oscillator with conventional chest physical therapy in candidates with spinal cord injury. The parameters to compare the effects of interventions are a) vital parameters (RR, HR, SpO2, and FiO2), b) clinical parameters (PEEP, FiO2, and ROASSCI), and c) radiological parameters (chest X-ray). It was observed that the candidates allotted to the intervention group had a higher respiratory rate and heart rate and lower SpO2 as compared to the control group which was suggestive of clinically deteriorated status before the intervention.

SpO2: The intervention group showed a significant improvement in SpO2 from Day 1 to Day 5 as compared to the control group, suggesting enhanced oxygenation efficiency with HFCWO. It has been proposed that HFCWO creates airflow velocities and cough-like shear forces within the lungs which results in a reduction of secretion viscosity as well as the mobilization and expectoration of secretions leading to better mucous clearance. (25) It is also thought to help with sputum removal by improving airflow at low lung volumes, enhancing expiratory flow bias (producing a peak expiratory flow rate that is 10% higher than peak inspiratory flow rate), increasing mucus annular flow toward the mouth, and lowering mucus viscoelasticity by lowering cross-linking. (26)

The results of the current study coincide with the previous study conducted on familial dysautonomia and patients with Acute Exacerbation of Chronic Obstructive Pulmonary Disease which resulted in a significant improvement in SpO2. (27)

Respiratory Rate (RR): The intervention group (HFCWO) consistently exhibited higher respiratory rates than the control group (CCPT) both before and after the sessions on Day 1. However, there was a significant decrease in RR in the intervention group from Day 1 to Day 5, indicating improved respiratory function over time. The respiratory rate was higher on day 1 as the intervention group had already clinically deteriorated compared to the control group. It could also be due to the changes in physiological demands i.e., the stimulatory effect of oscillations on ventilation associated with donning and doffing of the vest which led to an increased work of breathing. Also, anxiety and apprehension of assuming an awkward position could also have triggered an increase in physiological demands leading to high RR. (28,29)

However, the decrease in RR from day 1 to day 5 in the intervention group can be explained on the basis of improved lung function due to improved clearance of secretion. Moreover, the clearance of mucus secretions also leads to decreased work of breathing and improved airflow which resulted in a decrease in respiratory rate. (30) Other studies have not incorporated RR parameter, so there is a lacuna in the literature.

Heart Rate (HR): The intervention group was clinically more unstable than the control group. They exhibited higher HR as compared to the control group before the session on Day 1, which continued to stay higher even after the sessions on Day 1. However, there was an improvement in HR in the intervention group from day 1 to day 5 whereas the control group exhibited an increase from Day 1 to Day 5. The decrease in HR could be explained on the basis of mucus clearance. The clearance of mucus secretions leads to reduced work of breathing and improved airflow, hence reducing the heart rate. (30) Improving mucus clearance through exercise or other airway clearance techniques can have significant benefits for patients with respiratory diseases, including reduced symptoms and improved quality of life. (31,32)

The increase in HR in the control group can also be explained on the basis of the previous studies which were conducted on normal subjects, intensive respiratory care unit patients, and Severe Traumatic Brain Injury patients on ventilators, resulting in an increase in HR after conventional chest physical therapy. (29,33,34) Conventional chest physical therapy stimulates the sympathetic nervous system, leading to the release of neural hormones. These hormones accelerate the depolarization of the sinoatrial node, causing the heart to beat faster, and the release of catecholamines increases myocardial contractility. Moreover, over a period of time, there are chances that patients in the intervention group got comfortable with HFCWO which resulted in normal physiological response.

Mean Arterial Pressure (MAP): This study resulted in no significant differences in MAP between the two groups or within each group over time, indicating stable hemodynamic status across both interventions. The results of this study coincide with the previous studies conducted on normal healthy subjects which showed no significant changes in blood pressure after conventional chest physical therapy. (29,35) However, the result of our study was inconsistent with the previous studies, which showed an increase in systolic blood pressure, diastolic blood pressure, and mean arterial pressure in mechanically ventilated patients. This may be related to the fact that conventional chest physical therapy increases muscular activity and stress, thereby raising cardiac output and stroke volume to meet the higher oxygen demands. The afferent fibres of the larger airways pass through the vagus nerve, and stimulation of their sympatho-excitatory receptors leads to increased sympathetic activity. This results in peripheral vasoconstriction and an elevation in mean arterial blood pressure. (36) Other studies with HFCWO have not incorporated MAP as an outcome measure. So, there is a lacuna in the literature.

PEEP and FiO2: Both groups of this study showed a significant reduction in PEEP and FiO2 from Day 1 to Day 5, reflecting improved pulmonary status of the patient. However, the Intervention group showed a greater improvement in both parameters. Our findings are consistent with previous research conducted on chronically mechanically ventilated patients in ICU and hyper secretive COPD who received HFCWO which resulted in early weaning from the ventilator, reduction of symptoms, length of ICU stay, and improved lung condition and quality of life. It also contributes to expectoration and thus improves lung collapse among ventilated patients in ICUs. (37–39) There was early weaning from the ventilator in the intervention group due to a significant reduction in PEEP and FiO2.

ROASSCI: The intervention group exhibited a significant decline in ROASSCI scores from day 1 to day 5. Reduction in ROASSCI score is indicative of better outcomes and improved clinical status of the patient. Our findings are also in consensus with previous studies that observed greater comfort, improved lung condition, and a reduced number of days on ventilators with the application of HFCWO in mechanically ventilated patients in ICU. (38,40) Some studies have also shown reduced blood inflammation parameters such as C-reactive protein (CRP) in the HFCWO group as compared to conventional chest physical therapy in patients with bronchiectasis. (22)

Radiological Parameter (Chest X-ray): The intervention group had higher chest X-ray scores than the control group initially, indicating more severe lung involvement before the treatment. After follow-up, both groups showed notable reductions in Chest X-ray scores from Day 1 to Day 5, indicating improved lung condition. The intervention group experienced a significantly greater decrease in these scores over the same period.

HFCWO is a safe and comfortable treatment for patients that can significantly increase daily sputum clearance volume, improve Chest X-ray scores, and lighten sputum coloration within a short period. (37) Patients treated with high-frequency chest wall oscillation, their duration of mechanical ventilation ($p=0.014$), chest X-ray ($p<0.0001$), and their comfortability ($p<0.0001$) were significantly better than the conventional chest physical therapy in mechanically ventilated patients. (38) The findings reveal that resolution of atelectasis and infiltrates occurs in both groups but within the group analysis showed higher improvements in the intervention group as compared to the control group. Similar findings are supported by previous studies. (25,41,42)

Limitations of the Study

The follow-up period of five days might not be sufficient to fully assess the long-term effects of HFCWO compared to conventional chest physical therapy. There was only one size of vest available for the treatment, so various sizes could have had a better impact on patients with different BMIs or body shapes. HFWCO was applied twice a day whereas conventional chest physical therapy was given every 2nd hourly. Patient compliance and comfort levels with the HFCWO device were not rigorously assessed, which could affect the outcomes.

Future Recommendation

Extend the follow-up period to evaluate the long-term benefits and potential complications associated with HFCWO. More detailed parameters like arterial blood gas analysis, pulmonary function testing, C-reactive protein (CRP), number of days of hospitalization, and duration of ventilation could be assessed.

Conclusion

This study is the first to compare the effects of High-Frequency Chest Wall Oscillator (HFCWO) with conventional chest physical therapy (CCPT) in candidates with spinal cord injury. The findings support the hypothesis that HFCWO provides superior clinical and radiological benefits over CCPT in spinal cord injury patients. Overall, HFCWO led to a more substantial decrease in clinical parameters (PEEP, FiO2, and ROASSCI score) and radiological parameters (Chest X-ray) from Day 1 to Day 5 compared to CCPT, indicating improved respiratory function and lung condition. HFCWO also resulted in early weaning of the patient from the ventilator as compared to CCPT. These data suggest that HFCWO can be used as a substitute for CCPT with more effectiveness in intubated patients requiring assistance with airway clearance and it has advantages like making physiotherapy sessions consistent and getting rid of the need for hands-on treatments.

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