

HIGH-FREQUENCY CHEST WALL OSCILLATION: AIRWAY CLEARANCE MANAGEMENT FOR OBSTRUCTIVE PULMONARY DISEASE PATIENTS

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ABSTRACT

Ineffective mucous airway clearance is identified as the main concern in obstructive pulmonary disease. An impaired mucociliary mechanism and hyper secretive are leading to mucous retention. High-frequency chest wall oscillation (HFCWO) offers a great practical advantage for obstructive pulmonary disease treatment. A literature review was conducted to summarize the existing research evidence assessing the effectiveness and benefits of HFCWO as an airway clearance management among people with obstructive pulmonary disease. Literature was limited to accessible articles in the English language and sourced from electronic databases, PubMed and EBSCO, from their published date through 2010. Seven studies that fulfilled the inclusion criteria were included in the analysis. Two themes were identified from the summary of included studies, namely respiratory function improvement and quality of life outcomes. The overall results of the studies indicate that HFCWO positively affects health status and wellbeing in patients with excessive mucous production and impaired airway clearance mechanism. It also can be performed independently and enhances self-satisfaction. Thus, it will be advantageous to include the HFCWO in pulmonary rehabilitation. Further studies are needed to validate the effectiveness of HFCWO in obstructive pulmonary disease patients and develop better treatments in this field.

Keywords: Airway clearance, HFCWO, Obstructive Pulmonary Disease

INTRODUCTION

Obstructive pulmonary diseases are abnormalities in the small airways of the lungs characterized by persistent and progressive lung airflow obstruction (World Health Organization, 2021; O'Reilly, 2016). Obstructive pulmonary disease is the third leading cause of worldwide mortality, causing 3.23 million deaths in 2019 (World Health Organization, 2020). The most common conditions of obstructive pulmonary diseases are chronic obstructive pulmonary disease (COPD), bronchiectasis, asthma, emphysema, and bronchiolitis (Martinez-Pitre, Sabbula & Cascella, 2021).

People with obstruction lung diseases present with complaints of difficulty in breathing, cough, and excessive sputum production (Agarwal, Raja & Brown, 2021). Due to the damage or narrowing airways, the sputum becomes more difficult to be removed and leads to sputum retention. The obstructed airway has decreased lung function, impaired quality of life, and a higher risk of hospitalization and lower respiratory tract infections.

Airway clearance management has been a cornerstone of therapy to promote mobilization of pulmonary secretions and manipulate airflow (Volsko, 2013). Various

techniques include the active cycle of suctioning, breathing technique, postural drainage, physiotherapy, and positive expiratory pressure (PEP) as part of the airway clearance management (Katz, 2018; Phillips, Lee, Pope & Hing, 2021). Today a variety of technological development may be used to enhance the effectiveness of airway clearance and contributed to a better quality of life. One of the innovations in airway clearance management is high-frequency chest wall oscillation (HFCWO).

High-frequency chest wall oscillation is a non-assisted airway clearance device that applies positive and negative trans-respiratory pressure excursions to create high velocity, low amplitude oscillatory airflows. It consists of an inflatable soft and flexible vest covering the torso and flexible plastic hoses connecting it to an air pulse generator. The generator generates and delivers oscillating air pulses that make the vest expand and shrink rapidly, providing compression to the chest 5-20 times/second. It also can be adjusted for tolerance and comfort. These air pulses oscillate the chest and their vibrations causing the transient flow to increase in the respiratory tract, loosened mucus, and stimulating the cough reflex (Farag & El-Syed, 2017). Previous studies of HFCWO treatment have

concluded that HFCWO is beneficial for the pulmonary function of many groups of individuals with impaired mucociliary clearance (Kloni, Klonis & Benidis, 2018; Aryayev, Kononenko, Kukushkin, 2011; Hansen, Barto, Caceres & Daignault, 2019) and stroke (Kim & Park, 2017).

This study aimed to describe the benefits and effectiveness of using HFCWO as an airway clearance management in people with the obstructive pulmonary disease from the existing research evidence.

METHOD

Literature searches were conducted with EBSCO and Pubmed using English keywords included “high-frequency chest wall oscillation and airway clearance”. The inclusion criteria were applied: (1) the study was published in peer-reviewed journals with full text in English, (2) it examined the effectiveness of HFCWO to clear airway from mucus in patients with obstructive pulmonary disease, and (3) it was published in 2010-2021. Exclusion criteria were used to select literature based on the following: (1) irrelevant to study topic, (2) did not collect original data (literature reviews, editorial letter, not original research), (3) reported unrelated outcomes, (4) written in

a non-English language, and (5) no full text available.

Fig. 1 PRISMA Flow Diagram

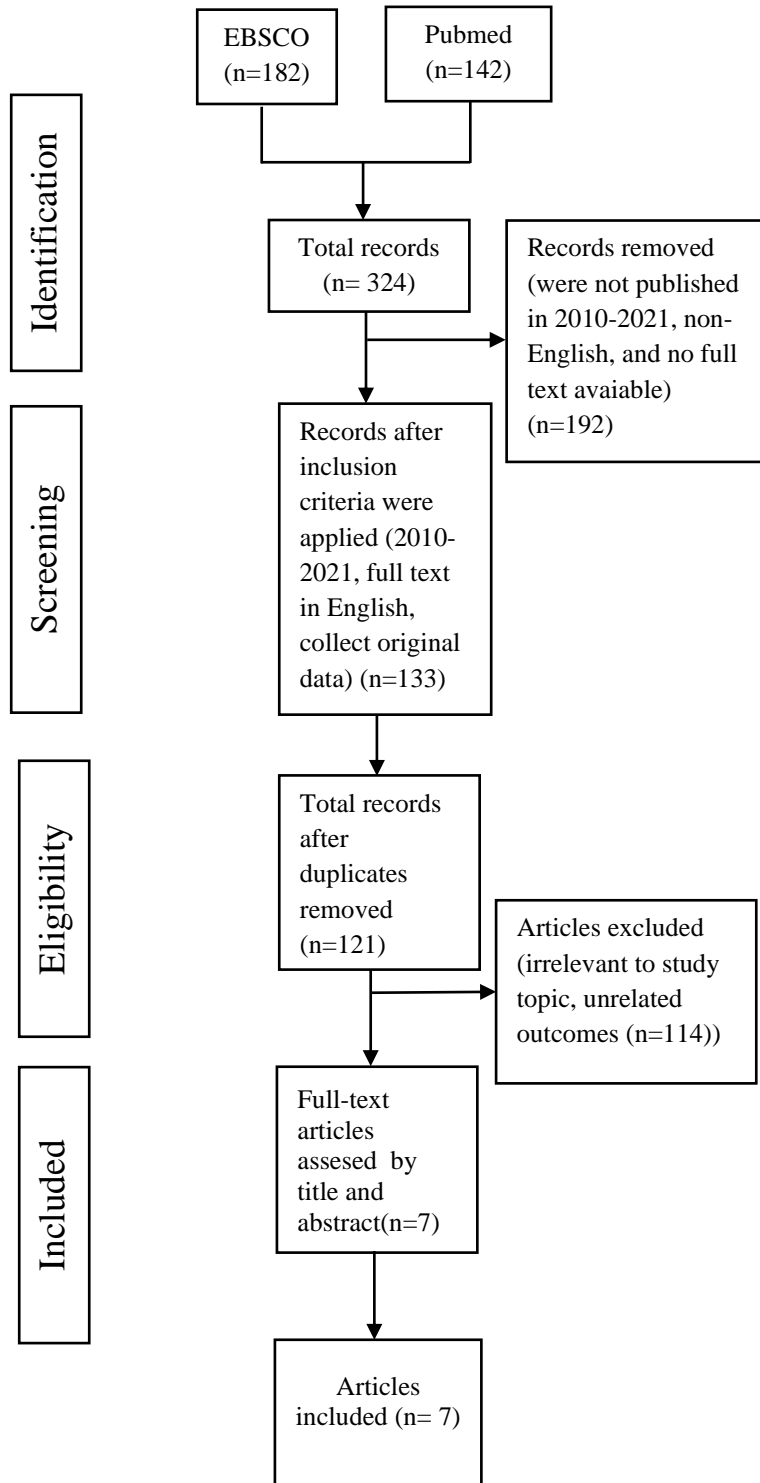


Table 1. Summary of studies included in the review

Author (Year)	Title	Purpose	Method	Participants	Intervention	Results
Mahajan et al. (2011)	High-frequency chest wall oscillation for asthma and chronic obstructive pulmonary disease exacerbations: a randomized sham-controlled clinical trial	To evaluate the use of HFCWO early in the treatment of adults hospitalized for acute asthma or chronic obstructive pulmonary disease (COPD)	Randomized sham-controlled clinical trial	52 adult patients (age 18 years and older) with acute asthma or COPD at an academic medical center	Patients received active or sham HFCWO treatment for 15 minutes three times a day for four treatments while the medical management was standardized across groups. The evaluation was conducted after four treatments.	A higher proportion of patients in the active HFCWO treatment group had a clinically significant improvement in dyspnea than in the sham HFCWO group (71% vs 42%, $p = 0.04$)
Powner et al. (2019)	Employment of an algorithm of care including chest physiotherapy results in reduced hospitalizations and stability of lung function in bronchiectasis	To determine the clinical effectiveness of HFCWO as an airway clearance treatment along with adjunctive nebulized bronchodilators, nebulized mucolytics and macrolide therapy for patients with Bronchiectasis	Observational comparative retrospective cohort study	65 patients with bronchiectasis and more than two exacerbations and significant symptom burden	Patients were given nebulized bronchodilators, mucolytics inhaled daily or twice daily, thrice-weekly macrolide therapy when appropriate, and HFCWO treatment daily to twice per issued protocol. The evaluation was conducted in the outpatient clinical setting every 2-3 months for one year.	The number of severe exacerbations and course of antibiotics decreased by a significant amount after the initiation of the algorithm.
Nicolini et al. (2013)	Effectiveness of treatment with high-frequency chest wall oscillation in patients with	To compare the efficacy and safety of HFCWO with conventional chest physiotherapy in	Comparative study	30 patients (18-85 years old) with bronchiectasis	10 patients were treated with HFCWO for 30 minutes per session and given twice daily	HFCWO group showed a significant improvement in breathlessness and life quality, a significant increase of forced vital

Author (Year)	Title	Purpose	Method	Participants	Intervention	Results
	bronchiectasis	patients with non-cystic fibrosis bronchiectasis.			for five days per week, 10 patients were treated with positive expiratory pressure techniques for 45 minutes per session and were given twice daily for five days per week 10 patients received medical therapy only. The evaluation was conducted after fifteen days.	capacity (FVC) and forced expiratory volume 1 second (FEV1), a significant reduction of C-reactive protein, a significant reduction of neutrophils percentages, and produced a greater of sputum volume.
Barto et al. (2020)	Real-life experience with high-frequency chest wall oscillation vest therapy in adults with non-cystic fibrosis bronchiectasis	To explore the effectiveness of HFCWO in patients with non-cystic fibrosis bronchiectasis	Longitudinal study	2596 patients (21-101 years old) from a registry of adult bronchiectasis, and 198 were included in the subset for detailed chart review.	The evaluation was conducted at structured intervals of zero months (the baseline HFCWO treatment date), 1-month, 3-month, 6-month, 12-month, and at 6-month intervals thereafter.	Initiation of HFCWO therapy showed a substantial reduction in the number of hospitalizations and improved quality of life and lung function.
Longhini et al. (2020)	Chest physiotherapy improves lung aeration in hyper secretive critically ill patients: a pilot randomized physiological study	To assess the effects of HFCWO on lung aeration and ventilation distribution and the effect of the association of HFCWO with recruitment manoeuvres.	Pilot randomized physiological study	60 critically ill patients (18 years old and older) undergoing invasive mechanical ventilation in a hospital in Italy	30 patients received HFCWO with recruitment maneuvers, and 30 patients only received HFCWO. HFCWO was applied for 10 minutes, and soon post-treatment, after 1 hour and 3 hours, the evaluation was	Chest physiotherapy by HFCWO may improve lung aeration of hyper secretive mechanically ventilated patients without affecting gas exchange.

Author (Year)	Title	Purpose	Method	Participants	Intervention	Results
					conducted by recording the result of electrical impedance tomography for 10 minutes	
Bose et al. (2013)	High-Frequency Chest Wall Oscillation Successful in Controlling Refractory Asthma	To describe the use of HFCWO as a mechanical approach to mucus clearance in a patient with refractory asthma	Case report	A 36-year-old, non-smoker male with a lifelong history of poorly controlled asthma	The HFCWO treatment was given twice daily, 20 minutes per session. The evaluation was conducted after 2 months and follow-up at 2 years.	HFCWO improved the mobilization of mucus with each cough and resolved the congestion.
Sontag et al. (2010)	Lessons learned from a randomized trial of airway secretion clearance techniques in cystic fibrosis	To compare three therapies (postural drainage, flutter device, and high frequency chest wall oscillation) by studying 1) change in pulmonary function; 2) time to need for IV antibiotics, 3) use of pulmonary therapies, 4) adherence to treatment, 5) treatment satisfaction, and 6) quality of life	Randomized trial	166 patients with cystic fibrosis (7 years old and older) and had FEV1% predicted at least 45 at The Children's Hospital Denver.	58 patients were given postural drainage and percussion treatment, 51 were given fluter device, and 57 were given HFCWO treatment. Patients were trained to do the treatment twice daily for 20-40 minutes/session. The evaluation was conducted quarterly study visits for 3 years and a screening visit within 7 randomization days.	HFCWO group reported higher satisfaction and the annual FEF25-75% predicted rate of decline was greater in this group.

RESULTS

The result of the search is illustrated in the flow chart in figure 1. A total of 324 records from Pubmed and EBSCO were screened by publication year, language, and full-text availability, in which 133 records were included. After duplicate removal, it resulted in 121 studies. Additionally, 114 studies were excluded since they did not meet the inclusion criteria. Finally, seven studies that fulfilled the inclusion criteria were included in the final analysis. A summary of the seven studies included in the final analysis is presented in table 1. These studies are organized into two themes, i.e., 1) Respiratory function improvement and 2) Quality of life outcomes.

Respiratory function improvement

Mahajan et al. (2011) evaluated the use of HFCWO in managing acute asthma and chronic obstructive pulmonary disease (COPD). The study results showed that 25 patients with acute asthma or COPD who received HFCWO treatment experienced an improvement in dyspnea. Another study conducted by Bose et al. (2013) also showed immediate improvement in the mobilization of mucus with each cough in a patient with refractory asthma after initiation of HFCWO.

Powner et al. (2019) found that a treatment algorithm that includes using HFCWO decreased exacerbations and stabilized lung function in patients with bronchiectasis. HFCWO treatment showed a significant increase in FVC and FEV1, which implies improvement of bronchial obstruction and dyspnea (Nicolini et al.,2013). The study also found that the effects of HFCWO on sputum production were more significant than conventional chest therapy.

Barto et al. (2020) evaluated the effectiveness of HFCWO in 2,596 patients with non-cystic fibrosis bronchiectasis using self-reported outcomes and sampled patient charts. The study showed that initiation of HFCWO treatment was associated with a positive experience of airway clearance. In another study, the use of HFCWO declined the annual FEF25-75% greater than conventional physiotherapy and flutter device (Sontag et al., 2010).

In prolonged mechanical ventilation patients, HFCWO effectively facilitated airway hygiene after removing endotracheal tubes and produced persistently greater numbers of daily sputum volume and lighter sputum coloration (Huang et al., 2014). Allam & Badawy (2020) found that

pulmonary function, including FVC, FEV1, and PEFr, increased significantly post HFCWO treatment in patients with smoke inhalation injury.

In a study conducted by Longhini et al. (2020), hyper secretive critically ill patients experienced significant improvement in aeration of the dorsal lung region without affecting arterial blood gases (ABGs) after receive HFCWO treatment. Yuan et al. (2010) found a statistical significance in the maximum level of oxygen in hemoglobin after pediatric patients with cerebral palsy and neuromuscular diseases underwent HFCWO treatment. However, the study reported that the apnea-hypopnea index was higher in the HFCWO group than in conventional chest physiotherapy, yet the difference was insignificant.

Quality of life outcomes

Mahajan et al. (2011) found that a high level of satisfaction in adults hospitalized with acute asthma or COPD indicates the need for HFCWO. A similar finding was also mentioned in a study that aimed to compare the effect of conventional airway clearance techniques, flutter devices, and HFCWO on lung function, adherence to therapy, satisfaction level regarding the treatments, and health-related quality of life

(Sontag et al., 2010). The study revealed that overall treatment satisfaction was higher in HFCWO, and there were no significant differences in adherence and health-related quality of life. Yuan et al. (2020) evaluated the safety, tolerability, and efficacy of HFCWO in pediatric patients with neuromuscular disease and cerebral palsy. The result of the study showed excellent safety and tolerability for HFCWO in these populations.

Furthermore, the improvement in airway clearance was associated with a reduction in incidence and duration of acute respiratory infection requiring antibiotics and hospitalizations. Powner et al. (2019) found that 33% of 43 patients who had severe exacerbation did not require hospitalization after receiving an algorithm that included HFCWO. A similar result of the study was also found by Lechtzin et al. (2016), which highlighted the benefits of HFCWO on healthcare use for patients with chronic neuromuscular disease.

Additionally, total medical claims cost and pneumonia claims decreased. In another study conducted by Barto et al. (2020), initiation of HFCWO led to the improvement in hospitalization rates and the patients' quality of life. Nicollini et al.

(2013) found that HFCWO treatment showed significant improvement in quality of life than traditional chest physiotherapy. Another study showed that the overall respiratory quality of life for amyotrophic lateral sclerosis patients who underwent HFCWO treatment was greater than the national mean for neuromuscular disease patients (Brooks et al., 2011).

DISCUSSION

High-frequency chest wall oscillation (HFCWO) is approved by the United States Food and Drug Administration (FDA) and is recommended by the American College of Chest Physicians (ACPP) as a treatment to improve bronchial drainage and enhance mucous clearance. HFCWO offers a practical advantage compare to chest physiotherapy, for it can be performed without assistance from health care providers. Thus, it minimizes the risk of nosocomial infection and enhances patients' satisfaction because they control the treatment process. We found that using HFCWO in facilitating airway clearance is feasible for adult and pediatric populations who experience increased mucous production and retention. In addition, HFCWO appeared to be an excellent treatment that positively affects health and quality of life.

O'Brien et al. (2018) reported that HFCWO treatment led to a significant decrease in FVC, FEV1, and FEF25-75%, indicating lung function improvement. However, the study did not note any alteration in tidal volume and peak expiratory flow. A pilot study conducted by Chakravorty, Chahal, and Austin (2011) found that the use of HFCWO led to a decreased daily sputum volume and reduced symptoms significantly in patients with advanced COPD and mucus hypersecretion. Reduction in retained mucous caused a decreased bacterial colonization.

Therefore, the use of HFCWO is associated with decreased exacerbations and the need for antibiotics. Sievert and Beaner (2018) found that bronchiectasis-related exacerbations were significantly reduced with HFCWO treatment, as well as the incidence of hospitalizations, emergency department visits, and antibiotic prescriptions. This finding is consistent with a study conducted by Fitzgerald et al. (2014), which noted that initiation of HFCWO in 22 children with neurologic impairment decreased hospitalization rates. Lin, Tung, and Wang (2017) found that intensive care unit (ICU) patients felt more comfortable with HFCWO than conventional chest physiotherapy.

Moreover, studies have shown that HFCWO is safe and causes no adverse complications (Lee et al., 2011; Nicolini, Grecchi & Ferrari-Bravo, 2018). In addition, Gwag et al. (2021) found that chest physiotherapy using HFCWO may be safely applied to patients with a cardiac implantable electronic device, except for an unwanted increase in pacing rate related to misdetection chest wall vibration. HFCWO treatment is associated with improved quality of life (Sievert, Beaner & Sievert, 2016).

This review has several limitations that should be noted. Firstly, this review only included published literature on HFCWO treatment for obstructive pulmonary disease patients from peer-reviewed journals with full text in English from two databases (PubMed and EBSCO), which might have caused bias due to incomplete collection and lack of resources. Second, even though the results of this review indicated that HFCWO treatment for people with obstructive pulmonary disease was highly significant, the long-term effect of HFCWO treatment on lung function improvement and quality of life needs to be investigated. Third, the lack of standardized intervention procedures such as differences in intervention methods, intervention duration, and evaluation period make it

difficult to compare the effects of HFCWO intervention.

Future studies should address previous methodological weaknesses by including a larger sample size to validate the findings. Additionally, there is a need to conduct more studies using a longer treatment period to determine if HFCWO improves other outcomes (e.g., local and systemic markers of inflammation, psychological health, and nosocomial infection rate in hospital settings) and use chest imaging as a supported outcome measure of lung function.

CONCLUSION

This review of the HFCWO treatment which facilitate airway clearance in obstructive pulmonary disease patients was based on seven original articles. The overall results of the studies indicate that HFCWO positively affects health status and wellbeing in patients with excessive mucous production and impaired airway clearance mechanism. Moreover, it can be performed independently and enhances self-satisfaction. Thus, it will be advantageous to include the HFCWO in pulmonary rehabilitation. Further studies are needed to validate the effectiveness of HFCWO in obstructive pulmonary disease patients and develop better treatments in this field.

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