Review

Is High-frequency chest wall oscillation (HFCWO) effective in COPD patients?

Marina E. Kloni[1], Alexios Klonis[2] MB/BChir, Kleomenis Benidis[3] MD

[1]Physiotherapist BSc, MSc, Pancyprian Association of Cancer patients and Friends, Nicosia, Cyprus
[2]The Royal Wolverhampton NHS Trust, Wolverhampton, WV10 0QP, UK
[3]First Class Medical Officer Respiratory Diseases, Pulmonologist, Nicosia and Larnaca General Hospital, Cyprus

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Correspondence:
Marina E. Kloni
Pancyprian Association of Cancer patients and Friends, Chalkanoros 2, Strovolos, Nicosia, Cyprus, 2000
E-mail: marina@pasykaf.org

SUMMARY

BACKGROUND The incidence of Chronic Obstructive Pulmonary Disease is increasing every year, increasing the economic burden on the healthcare system. High frequency chest wall oscillation device is another airway clearance technique that according to several studies has a positive benefit in the respiratory symptoms experienced in cystic fibrosis and bronchiectasis patients. **METHODS** Literature search in the Cochrane library, PubMed, Medline, PEDro SPORTDiscus, AMED, and CINAHL with the following keywords: physiotherapy, exercise, rehab, HFCWO, high frequency chest wall oscillation, positive pressure, COPD, Chronic obstructive pulmonary disease. **RESULTS** Four studies met the inclusion criteria. Overall, the studies showed positive results for the use of HFCWO in COPD patients of varying stages and acuteness. Only one study reported adverse effects. **CONCLUSIONS** HFCWO could be potentially added to the treatment of patients with COPD, however future studies need to be done using HFCWO in patients with COPD.
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INTRODUCTION

Aim of the study:

The aim of this review is to describe the current and available evidence for the use of High Frequency Chest Wall Oscillation in patients with Chronic Obstructive Pulmonary Disease.

Background:

COPD:

Chronic Obstructive Pulmonary Disease (COPD) is defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) as a "common, preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar

abnormalities usually caused by significant exposure to noxious particles or gases. The chronic airflow limitation that is characteristic of COPD is caused by a mixture of small airways disease (e.g., obstructive bronchiolitis) and parenchymal destruction (emphysema), the relative contributions of which vary from person to person" (GOLD 2017[1]).

The main cause of COPD is smoking; by inhaling the smoke and thus all the toxins, chronic lung inflammation occurs as these harmful particles become trapped in the alveoli (Kaul 2007[2]). Chronic inflammation then causes structural changes (dysfunction and the loss of cilia in combination with the enlargement of the mucus-secreting glands), narrowing of the small airways and damage of the lung parenchyma. These result to loss of lung volume, reduction in the lung elastic recoil and increase the risk of lung collapse during expiration. In addition, COPD patients experience airflow limitation and recurrent chest infections (GOLD 2017[1], Kaul 2007[2], West 2008)[3].

The most common symptoms these patients experience include dyspnoea, chronic cough and excessive mucus production (WHO 2018[4]).

Large epidemiological studies have estimated the incidence of COPD cases to be 384 million in 2010 (global prevalence of 11.7%), with an annual mortality of approximately 3 million deaths. It is believed that there is going to be an increase in the prevalence of COPD over the next 30 years with a mortality approaching 4.5 million annually. This is thought to be due to the increase in smoking in the developing countries and the increase in the aging population in the developed countries (GOLD 2017[1], WHO 2018[4]). The World Health Organisation (WHO) predicts that by 2030 COPD will become the third leading cause of death worldwide (WHO 2018[4]).

In addition to the social burden, COPD has significant economic consequences. According to GOLD[1] (2017) the cost for COPD is approximately 38.6 billion Euros in the European Union (56% of the total cost of respiratory disease), with COPD exacerbations accounting for the biggest part of that cost. Furthermore, not all healthcare systems offer long-standing care services for these patients, especially as the disease progresses. Thus, it might lead to at least 2 people taking early retirement (the individual with COPD and their carer- who will have to look after them). This has an economic and social impact as it reduces both the family income and the human capital (GOLD 2017[1]).

HFCWO:

Hight frequency chest wall oscillation (HFCWO) device is an airway clearance technique that was firstly used by [5]King et al in 1983 on dogs. Currently, it is used in the mobilisation of secretions in patients with cystic fibrosis, bronchiectasis and neuromuscular disorders. It entails that the user wears an inflatable (pneumatic) vest over their thorax which is connected to an air pulse generator. The generator sends rapid pulses of air (5-20 times/second) to the vest, causing it to inflate and deflate and putting pressure on the chest walls. The changes in the pressure result in oscillatory chest wall compressions, of high velocity and low amplitude, which loosen the mucus from the airway lining and move phlegm proximally to be removed by coughing or suctioning (Goktalay et al 2013[6], Farag and EL-Syed 2018[7], Mahajan et al 2011[8]).

Further advantages of HFCWO include its use in more severe cases when the patient is unable to use a handheld device well. Also, once the carer is trained, there is limited need for a professional healthcare provider to be present at every use, This allows the patients to stay at home, increasing patient autonomy and reducing the need of hospital admissions and healthcare costs (Farag and EL-Syed 2018[7], Chakravorty, Chahal and Austin 2011[9]).

Typically, treatment lasts for 20 to 30 minutes with the patient stopping every 5 minutes to cough out any phlegm if needed. Initially the HFCWO device is set at a low pressure and frequency settings which are then gradually increased to the recommended values according to the patient's tolerance. This is called the "tuning procedure" with an optimum oscillating frequency recommended between 13-15Hz (Farag and EL-Syed 2018[7], Mahajan et al 2011[8], Chakravorty, Chahal and Austin 2011[9], Goktalay et al 2013[6]).

Indications, contraindications and potential adverse effects of HFCWO (UTMB Respiratory Care Services 2018[10]) can be found in Table 1.

Current Evidence:

Below, the current evidence is presented which is scarce and controversial. It mostly includes posters and studies with a mixed population sample (i.e. patients with COPD and asthma).

Krishman et al[11] (2009) and Mahajan et al[8] (2011) compared active and sham HFCWO in 52 COPD and asthma patients, respectively. Although, both showed a high patient adherence, comfort, perceived benefit, satisfaction, change in predicted percentage of Forced expiratory volume in 1 second (FEV_1% predicted) and sputum volume, only the dyspnoea score was significantly improved in HFCWO group at the end of the studies.

TABLE 1: Indications, Contraindications and Potential Adverse Effects of HFCWO device.

Use of HFCWO device		
Indications	**Contraindications**	**Potential Adverse effects**
1. Difficulty with phlegm clearance 2. Expectorated secretions production >25-30ml/day 3. Retained secretions (in an artificial airway) 4. Atelectasis caused by secretions plugging 5. Diagnosis of a lung disease	1. Unstable head and/or neck injury 2. Active haemorrhage with hemodynamic instability 3. Temporary pace maker 4. Acute pulmonary emboli 5. Hemoptysis 6. Empyema 7. Untreated pneumothorax 8. Fractured ribs	1. Decreased Oxygenation (Increased ventilation drive and heart rate) 2. Bronchospam (Wheezing and dyspnoea) 3. Pulmonary Hemorrhage (Frank Hemoptysis and dyspnoea)

Diette et al[12] (2007) compared active and sham HFCWO therapy in 50 COPD patients. They showed that after 12 weeks the active group had a lower rate of acute exacerbations and lower phlegm production compared to the sham group. Also, coughing up phlegm was more likely to become easier in the active group and the quality of life improved in both groups without any significant differences. In contrast with the other two studies, self-adherence was lower in the active group.

When intrapulmonary percussive ventilation (IPV) was compared to HFCWO and control in 60 severe COPD patients, the results showed a significant improvement in the tests for dyspnoea, quality of life assessment, pulmonary function tests and Arterial Blood Gases (ABGs) in the active groups compared to the control. With in-between group comparison results favouring the IPV technique. (Russo et al[13] 2014)

In Waycker et al's[14] (2012) retrospective pre/post cohort study, they looked at 1000 non-cystic fibrosis bronchiectasis and COPD patients. The results from the COPD patients only, using HFCWO, demonstrated a 40% reduction in the mean number of all-cause hospitalisation and a significant reduction in the physician office visits and emergency department visits.

Kachel et al[15] (2005) favour the long-term (90 days) use of HFCWO in 94 moderate-to severe COPD patients, who were trained to use the HFCWO at home. Improvements were seen in symptoms such as dyspnoea, 6-min waking distance (which was clinically significant) and in the role-physical domain in the quality of life questionnaire.

Lastly, Chakravorty et al[16] (2011) showed that 16 COPD patients with acute exacerbations improved in terms of lung function, exercise capacity and health-related quality of life scores when discharged home using the HFCWO vest compared with conventional treatment.

Sievert and Beaner's[17] (2017) study analysed the cost-effectiveness of using HFCWO (SmartVest) in 59 non-CF bronchiectasis patients and they found statistically significant results when compared to standard care (control). There was a 58% reduction in cost due to less antibiotic use, a 63% reduction in Accident &Emergency cost due to less attendances and a 60% reduction in hospitalization cost due to less admissions. Overall, the analysis of SmartVest use, showed an annual savings of $3,045 per patient per year (Sievert and Beaner 2017).

Reasoning:

COPD puts a heavy load to the healthcare sector every year. In view of the above evidence supporting patient benefit and cost-effectiveness, it might be useful for physicians to consider the use of HFCWO for their COPD patients.

METHODS AND RESULTS

A comprehensive literature search was done in the Cochrane library, PubMed, Medline, PEDro SPORTDiscus, AMED, and CINAHL with the following keywords: physiotherapy, exercise, rehab, HFCWO, high frequency chest wall oscillation, positive pressure, COPD, Chronic obstructive pulmonary disease. The titles of the articles obtained were then screened to ensure relevance. The articles whose titles lacked clarity had their abstract checked. Studies evaluated to be inappropriate to the study by their titles or abstracts were discarded. The full-text versions of the potential articles were retrieved and checked according to the criteria for this review. Studies that failed to meet the criteria were also discarded (Figure 1).

The inclusion and exclusion criteria can be found in

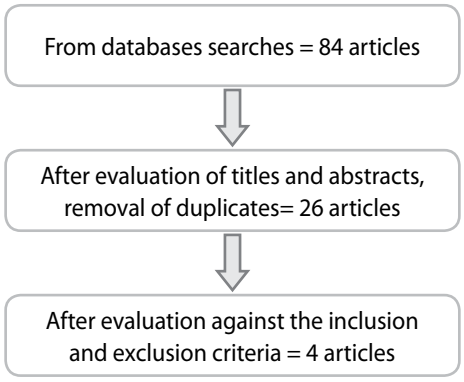

FIGURE 1. Illustrates the number articles found and the reasons for their dismissal.

Table 2 and a summary of the eligible articles can be found in Table 3.

Quality assessment

The quality assessment of the retrieved studies was performed using the PEDro scale for bias. This scale has 10 questions and according to Maher et al[18] (2003) it is a reliable and accurate grading system.

DISCUSSION

The aim of this paper is to present the relevant literature and current evidence for the potential use of HFCWO device with COPD patients. In terms of study quality, the four studies included have different sample sizes, outcome measures and comparison groups and their subjects had different stage/acuteness of COPD. As a consequence, a metanalysis was not appropriate due to the heterogeneity of these studies.

Farag and EL-Syed[7] (2018) found that both HFCWO and flutter groups have a positive effect on the spirometric indices, oxygenation parameters and COPD Assessment Test (CAT) scores in acute exacerbation COPD patients compared to the control group. Both techniques had a good tolerance but no statistically important differences were found between them. It was suggested that this improvement could be potentially from the effect the techniques have on airway clearance. HFCWO produce improvements in gas mixing and homogenisation of alveolar ventilation for previously closed or under ventilated lung units. Flutter enhances movement of secretions from the peripheral to the central airways, improving lung function and oxygenation. As a consequence, it increases oxygen delivery to the tissues which further enhances metabolic activity and thus improving the symptoms. More adverse effects were detected in the flutter group. This was attributed to the flutter being a semi-invasive technique requiring forced expiration which rises the intrathoracic pressure, potentially causing internal damage.

Nicolini et al[19] (2018) suggested that the greater improvement in the IPV group (compared to the HFCWO) in their outcome measures could be due to IPV resolving the obstruction on the small bronchial airways, improving the alveolar ventilation and reducing lung hyperinflation. This further reduced the respiratory workload and improved the patients' symptoms. Also, the changes in the sputum cellularity for both groups (but greater in IPV group), could be due to both techniques having a modulation effect on the inflammatory cells and thus reducing the C-Reactive Protein value (CRP). High CRP indicates an infection which might lead to another exacerbation of COPD and potentially another hospitalisation. The major limitations of this study were its short duration and the absence of sham treatment group to reduce bias on the subjective elements of the outcome measures.

Chakravorty, Chahal and Austin[9] (2011) used a cross-over study design in order for the subjects to act as their own control and thus reduce the inter-subject variability. The authors suggest that it is possible that some of the

TABLE 2. Inclusion and exclusion Criteria of this review.

Inclusion Criteria	Exclusion Criteria
People diagnosed with Chronic Obstructive Pulmonary Disease with any degree of severity and state of condition	People diagnosed with pathologies other than Chronic Obstructive Pulmonary Disease
Adults	Children
Use of High Frequency Chest Wall Oscillation device	Studies written in other languages
Studies written in English or Greek	Animals
Randomised Control Trials	

TABLE 3.

Title	Author/s (date)	Sample Size (M: F)	Mean Age	Outcomes used	Comparison groups	Methodology	PEDro Score	Results	Side effects
Utility of vest high frequency chest wall oscillation device versus flutter device in acute exacerbation of chronic obstructive pulmonary disease	Farag TS and EL-Syed M (2018)	108 (76:32) Exacerbation of COPD Hospitalised on ward (exclusion if admitted to Intensive Care Unit)	Control grp: 63.7 Flutter grp: 60.9 HFCWO grp: 64.0	Spirometry Arterial blood gas analysis CAT BODE index	Control group Flutter group HFCWO group	All groups had medications for acute exacerbation (bronchodilators, antibiotics, inhaled/ oral steroids, oxygen if indicated and advice on regular exercise) Participants received 3 sessions per week for 20-30 minutes from day 1 of hospital admission and continue post discharge with a total of 4 weeks study period	6/11	Most of the spirometric indices (FEV_1%, FVC%, FEV_1/FVC%) were significantly improved in HFCWO and Flutter groups only, while oxygenation parameters (PaO_2, SaO_2%) were significantly improved ($p<0.05$) in all groups. Level of perceived dyspnoea decreased significantly, walking distance during 6MWT was extended significantly, while BODE index, MMRC and CAT scores were reduced significantly in HFCWO and Flutter groups only. No statistical significant differences were observed in BMI, $FEF_{25-75\%}$, pH, $PaCO_2$ and HCO_3 in all groups No statistical significant difference was found between HFCWO and Flutter groups in all parameters ($p>0.05$)	Flutter group: inability to perform forced expiratory manoeuvres, throat discomfort, musculoskeletal chest discomfort, significant haemoptysis, syncope and paroxysm of cough, HFCWO group: throat discomfort, musculoskeletal chest discomfort, significant haemoptysis
Safety and effectiveness of the high-frequency chest wall oscillation vs intrapulmonary percussive ventilation in patients with severe COPD	Nicoloni A et al (2018)	63 (35:28) Stable Severe to very severe COPD Stage 3-4 Outpatient Clinic (exclusion if admitted hospital)	Control grp: 74.9 IPV grp: 72.8 HFCWO grp: 73.8	Modified MRC BCSS CAT Pulmonary function testing Arterial blood gas analysis Haematological examinations Sputum cell count Patient acceptability	Control group IPV group HFCWO group	Each IPV session lasted 15 minutes, twice a day Each HFCWO session lasted 20 minutes, twice a day Study period was 2 weeks. Participants were evaluated 1-week pre and 1 week post the study period	8/11	IPV and HFCWO groups showed significant improvement in MMRC, BCSS and CAT compared to the control group. IPV group's improvement was greater in BCSS ($p<0.001$) and CAT ($p<0.02$) compared to HFCWO group's. IPV and HFCWO group showed improvement in pulmonary function tests, arterial blood analysis and haematological examinations (FVC, FEV_1, FEV_1/ FEV %, TLC, RV, RV/TLC%, DLCO, MIP, MEP, PaO_2, $PaCO_2$ and pH) compared to the control group. IPV group had significant improvement in TLC+TLC% ($p<0.03$), RV +RV% ($p<0.04$), DLCO, MIP and MEP ($p<0.01$). IPV and HFCWO group showed improvement in total cell count and neutrophil, lymphocyte and macrophage count, compared to the control group. IPV group showed an improvement in neutrophil count compared to HFCWO group ($p<0.05$). A similar ranking of acceptability was expressed by the participants for IPV and HFCWO group.	No changes in respiratory therapy or COPD exacerbations

TABLE 3. (continued)

Title	Author/s (date)	Sample Size (M: F)	Mean Age	Outcomes used	Comparison groups	Methodology	PEDro Score	Results	Side effects
A pilot study of the impact of high-frequency chest wall oscillation in chronic obstructive pulmonary disease patients with mucus hypersecretion	Chakravorty I, Chahal K and Austin, G (2011)	30 (22:8) Moderate to severe COPD Not available information about the study site	71 years	HRQoL (St George's Respiratory questionnaire and self-reported questionnaire) Patient tolerability and compliance Spirometry Wet sputum volume	HFCWO group Conventional treatment group	4 weeks with 2 weeks wash-out period followed by 4 weeks. HFCWO session lasted for 20 minutes twice per day Conventional group followed their own COPD management regime (prescribed medication, advice on regular exercise and cough clearance of sputum) Medications included: long-acting bronchodilator, inhaled corticosteroid, acting anticholinergic inhaler	4/11	The SGRQ impact score and the spirometry values- FEV_1 (HFCWO group: pre-1.05 L, post- 1.07 L, conventional group: pre-0.97 L, post- 1.01L) remained nonsignificant for both groups. Sputum expectoration remained individually variable but showed a trend towards a reduction in HFCWO group. There was a significant improvement in the mean total score in the five-symptom self-reported questionnaire in patients in HFCWO group (p=0.03) SGRQ scores showed significant improvement in the symptom dimension (p=0.028) only in the HFCWO group. No statistically significant improvement in any dimension of the SGRQ scores in the conventional group. The HFCWO device was well tolerated with good reported compliance	8 participants drop out as they developed exacerbations of COPD
Does high-frequency chest wall oscillation therapy have any impact on the infective exacerbations of chronic obstructive pulmonary disease? A randomized controlled single-blind study	Goktalay T et al (2013)	50 (49:1) COPD Stage III-IV hospitalised with acute infection exacerbation	65.06 years	Saint George's Respiratory Diseases Questionnaire BODE index (Body mass index, FEV_1, modifies Medical research council dyspnoea scale and 6minutes walking test) Exercise capacity Hospitalisation duration Arterial Blood gases analysis	Group 1: control Group 2: HFCWOT	5 days study duration Both groups had general therapy for the infective exacerbation of COPD (controlled oxygen therapy, short-acting b_2 bronchodilator and anti-cholinergic inhaler, 1mg/kg/day parenteral steroid and antibiotherapy in case of signs of bacterial infection, pathology-oriented therapy in case of any underlying causes of COPD exacerbations HFCWO group had the standardised medical exacerbation therapy (above) plus HFCWO for 20 minutes, 3 times a day.	7/11	3rd day assessment: Both group showed significant improvement in BODE index, FEV_1, 6minutes walking test, PO_2 and SpO_2 were significantly improved. 5th day assessment: No significant changes were observed in the modified research council scale and PCO_2 in group 1 however they were significantly improved in group 2. (Two-group comparisons showed that the difference was not significant) There were no statistically significant differences (p> 0.05) in FEV_1, MMRC dyspnoea scale, 6m walking test, BODE index and arterial blood gas parameters between group 1 and 2 at the 3rd and 5th day. However, the most significant changes were observed in FEV_1 (group 1:3%, group 2: 5%) and 6m walking test (group 1:75m, group 2: 119m) from baseline to day 5. No significant differences (p=0.527) were observed in the durations of hospitalization between the two group (median duration in both groups to be 7 days)	None reported

improvement in the HFCWO group could be attributed to the placebo effect as both groups had positive results. The mucus production was variable in the study, as was the range of Force Expiratory Volume in one second (FEV_1). In the participants, however, the results show a positive reduction trend in mucus production in the HFCWO phase compared to the conventional phase. According to the authors, this could be explained by a decrease in the sputum production and the subjects having an efficient mucus clearance. Another explanation could be due to subjects swallowing the phlegm.

Goktalay et al[6] (2013) found an improvement in the Partial Pressure of Carbon Dioxide (P_aCO_2) and the Medical Research Council (MRC) scale for dyspnoea in the HFCWO group. This could be due to its effect on removing excess mucus and mucus plugs from the peripheral airways, thus improving the gas exchange and the feeling of dyspnoea. These small changes could be attributed to the small sample size, the relatively short duration (5 days) and the single blinded methodology, increasing bias in their results.

Quality of studies

The quality of the studies was average to moderate. Only Farag and Syed's[7] (2018) study failed to randomly allocate their subjects, increasing bias as it reduced the comparability of the groups in terms of intervention and reduced the similarities at baseline between the two groups. Furthermore, only Nicolini et al's[19] (2018) study concealed allocation of the subjects, minimising the allocation bias of the researcher allocating subjects in order to favour a particular group. Also, Goktalay et al[6] (2013) was the only study that blinded the assessors.

Blinding subjects and therapists is difficult as the techniques used in the studies require special equipment. However, having independent assessors would prevent the researchers from influencing the findings by altering the subjects' evaluations or encouraging the subjects in one group to do better. Lastly, all studies showed point estimates and variability.

Future Studies

Furthermore, they need to assess the implementation of HFCWO at home, in intensive care unit, its use by the cancer and at earlier stages of COPD. Future studies comparing HFCWO to control or other techniques need to have a larger sample size, longer implementation period, use a sham group and include inflammatory markers as outcome measures. Furthermore, they need to assess the implementation of HFCWO at home, its use by the carer and at earlier stages of COPD.

CONCLUSION:

To conclude, more randomised-controlled trials need to be done comparing HFCWO technique with a larger sample size and a longer trial duration. Overall, HFCWO has positive effects on subjective and objective outcome measures for patients with COPD of varying severity and acuteness. The positive results from the studies included agree with the results from the other studies mentioned above. Only one study mentions adverse effects (mostly haemoptysis). Therefore, physicians might want to consider HFCWO as another tool they can use in patients with COPD, in conjunction with pharmacological treatment. This could potentially facilitate early discharge, better self-management of symptoms, improve the quality of life and lastly reduce the healthcare costs.

ΠΕΡΙΛΗΨΗ

Αξιολόγηση της εφαρμογής ταλαντώσεων υψηλής συχνότητας στο θωρακικό κλωβό σε ασθενείς με Χρόνια Αποφρακτική Πνευμονοπάθεια

Μαρίνα Ε. Κλώνη[1], Αλέξιος Κλώνης[2], Κλεομένης Μπενίδης[3]

[1]Φυσιοπεραπεύτρια BSc, MSc, Παγκύπριος Σύνδεσμος Καρκινοπαθών και Φίλων, Λευκωσία, Κύπρος
[2]The Royal Wolverhampton NHS Trust, Wolverhampton, WV10 0QP, Ηνωμένο Βασίλειο,
[3]Πνευμονολόγος, Φυματιολόγος, Ιατρικός Λειτουργός 1ης τάξης,
Γενικό Νοσοκομείο Λευκωσίας και Γενικό Νοσοκομείο Λάρνακας, Κύπρος

Ιστορικό *Η συχνότητα εμφάνισης της χρόνιας αποφρακτικής πνευμονοπάθειας αυξάνεται κάθε χρόνο, αυξάνοντας την οικονομική επιβάρυνση του συστήματος υγείας. Η συσκευή ταλάντωσης τοιχώματος υψη-*

λής συχνότητας (HFCWO) είναι μια τεχνική εκκαθάρισης των αεραγωγών που σύμφωνα με αρκετές μελέτες έχει θετικό όφελος στα συμπτώματα του αναπνευστικού συστήματος που εμφανίζονται στους ασθενείς με κυστική ίνωση και βρογχεκτασίες. ***Μέθοδος*** *Έγινε αναζήτηση σε επτά βάσεις δεδομένων με αρκετές λέξεις-κλειδιά.* ***Αποτελέσματα*** *Τέσσερις μελέτες πληρούσαν τα κριτήρια ένταξης. Συνολικά, οι μελέτες έδειξαν θετικά αποτελέσματα για τη χρήση του HFCWO σε ασθενείς με ΧΑΠ με διαφορετικό στάδιο και οξύτητα. Μόνο μία μελέτη ανέφερε ανεπιθύμητες ενέργειες για τη συσκευή HFCWO.* ***Συμπεράσματα*** *Συμπερασματικά, το HFCWO θα μπορούσε να προστεθεί στη θεραπεία του ΧΑΠ, από τους γιατρούς. Ενδείκνυται να γίνουν μελλοντικές μελέτες, με τη χρήση του HFCWO με ασθενείς με ΧΑΠ μεγαλύτερης διάρκειας.*

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Λέξεις - κλειδιά: *ΧΑΠ, HFCWO*

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