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The effects of oscillating positive expiratory pressure therapy in adults with stable non-cystic fibrosis bronchiectasis: A systematic review

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Abstract

Airway clearance techniques (ACTs) are recommended for patients with stable non-cystic fibrosis (non-CF) bronchiectasis, but the efficacy of oscillating positive expiratory pressure (PEP) therapy compared to other techniques has not been reviewed. A systematic review of studies was conducted in stable patients comparing the effect of oscillating PEP therapy to other ACTs or a control condition. Data were extracted related to sputum expectoration, lung function, gas exchange, quality of life (QOL), symptoms, and exacerbation rate. Seven studies were included with a total of 146 patients, with a mean (SD) PEDro score of 7(1). Oscillating PEP therapy enhanced sputum expectoration compared to no treatment, but has equivalent benefits as the active cycle of breathing technique with gravity-assisted drainage (mean difference [95% CI] −2.8 g [−8.8 to 3.2 g]). Oscillating PEP has a similar effect as other ACTs on dynamic lung volumes, gas exchange and breathlessness. Use of oscillating PEP improved disease-specific QOL ($p < 0.001$) and cough-related QOL ($p < 0.002$) compared to no treatment but did not reduce exacerbation rate. In conclusion, in stable non-CF bronchiectasis, oscillating PEP therapy is associated with improvement in sputum expectoration and QOL compared to no treatment. Compared to other ACTs, the effect upon sputum expectoration, lung function, gas exchange, and symptoms are equivalent.

Keywords

Oscillating positive expiratory pressure therapy, non-cystic fibrosis bronchiectasis, airway clearance therapy, systematic review

Introduction

Non-cystic fibrosis (non-CF) bronchiectasis is a chronic respiratory disease characterized by permanent dilatation of the airways arising from bronchial inflammation, infection, and impaired mucociliary clearance.[1] Predominant symptoms include chronic sputum production, dyspnoea, and fatigue[2,3] and this profile is associated with diminished health-related quality of life (HRQOL).[4,5] This clinical presentation of non-CF bronchiectasis supports the prescription of airway clearance techniques (ACTs) as part of management.[6–8] ACTs are designed to facilitate mucociliary clearance and remove excess bronchial secretions.[9] There are a myriad of ACTs available for patients with non-CF bronchiectasis. Specific

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techniques include gravity-assisted drainage (GAD), breathing exercises such as the active cycle of breathing technique (ACBT), autogenic drainage, manual techniques, forced expiratory technique, and the application of positive expiratory pressure (PEP) through devices.[10] A previous systematic review found that compared to no treatment, ACTs in non-CF bronchiectasis are associated with enhanced sputum expectoration, improvement in selected measures of lung function, and greater HRQOL.[11]

Surveys of clinical practice indicate that different types and combinations of ACTs are prescribed in patients with non-CF bronchiectasis,[12–14] of which oscillating PEP therapy is often applied. Oscillating PEP devices generate oscillating waves on expiration with varying frequencies which are transmitted through the airways, resulting in shearing forces which reduce the viscoelasticity of bronchial secretions[15] and improve mucus transport.[16,17] In addition, the positive pressure generated during expiration facilitates collateral ventilation to maintain airway patency and facilitate movements of secretions centrally.[10] Intrathoracic oscillating PEP therapy is commonly applied using the Flutter® valve and Acapella®, with similar pressure flow characteristics generated for each device.[18] Several studies have compared the effects of oscillating PEP therapy to other ACTs.[19–22] However, there is considerable variability in study findings and therefore the overall effect of oscillating PEP therapy is unclear. This review aimed to systematically search the literature and undertake a meta-analysis of data from studies which evaluated the effect of intrathoracic oscillating PEP therapy compared to other ACTs or no treatment in adults with stable non-CF bronchiectasis.

Methods

Eligibility criteria

Studies were eligible for inclusion if they were (1) written in English; (2) included adults with non-CF bronchiectasis, according to physician's diagnosis or chest high resolution computed tomography (cHRCT), who were in a stable clinical state, and (3) investigated the effects of a form of intrathoracic oscillatory PEP therapy compared to other ACTs or control. Studies were randomized controlled or randomized crossover trials in which the difference between two groups was the application of ACTs. Included studies were those which compared responses between groups that underwent (1) a form of oscillatory PEP therapy (experimental group) versus usual medical care (control group); (2) a form of oscillatory PEP (experimental group) versus other ACTs or (3) a treatment in which a specific technique of oscillatory PEP was included (experimental group) versus excluded (control group). Other ACTs included low pressure PEP therapy (10–20 cm H_2O, using a mask or mouthpiece interface), GAD, manual techniques (percussion/vibrations/shaking), ACBT, forced expiratory technique/huffing, autogenic drainage, coughing manoeuvres, inspiratory muscle training, inhalation therapy using mucolytics, and exercise for the purpose of airway clearance. Studies were excluded if they specifically examined rehabilitation or exercise therapy of which the primary aim was to improve exercise capacity.

Data sources

Prior to conducting this review, the Cochrane Library and the Physiotherapy Evidence Database (PEDro) were searched to ensure a similar systematic review had not been published. One investigator (AL) performed the database search. The primary search reviewed the electronic databases of MEDLINE (1946 to week 40, 2013), EMBASE (1980 to week 40, 2013), CINAHL (1982 to week 40, 2013), Physiotherapy Evidence Database (PEDro; inception to week 40, 2013), and Cochrane Central Register of controlled trials (inception to week 40, 2013) (Figure 1). A repeat search was conducted in week 17 in 2014. Clinical trials registry (Clinicaltrials.gov) were also reviewed to identify any trials which may have been 'in press'. The reference lists of all potentially eligible studies were scanned to identify additional studies. Similar keywords were used to search all databases, which included non-CF bronchiectasis, respiratory therapy, physical therapy, physical medicine, respiratory care, and chest physiotherapy. No attempt was made to translate articles published in a language other than English or to contact study authors.

Study selection

The study selection process is outlined in Figure 1. Eligibility assessment was performed by two independent reviewers (HW and SL). All articles identified by the search were independently assessed based on title and abstract for eligibility against the defined inclusion criteria. Full text versions of all relevant studies were obtained and reviewed by two independent authors (HW and SL) to ensure the inclusion criteria

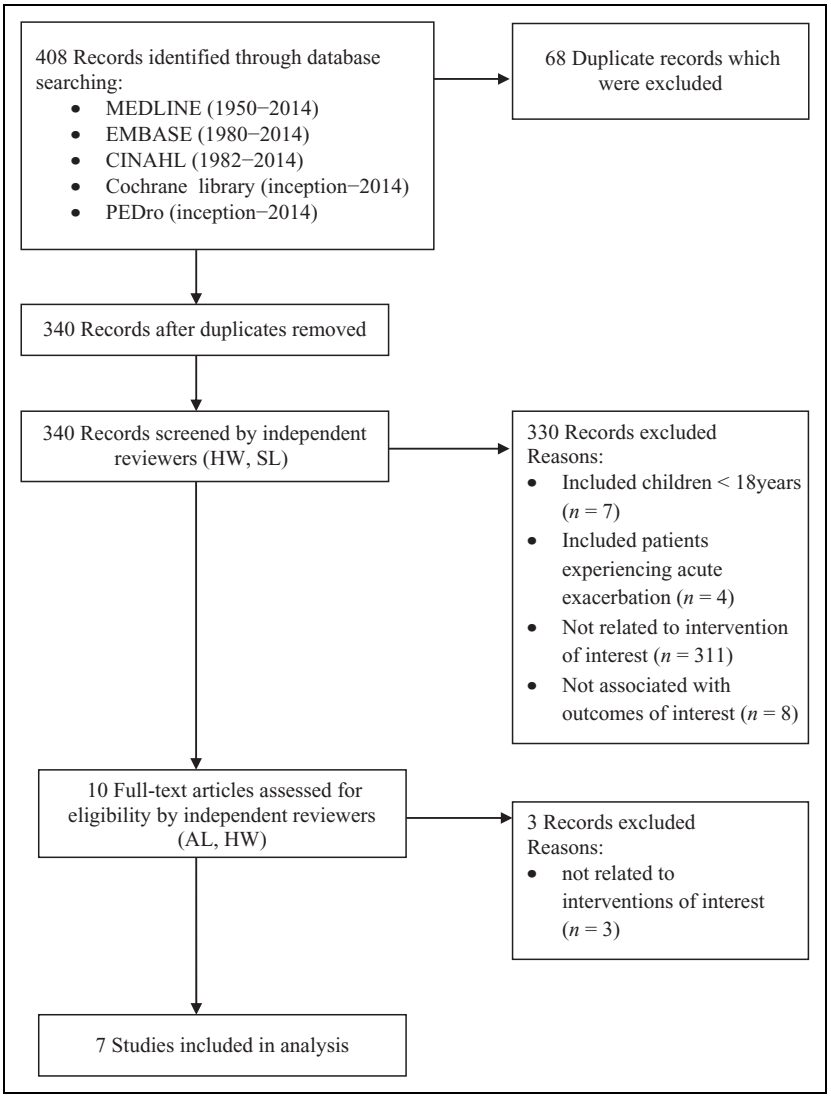

Figure 1. PRISMA flow diagram of study selection process. CINAHL: Cumulative Index to Nursing and Allied Health Literature; EMBASE: Excerpta Medica Database; PEDro: Physiotherapy Evidence Database.

were met. Where disagreement regarding a study's eligibility was present, decisions were made by consensus.

Data extraction, quality assessment, and outcome measures

Two members of the review team (HW and SL) independently extracted data using the form available from the Cochrane website[23] as a template for data extraction. Quality assessment for the RCTs or randomized crossover trials was rated using the 10-point PEDro scale.[24] Quality assessment for the single-group studies was rated using a modified Downs and Black tool.[25] This tool consisted of 27 questions that relate to study description, external, and internal validity. A question related to statistical power was assigned one point if prospective sample size calculations were provided and 0 points if absent, which allowed a maximal score of 27, a modification which has been previously applied.[26] Studies were classified to meet the intention-to-treat criteria on the PEDro scale if authors (1) reported that analyses were performed according to the intention-to-treat principles or explicitly stated that all subjects were analyzed according to the group into which they were randomized. The following data were extracted: number of participants, age and gender of participants, type of ACTs and outcomes measures including lung function, physiological measures of sputum clearance (sputum weight, volume), gas exchange, symptoms, HRQOL, exacerbation, and hospitalization rates.

Data analysis

Agreement between reviewers regarding study eligibility as well as agreement between investigators for PEDro scores and quality assessment, which was calculated as the proportion of the total articles assigned the same score by both investigators were quantified using Kappa statistics. Meta-analysis was performed using RevMan (version 5.2).

Results

The search strategy yielded 408 records, of which 68 were duplicates and therefore excluded (Figure 1). Of the remaining 340 records, 330 were excluded on the basis of title or abstract and three were excluded after reviewing the full text. There were seven studies, pertaining to 146 participants that met the criteria for inclusion (Table 1). Strong agreement ($k = 0.87$) was achieved between reviewers regarding study selection.[27] Limited meta-analysis was possible due to study heterogeneity related to technique application and outcome measure metrics.

Quality assessment

There was consistent agreement between reviewers for the quality assessments, with ratings outlined in Table 1. Agreement between reviewers for the Pedro items was 85%, with the mean (SD) PEDro score of 5(1) points. For the Downs and Black item, agreement was 87% between reviewers, with a mean score of 20(2) points. All trials scored high on the quality of reporting but lower for the external and internal validity. The majority of study designs limited the ability to blind participants or therapists to group allocation, and some studies did not utilize a blinded assessor. It was frequently difficult to determine if compliance with the intervention was reliable. As all studies had a relatively small sample size, there is a risk that a clinically important intervention effect was recorded as statistically insignificant.[28]

Participants

A total of 146 participants were included in these studies, of whom 55 (37%) were males. The sample sizes ranged from eight to 36 participants. The mean age range was 47–73 years, while disease severity ranged from a forced expiratory volume (FEV_1) of 53–76% predicted.

Intervention

This review included seven randomized crossover trials.[19–22,29–31] One study had a treatment duration of 6 months,[29] one included four weeks of treatment,[21] and the five studies compared single treatment sessions.[19,20,22,30,31] Oscillating PEP using the Flutter® valve was compared to GAD with ACBT in three studies,[19–21] to ACBT in a seated position in one study,[22] and a control condition in two studies.[30,31] In the three studies of single treatment sessions, oscillating PEP using the Acapella® was compared to the GAD with ACBT,[20] to inspiratory muscle training (IMT),[30] and a control condition.[31]

Outcome measures

Lung function

The studies comparing longer-term treatment exhibited contrasting results. Three months of oscillating PEP were associated with no difference in lung function compared to no treatment.[29] In contrast, four weeks of GAD with ACBT were associated with greater post bronchodilator FEV_1 (mean difference [95% CI] of 0.08 L [0.01–0.15 L]) compared to Flutter®, although there was no difference between FVC ($p = 0.09$) between techniques.[21] A single treatment session of oscillating PEP using either the Acapella® or Flutter® compared to ACBT with or without GAD was associated with no difference in spirometry measures.[19,20,22] Compared to control (seated comfortably for 15 minutes with no manoeuvres), the Flutter® reduced functional residual capacity (FRC; −25.8% predicted [−52.0 to −5.4%] vs. 4.3% predicted [−18.9 to 22.4], $p < 0.05$) and total lung capacity (TLC; −18.3% predicted [−42.8 to −5.1] vs. 4.6% predicted [−7.5 to 12.6], $p < 0.05$), but there was no difference for inspiratory capacity (IC), vital capacity (VC), and residual volume (RV).[19] The Flutter® had a similar effect on FRC, TLC, RV, IC, and VC as expiratory manoeuvres to residual volume with an open glottis in the lateral decubitus position (Table 2).[19]

Measures of sputum clearance

Two studies recorded sputum wet weight,[20,30] one study measured dry weight,[19] one study measured both wet volume and dry weight,[22] and three studies did not specify whether wet or dry sputum was assessed.[21,29,31] The results of the seven studies examining the effects of treatment on sputum expectoration were mixed (Table 2). Compared to no treatment,

Table 1. Characteristics of study participants in randomized trials.[a]

Study design	PEDro	Downs and Black	*N*	Gender M/F	Age (years)	Baseline sputum volume (ml)	FEV_1 (% pred)	Intervention
Thompson 2002 RC-OT	3/10	20/27	22	8/11	NR	NR	NR	Intervention: Oscillatory PEP – Flutter® tilted to achieve maximum vibrations felt in chest, followed by FET, twice daily until no further sputum to expectorate. Control: GAD with ACBT, twice daily until no further sputum to expectorate.
Patterson 2005 RC-OT	6/10	23/27	20	7/13	58(11)	½ egg cup sputum per day	64(22)	Intervention: Oscillatory PEP —Acapella® (10–20 cm H_2O during 10 breaths, SMI, FET and cough) in 2 GAD positions. End of Rx set by 15 minutes in each GAD position, no further sputum expectoration or patient fatigue. Control: ACBT (TEE with FET) in 2 GAD positions with percussion and/or vibrations. End of Rx set by 15 minutes in each GAD position, no further sputum expectoration or patient fatigue.
Eaton 2007 RC-OT	5/10	22/27	36	12/24	62(10)	NR	58(20)	Intervention: Oscillatory PEP —Flutter® Control 1: ACBT (BC, TEE, FET, cough) in GAD. End of Rx set by two non-productive cycles and clear huff, completed minimum of 10 minutes, still productive but reached maximum of 30 minutes. Control 2: ACBT (BC, TEE, FET, cough) in sitting. End of Rx set by two non-productive cycles and clear huff, completed minimum of 10 minutes, still productive but reached maximum of 30 minutes.
Murray 2009 RC-OT	4/10	22/27	20	12/8	73(5)[b]	NR	76(50)[b]	Intervention: Oscillatory PEP—Acapella® (3 sets of 10 breaths, 2–3 FET or cough), 2 sessions per day. Control: no Rx.
Naraparaju 2010 RC-OT	4/10	18/27	30	10/20	51(6)	30 ml per day	NR	Intervention: Oscillatory PEP —Acapella® (10 breaths, 2–3 seconds SMI), with FET/cough after every five breaths in seated position. Control: Threshold inspiratory muscle trainer (maximal expiration/inhalation to 80% of MIP, 10 breaths, 2–3 seconds SMI), with FET/cough after every five breaths in seated position.
Guimarães 2012 RC-OT	7/10	21/27	10	2/8	56(18)	NR	53(19)	Intervention: Oscillatory PEP—Flutter (tilt set by pt, 15 minutes) with coughing, followed by 5 minutes coughing at end of Rx) in seated position. Control 1: Positioned in lateral decubitus position with slow expirations with glottis open from FRC to RV, with affected lung in dependent position, three sets of ten breaths (ELTGOL). Control 2: Control: seated for 15 minutes.

(continued)

Table 1. (continued)

Study design	PEDro	Downs and Black	*N*	Gender M/F	Age (years)	Baseline sputum volume (ml)	FEV_1 (% pred)	Intervention
Figueiredo 2012 RC-OT	6/10	17/27	8	4/4	47(6)	>25 ml per day	65(11)	Intervention: Oscillating PEP —Flutter® (tilt set by pt and perception of sputum, 15 minutes breathing, free to cough during Rx, followed by 5 minutes coughing) in seated position. Control: Sham Flutter® (no sphere or cover) (tilt set by pt and perception of sputum, 15 minutes breathing, free to cough during Rx, followed by 5 minutes coughing) in seated position.

IQR: interquartile range; RC-OT: randomized crossover trial; Rx: treatment; M: male: F: female; FEV_1: forced expiratory volume in one second; PEP: positive expiratory pressure; FET: forced expiratory technique; GAD: gravity-assisted drainage; ACBT: active cycle of breathing technique; BC: breathing control; SMI: sustained maximal inspiration; NR: not reported; TEE: thoracic expansion exercises; ELTGOL: expiration to residual volume with open glottis in the lateral decubitus position with the affected lung dependent; FRC: functional residual capacity; RV: residual volume; PT: patient.
[a]Data are mean (SD) unless otherwise stated.
[b]Median (IQR).

oscillating PEP was associated with greater sputum expectoration over 24 h with three months of treatment (median interquartile range [IQR] 2 [0–6] ml vs. −1 [−5–0] ml, $p = 0.02$)[29] and following a single treatment session (mean difference [95% CI] of 8.4 [3.4–13.4 ml]).[31] Similarly, oscillating PEP resulted in a greater sputum volume compared to threshold IMT (mean difference [95% CI] 0.9 [0.13 to 1.27 ml], $p = 0.01$).[30] In contrast, three studies found oscillating PEP (Flutter® or Acapella®) to be equally effective as GAD with ACBT in sputum expectoration prescribed over four weeks ($p = 0.77$)[21] or over a single treatment session[20,22] (Figure 2). ACBT in a seated position was also equally effective in sputum yield as the Flutter® (7.9 [11.4] vs. 7.3 [9.6 ml]).[22] However, greater volumes of sputum were expectorated with GAD and breathing exercises and in the five minutes posttreatment[19] compared to oscillating PEP therapy.

Oximetry

Two studies examined measures of gas exchange before and after treatment sessions (Table 2).[20,22] No differences in peripheral oxygen saturation (SpO_2) were evident between oscillating PEP therapy using the Acapella® compared to ACBT with GAD (97 [1] % vs. 97 [2] %)[20] or the Flutter® compared to ACBT with or without the addition of GAD.[22]

Symptoms

Three studies compared the effect of oscillating PEP with other types of ACT on dyspnoea levels,[20–22] using the Borg scale[32] or the 15-count breathlessness questionnaire (Table 2).[33] Compared to four weeks of ACBT with GAD, oscillating PEP therapy did not reduce levels of breathlessness (mean difference [95% CI], 0.13 [−0.1 to 0.3], $p = 0.36$).[21] After a single treatment session, there was no difference in Borg scale[22] or the 15-count breathlessness scale between oscillating PEP and ACBT with GAD.[20]

Acceptability of the technique

Three studies explored patient preference and subjective measures of acceptability and tolerability of other treatment techniques (Table 2).[20,22,30] A greater preference for oscillating PEP was reported in two studies over ACBT with or without GAD,[20,22] with higher patient comfort levels with the oscillating PEP.[22] While the Acapella® was perceived to be more useful in clearing secretions compared to IMT ($p = 0.03$), there was no difference in patient comfort ($p = 1.00$).[30]

Quality of life

Two studies examined the effect of oscillating PEP on HRQOL with conflicting results (Table 2).[21,29] Three

Table 2. Summary of study findings for randomized trials.

Study design	Study duration	Outcome measures	Changes in oscillating PEP group compared to control group
Thompson 2002 RC-OT	8 weeks (4 weeks per Rx)	Sputum weight: over 4 weeks (measured using daily sputum expectoration)	Improvement in FEV_1 in those performing Flutter® first ($p = 0.03$)
		Dyspnoea: Borg scale, pre and postsession	No difference in sputum weight, FVC or CRDQ
		Lung function: Postbronchodilator FEV_1, FVC (L) at baseline and after 4 weeks of treatment	No difference in dyspnoea score
		QOL: CRDQ	65% patients preferred Flutter® for daily use, 18% preferred ACBT with GAD, 18% no preference
		Patient preference	
Patterson 2005 RC-OT	2 days of Rx	Lung function: FEV_1, FVC % predicted	No difference in lung function, SpO_2 or breathlessness
		SpO_2	Trend towards greater proportion of patients preferring Acapella® (70% vs. 30%)
		Sputum weight (g): collected during treatment and 30 minutes posttreatment	
		15-count breathlessness score	
		Patient preference	
Eaton 2007 RC-OT	3 days (1 day per Rx)	Sputum wet volume (g and ml): collected during treatment and 30 minutes post treatment	Less sputum volume/weight with Flutter® compared to ACBT with GAD, but not ACBT
		SpO_2	No difference in dyspnoea scores, SpO_2 or FEV_1
		Lung function: FEV_1, FVC (% predicted)	ACBT with GAD perceived to be more useful in clearing secretions than ACBT.
		Dyspnoea score: Borg scale	Flutter® associated with less discomfort and interference than ACBT + GAD
		Scale of acceptability and tolerability (7-point Likert scale)	44% preferred Flutter versus 22% for ACBT and 33% for ACBT + GAD
		Patient preference	
Murray 2009 RCT	6 months (3 months per Rx)	Lung function: FEV_1 (L), FVC (L), $FEF_{25–75}$ (L/second)	Greater sputum expectoration with Acapella®
		QOL: SGRQ, LCQ	Improvement in HRQOL in activity domain of SGRQ and all domains of LCQ
		Sputum expectoration (ml): 24 hours volume	No change in lung function, exacerbation frequency
		Exacerbation frequency	
Naraparaju 2010 RC-OT	2 days (1 day per Rx)	Sputum expectoration (ml): collected during and up to 2 hours posttreatment	Greater sputum expectoration with Acapella®
		Patient preference scale for usefulness, convenience, comfort, and overall performance	More usefulness in clearing secretions, but no difference in comfort, convenience or overall performance
Guimarães 2012 RC-OT	3 day (1 day per Rx)	Static lung volumes: FRC, RV, TLC, IC, VC	Lower IC and TLC with Flutter® compared to control and ELTGOL
		Lung function: FEV_1, FVC, FEV_1/FVC, $FEF_{25–75\%}$ (L)	RV, FRC and TLC reduced in Flutter® compared to control, but no difference to ELTGOL
		Sputum expectoration (g—dry weight): expectorated during intervention and in later 5 minutes coughing period.	Less sputum with Flutter® compared to ELTGOL
Figueiredo 2012 RC-OT	1 day per Rx	Sputum expectoration (ml—wet weight): during intervention	Greater sputum expectoration with Flutter® compared to sham treatment

RC-OT: randomized crossover trial; RCT: randomized controlled trial; PEFR: peak expiratory flow rate; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; PEFR: peak expiratory flow rate; CRDQ: chronic respiratory disease questionnaire; FET: forced expiratory technique; GAD: gravity-assisted drainage; ACBT: active cycle of breathing technique; TLC: total lung capacity; RV: residual volume; IC: inspiratory capacity; VC: vital capacity; QOL: quality of life; LCQ: Leicester cough questionnaire; Rx: treatment; ELTGOL-L: expiration Lente Totale Glotte Ouverte en Decubitus Lateral.

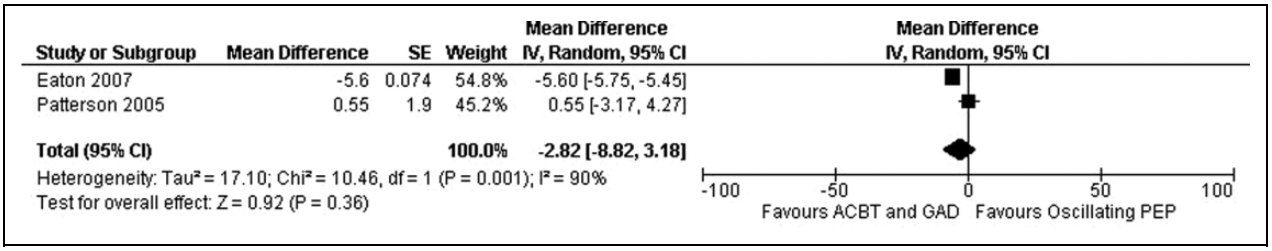

Figure 2. Forest plot comparing oscillating PEP to ACBT with GAD for sputum expectoration (wet weight (g)). PEP: positive expiratory pressure; ACBT: active cycle of breathing technique; GAD: gravity-assisted drainage.

months of treatment was associated with improvement in cough-related quality of life (QOL) according to the Leicester cough questionnaire for the domains of physical ($p = 0.002$), psychological ($p < 0.0001$), and social impact ($p = 0.02$) compared to no treatment. There was also improvement in the total St. George's respiratory questionnaire score with twice daily oscillating PEP compared to no treatment ($p = 0.005$) as well as the activities domain ($p = 0.02$) but not symptoms or impact.[29] In contrast, four weeks of oscillating PEP produced equivalent effects as GAD with ACBT on dyspnoea, fatigue, emotional function, and mastery according to the chronic respiratory disease questionnaire ($p > 0.99$).[21]

Exacerbation and hospitalization rates

The effect on exacerbation rates was explored in only one study.[29] A total of five exacerbations were experienced during three months of oscillating PEP compared to seven exacerbations with no treatment ($p = 0.48$). No study explored the impact on hospitalization rates.

Discussion

This is the first systematic review examining the effects of oscillating PEP therapy compared to other techniques or control in patients with non-CF bronchiectasis. The key findings are that compared to no treatment, oscillating PEP therapy enhanced sputum expectoration and HRQOL. However, when compared to combinations of GAD and ACBT, there was no advantage in sputum yield or HRQOL. Oscillating PEP offered no advantage in improving gas exchange or reduction in breathlessness. There was, however, a greater patient preference of oscillating PEP compared to ACBT with or without GAD.

The improved sputum volume and expectoration with oscillating PEP therapy compared to no treatment suggests that altered sputum rheology and enhanced mucociliary clearance may be achieved with this intervention.[15,16] This is despite the lack of consensus surrounding the optimal use of sputum expectoration as an outcome, including dry versus wet weight/volume, collection duration and the reliance on patient compliance with collection strategies. The evidence of greater sputum yield following three months of treatment or a single session implies that modes of oscillating PEP may result in both long- and short-term results in sputum clearance.[29,31] In contrast, while the mode of threshold IMT was designed to facilitate secretion movement through expiratory flow (two-phase gas–liquid flow),[34] it appears to be a less effective technique compared to oscillating PEP.[34]

The comparable effects of oscillating PEP to ACBT with or without GAD on sputum expectoration in some studies[20,21] is encouraging. While this may be influenced by the inclusion of FET and coughing manoeuvres and the similar duration of treatment for both interventions, equivalent benefits for this outcome suggests other factors which guide the selection of ACT, including patient preference and factors affecting adherence, including side effects can be considered in clinical practice. In addition, irrespective of whether treatment is applied for a single session or four weeks of therapy, there was a greater patient preference towards modes of oscillating PEP therapy over alternative techniques.[20–22] This predilection has been previously reported in patients with CF for PEP therapy[35] and may be related to the independence and novelty of the technique in non-CF bronchiectasis.

The greater sputum expectoration with other ACTs evident in two studies could be related to the performance of the actual technique. Compared to the Flutter®, the breathing manoeuvres used with lateral positioning focused on expiration to residual volume.[19] While a similar reduction in pulmonary hyperinflation was achieved with both techniques, the two-phase gas–liquid flow achieved through expiration

to residual volume[17] may promote greater mobilization of more peripheral secretions compared to oscillating PEP therapy. This should be confirmed through further physiological study. Eaton et al. found greater sputum expectoration with ACBT and GAD which may be due to the precise positioning which was based on cHRCT to maximize the effectiveness of this technique.[22] With the lack of a description of the exact instructions applied for the Flutter® in this study, it is difficult to identify if variations in technique application may have accounted for greater sputum expectoration in this study.

The lack of improvement in oxygen saturation with oscillating PEP compared to other techniques could be related to the minimal gas exchange impairment prior to commencement of therapy, with SpO_2 measures as high as 97%.[20] GAD has not been associated with improvements in gas exchange in a previous report of patients with non-CF bronchiectasis.[36] However, the current review included only patients in a stable clinical state; differing results may be apparent in those experiencing an acute exacerbation. While oscillating PEP did not offer a greater advantage in reducing breathlessness compared to ACBT with or without GAD,[20–22] the prescribed routine for oscillating PEP did not increase dyspnoea. Although this symptom is not considered a common side effect of ACTs in non-CF bronchiectasis in clinical practice, minimal symptom exacerbation may influence patient adherence.

Lung function is a common clinical index of treatment efficacy in non-CF bronchiectasis.[37] However, in these studies of oscillating PEP therapy, irrespective of the timing of spirometry measurement, the majority of studies found no change in dynamic lung volumes. Even the degree of reduction in FEV_1 with Flutter® performed in seated position compared to GAD with ACBT was not clinically significant.[21] This is possibly related to the measurement procedure, with the compressive manoeuvres during spirometry limiting its use as an outcome measure.[38] In non-CF bronchiectasis, factors which contribute to airway narrowing, including mucus retention, inflammation, and airway remodelling may influence ventilation heterogeneity and therefore measures of FEV_1 and FEV_1/FVC.[39] In contrast, static lung volumes reflect airway alterations such as bronchiolectasis and bronchiolitis which are not always linked to airway obstruction.[5,40] The improvement in TLC and FRC suggests that both oscillating PEP and breathing manoeuvres in lateral positions may reduce pulmonary hyperinflation and improve respiratory mechanics in non-CF bronchiectasis.[19] These measures, together with other outcomes including the lung clearance index may be more sensitive to change following any type of ACT and of greater clinical utility.[41]

The three-month improvements in disease-specific and cough-related QOL with oscillating PEP compared to no treatment[29] are promising findings for clinical practice, suggesting that for those patients not previously performing ACTs, improvements in HRQOL following introduction of this technique as part of overall management could be expected. The lack of advantage of oscillating PEP compared to GAD with ACBT[21] implies that the inclusion of an ACT is more important than the actual technique.

Acute exacerbations in non-CF bronchiectasis are a significant source of morbidity[42] and reducing their frequency is a key goal of treatment.[4,43] While twice daily oscillating PEP did not positively impact on exacerbation frequency,[29] the three-month study duration may limit the ability to accurately assess this end point. Measurement of exacerbation frequency over a longer period of at least six or 12 months is necessary to gain a clearer indication of the impact of oscillating PEP therapy on exacerbation frequency as well as the number of hospital and emergency admissions, days of hospital admissions, and the need for antibiotic therapy.

The primary limitations of this review are related to the small number of studies and the diverse application of treatment regimens. The small study sample sizes may introduce the risk of not identifying clinically important effects for some outcomes. The lack of assessor blinding in studies measuring the impact on symptoms and QOL increases the risk of bias. The exclusion of articles published in language other than English may also limit the results. The majority of studies in this review included patients with mild to moderate disease severity based on spirometry; the ability to generalize the findings to a broader non-CF bronchiectasis population is limited. For randomized crossover trials, a washout period was not consistently included and for selected outcomes in both short and longer-term studies, this may influence the results.

In conclusion, despite the diversity of techniques applied, this review suggests that oscillating PEP therapy facilitates sputum expectoration compared to no treatment and may be as equally effective as other ACTs in patients with non-CF bronchiectasis. Oscillating PEP therapy may reduce measures of

pulmonary hyperinflation. Short-term treatment using the Acapella® or the Flutter® is a preferred mode of therapy compared to other techniques. Further study is required to determine the longer term treatment of oscillating PEP therapy compared to other ACTs in patients with non-CF bronchiectasis, with a mix of physiological and clinical outcomes measures, including lung clearance markers, indices associated with acute exacerbations, HRQOL, and economic evaluation.

Conflict of interest

The authors declared no conflicts of interest.

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