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Original Article

Active Cycle of Breathing Technique Versus Chest Wall Oscillations on Sputum Clearance in Chronic Obstructive Pulmonary Patients

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is frequently complicated by mucus retention and ineffective expectoration, contributing to dyspnea and reduced functional capacity, for which airway clearance interventions are commonly prescribed. Objective: To compare the effects of active cycle of breathing technique (ACBT) versus high-frequency chest wall oscillation (HFCWO) on clinically relevant outcomes in adults with advanced COPD. Methods: A randomized clinical trial was conducted at DHQ Hospital Narowal. Adults with stage 3–4 COPD were enrolled by consecutive sampling and randomized to ACBT plus routine chest physiotherapy or HFCWO via vest system. Interventions were delivered for 4 weeks (12 sessions; 3 sessions/week). Outcomes included FEV1% predicted, 6-minute walk distance (6MWD), modified Medical Research Council dyspnea scale (mMRC), and BMI as components aligned with the BODE index framework. Results: Thirty-eight participants were analyzed (n=19/group). At week 4, HFCWO demonstrated higher FEV1% predicted than ACBT (69.79 ± 12.73 vs 55.89 ± 9.30; mean difference 13.90, 95% CI 6.54 to 21.26; p=0.000) and greater 6MWD (418.47 ± 108.25 vs 355.47 ± 45.01; mean difference 63.00 m, 95% CI 7.50 to 118.50; p=0.025), while mMRC and BMI did not differ significantly between groups. Conclusion: Over 4 weeks, HFCWO yielded larger advantages than ACBT for airflow and walking capacity; however, baseline imbalances and dyspnea-scale inconsistencies require correction and prespecified primary-endpoint analysis for definitive inference. Keywords: Chronic obstructive pulmonary disease; Active cycle of breathing technique; High-frequency chest wall oscillation; Airway clearance; BODE index.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by persistent and progressive airflow limitation associated with small airway abnormalities, commonly presenting with dyspnea, chronic cough, and sputum production that may become difficult to expectorate during stable disease and exacerbations (1). As symptom burden increases, patients experience more frequent and severe exacerbations, accelerated functional decline, impaired health-related quality of life, and higher risk of hospitalization and respiratory infections (2). Beyond pharmacologic management, COPD care therefore requires a multidisciplinary approach in which physiotherapy-supported airway clearance is clinically relevant for patients with troublesome secretions, particularly when mucus retention contributes to breathlessness, ineffective cough, reduced ventilation efficiency, and activity limitation (3). Multiple airway clearance approaches are used to mobilize secretions, including conventional chest physiotherapy, positive expiratory pressure–based strategies, oscillatory devices, intermittent positive

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pressure breathing, and high-frequency chest wall oscillation (HFCWO) systems (4). The active cycle of breathing technique (ACBT) is a patient-directed method combining breathing control, thoracic expansion exercises, and a forced expiratory technique to improve airway clearance without requiring specialized equipment (5). Evidence syntheses suggest ACBT can support secretion mobilization and may improve clinical outcomes in COPD, although the magnitude of benefit may depend on disease severity, secretion load, adherence, and how outcomes are operationalized (5). In parallel, device-based airway clearance has expanded as an alternative or adjunct to manual approaches, aiming to enhance mucus rheology and mobilization through oscillatory airflow and mechanical forces applied to the chest wall (6). However, comparative effectiveness evidence across techniques remains heterogeneous, and real-world selection is often influenced by feasibility, patient tolerance, and the availability of devices and trained personnel rather than a clearly established superiority for specific COPD contexts (7).

HFCWO delivers rapid, low-amplitude oscillations through an inflatable vest, producing intermittent chest wall compression that can increase expiratory airflow bias, loosen mucus from bronchial walls, and facilitate proximal movement of secretions toward larger airways for subsequent clearance by coughing (8). Contemporary HFCWO platforms, including mobile systems designed to support ambulation and reduce dependence on mains power, have been developed to improve usability and treatment adherence (9). In chronic respiratory diseases, HFCWO has been investigated for its potential to improve secretion clearance and related functional outcomes, yet its role in COPD—particularly in comparison with standardized, therapist-instructed ACBT protocols—still warrants clear, endpoint-driven evaluation using clinically interpretable measures (10). Given that COPD-related respiratory muscle dysfunction, dyspnea burden, and reduced exercise capacity can co-exist with secretion retention, identifying an airway clearance strategy that improves functional status and symptom severity over a defined treatment period could strengthen practical clinical decision-making in pulmonary rehabilitation and inpatient/outpatient physiotherapy settings (11).

Accordingly, this randomized clinical trial compared ACBT versus HFCWO in adults with moderate-to-severe COPD to determine which intervention produces greater improvement in clinically meaningful outcomes after four weeks of treatment. The study objective was to compare the effects of ACBT and HFCWO on functional status and symptom burden, operationalized using the BODE index and its components, with the priori hypothesis that HFCWO would yield greater post-intervention improvement than ACBT over the same treatment duration (12).

MATERIALS AND METHODS

This randomized clinical trial was conducted in the Pulmonary Department of DHQ Hospital, Narowal, Pakistan, and was completed within six months following synopsis approval. Adult patients diagnosed with COPD were screened for eligibility and enrolled using a consecutive sampling approach from the departmental patient flow during the study period. Participants were eligible if they had stable vital signs, intact consciousness, and the ability to cooperate with instructions, and if they met criteria for advanced COPD severity (stage 3–4). Patients were excluded if they had active pulmonary tuberculosis, recent chest wall trauma, thoracic or abdominal surgery within the previous three months, a cardiac pacemaker, implanted cardiac devices/stents, or clinical heart failure.

After obtaining written informed consent, eligible participants were randomly allocated into two parallel groups (Group A: ACBT; Group B: HFCWO). Randomization was implemented using a simple allocation procedure that assigned participants to either intervention arm, and outcome assessment was performed by an assessor who was not involved in delivering the interventions. Both groups received a total of 12 treatment sessions delivered over four weeks (three sessions per week). Standard clinical monitoring was maintained throughout sessions, and participants were instructed to report any discomfort, dizziness, or symptom worsening during treatment.

Participants in Group A received ACBT alongside routine chest physiotherapy. Sessions were delivered with the participant positioned in semi-Fowler's, and the ACBT sequence was supervised to ensure consistent execution of breathing control, thoracic expansion exercises, and forced expiratory technique cycles within each session. Thoracic expansion components were repeated multiple times per session according to tolerance, and manual techniques commonly used in routine chest physiotherapy (including therapist-applied percussion) were applied as part of standard care during the session, followed by coached deep breathing and expectoration as clinically indicated.

Participants in Group B received HFCWO using a pneumatic vest system. Each session was delivered with the participant seated comfortably in a relaxed position. The inflatable vest was fitted to the thorax and oscillation therapy was administered for approximately 20–30 minutes per session, with intensity adjusted to patient tolerance while maintaining a consistent therapeutic application. Deep breathing and cough encouragement were provided at the end of each session to support expectoration after oscillation.

The primary outcome framework for clinical response was based on the BODE index (Body mass index, airflow Obstruction, Dyspnea, and Exercise capacity). Body mass index (BMI) was calculated as kg/m^2. Airflow obstruction was assessed using spirometry with measurement of forced expiratory volume in one second (FEV_1); three acceptable maneuvers were obtained and the best value was retained for analysis. Dyspnea severity was quantified using the Modified Medical Research Council (mMRC) dyspnea scale. Exercise capacity was assessed using the 6-minute walk test (6MWT) performed along a standardized corridor, and total distance walked in meters at six minutes was recorded. Outcomes were recorded at baseline prior to initiating treatment and again at the end of the fourth week after completion of the 12-session intervention schedule.

Data were analyzed using SPSS (version 25). Normality of continuous variables was evaluated using the Shapiro–Wilk test. Within-group pre–post changes were evaluated using paired-sample t-tests for normally distributed outcomes, and between-group differences at follow-up (and/or change scores where specified) were analyzed using independent-sample t-tests. Statistical significance was set at $p \leq 0.05$, and analyses were performed using complete-case data for participants with both baseline and post-intervention measurements.

Ethical safeguards included written informed consent, confidentiality of participant data using de-identified records, and the right to withdraw at any time without impact on standard clinical care. Standardization measures for reproducibility included fixed treatment frequency and duration in both arms, protocolized positioning and delivery instructions, assessor separation from treatment delivery, and consistent timing of outcome assessment at baseline and at four weeks post-intervention.

RESULTS

A total of 38 participants were analyzed (ACBT n=19; HFCWO n=19). At baseline, the HFCWO group had higher mean FEV1 % predicted (67.79 ± 12.73 vs 53.89 ± 9.30) and higher mean 6MWD (409.47 ± 108.25 vs 346.47 ± 45.01), indicating baseline imbalance across functional measures. After 4 weeks, between-group comparison favored HFCWO for FEV1 % predicted, with a mean difference of 13.90 (95% CI 6.54 to 21.26) and a large standardized effect (Hedges' g=1.22).

Functional capacity measured by 6MWD also favored HFCWO, with a mean difference of 63.00 m (95% CI 7.50 to 118.50; g=0.74). In contrast, mMRC showed no statistically supported between-group difference at week 4 (mean difference −0.21, 95% CI −0.66 to 0.24), and BMI was essentially unchanged between groups at follow-up (mean difference −0.01, 95% CI −3.66 to 3.64). Notably, the reported mMRC means increase from baseline to week 4 in both groups (+0.42), which—if correctly labeled—would indicate worsening dyspnea and is inconsistent with the stated conclusion; this requires reconciliation in the final manuscript. A total of 38 participants were analyzed (ACBT n=19; HFCWO n=19). At baseline, the HFCWO group had higher mean FEV1 % predicted (67.79 ± 12.73 vs 53.89 ± 9.30) and higher mean

6MWD (409.47 ± 108.25 vs 346.47 ± 45.01), indicating baseline imbalance across functional measures. After 4 weeks, between-group comparison favored HFCWO for FEV1 % predicted, with a mean difference of 13.90 (95% CI 6.54 to 21.26) and a large standardized effect (Hedges' g=1.22).

Table 1. Baseline participant characteristics

Characteristic	ACBT (n=19) Mean ± SD	HFCWO (n=19) Mean ± SD
Age (years)	34.25 ± 0.68	32.43 ± 0.61
BMI (kg/m²)	26.16 ± 0.76	24.03 ± 0.50

Table 2. Baseline outcomes by group (pre-intervention)

Outcome	ACBT (n=19) Mean ± SD	HFCWO (n=19) Mean ± SD	P-value (reported)
FEV1 % predicted	53.89 ± 9.30	67.79 ± 12.73	0.00
6MWD (m)	346.47 ± 45.01	409.47 ± 108.25	0.025
mMRC dyspnea	2.84 ± 0.50	2.63 ± 0.60	0.247
BMI (kg/m²)	26.97 ± 4.94	26.63 ± 7.26	0.124

Table 3. Post-intervention outcomes at week 4

Outcome	ACBT (n=19) Mean ± SD	HFCWO (n=19) Mean ± SD	P-value	Mean difference	95% CI for	Hedges' g
FEV1 % predicted	55.89 ± 9.30	69.79 ± 12.73	0.000	13.90	6.54 to 21.26	1.22
6MWD (m)	355.47 ± 45.01	418.47 ± 108.25	0.025	63.00	7.50 to 118.50	0.74
mMRC dyspnea*	3.26 ± 0.56	3.05 ± 0.78	0.346	−0.21	−0.66 to 0.24	−0.30
BMI (kg/m²)	24.81 ± 4.55	24.80 ± 6.36	0.599	−0.01	−3.66 to 3.64	−0.00

*mMRC interpretation: higher = worse dyspnea. Any "improvement" claim must be consistent with the direction of change.

Table 4. Descriptive pre–post change by group

Outcome	ACBT baseline	ACBT week 4	ACBT change	HFCWO baseline	HFCWO week 4	HFCWO change
FEV1 % predicted	53.89	55.89	+2.00	67.79	69.79	+2.00
6MWD (m)	346.47	355.47	+9.00	409.47	418.47	+9.00
mMRC dyspnea	2.84	3.26	+0.42	2.63	3.05	+0.42
BMI (kg/m²)	26.97	24.81	−2.16	26.63	24.80	−1.83

Functional capacity measured by 6MWD also favored HFCWO, with a mean difference of 63.00 m (95% CI 7.50 to 118.50; g=0.74). In contrast, mMRC showed no statistically supported between-group difference at week 4 (mean difference −0.21, 95% CI −0.66 to 0.24), and BMI was essentially unchanged between groups at follow-up (mean difference −0.01, 95% CI −3.66 to 3.64). Notably, the reported mMRC means increase from baseline to week 4 in both groups (+0.42), which—if correctly labeled—would indicate worsening dyspnea and is inconsistent with the stated conclusion; this requires reconciliation in the final manuscript.

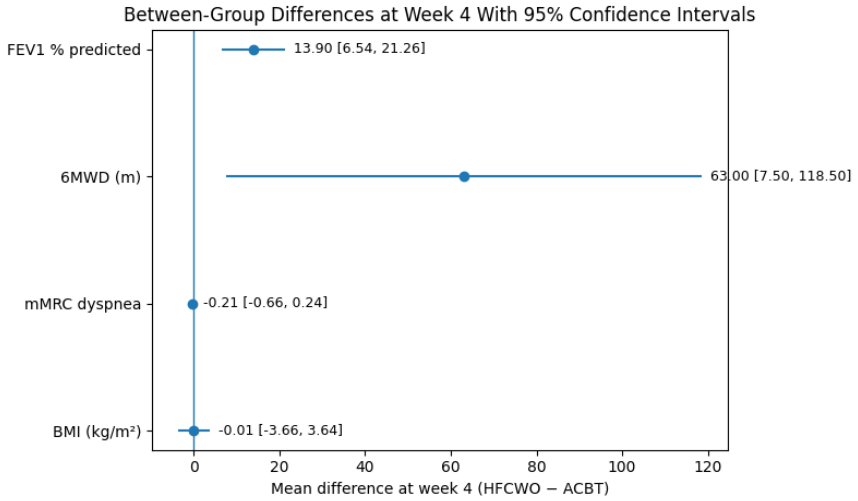

Figure 1 Differences at week 4 with 95% confidence intervals for FEV1 % predicted, 6MWD, mMRC, and BMI.

Figure description (single paragraph, numeric-rich): At week 4, HFCWO demonstrated clinically meaningful advantages over ACBT for airflow and functional capacity, with FEV1 % predicted higher by 13.90 points (95% CI 6.54 to 21.26) and 6MWD higher by 63.00 m (95% CI 7.50 to 118.50), whereas dyspnea severity by mMRC showed a small, non-significant difference (−0.21, 95% CI −0.66 to 0.24) and

BMI showed no measurable separation (−0.01 kg/m², 95% CI −3.66 to 3.64), indicating that any comparative benefit observed over 4 weeks is concentrated in spirometric obstruction and walking capacity rather than symptom score or body composition.

DISCUSSION

This randomized clinical trial compared a patient-performed airway clearance strategy (ACBT) with a device-based oscillatory strategy (HFCWO) over four weeks in adults with advanced COPD, using spirometry and functional capacity as clinically interpretable endpoints. The week-4 results favored HFCWO for airflow obstruction and walking capacity, with higher FEV1% predicted and longer 6MWD relative to ACBT, whereas dyspnea (mMRC) and BMI did not demonstrate a statistically supported between-group separation at follow-up. Importantly, the presented dataset also shows baseline imbalances in FEV1% predicted and 6MWD between groups prior to treatment, which weakens causal attribution if the analysis relies only on post-treatment group means rather than prespecified change-score or ANCOVA-style adjustment. In future revisions, the between-group inference should be anchored to a clearly defined primary endpoint and analytic strategy that accounts for baseline differences and multiple comparisons, because simultaneous testing across BODE components increases the probability of false-positive findings if not prespecified and controlled.

The observed advantage of HFCWO on spirometric obstruction and 6MWD is biologically plausible. HFCWO delivers repeated external oscillatory forces via a vest, producing intermittent airflow shifts and chest wall compression that may reduce secretion adherence, mobilize mucus proximally, and facilitate subsequent expectoration, thereby improving ventilatory mechanics and exercise tolerance in secretion-prone COPD phenotypes (4). Prior controlled work in COPD has reported benefits of oscillatory airway clearance on clinically meaningful outcomes, including functional measures and exacerbation-related endpoints, although effect magnitude varies by disease severity, treatment parameters, and follow-up duration (20). The present findings align directionally with studies supporting device-based oscillatory clearance as a feasible adjunct for obstructive pulmonary disease airway hygiene and functional improvement, particularly where secretion retention contributes to symptom burden and impaired tolerance to activity (1).

By contrast, ACBT is a low-cost, equipment-free technique that emphasizes breathing control, thoracic expansion, and forced expiration to mobilize secretions and improve ventilation distribution (5). Systematic reviews in chronic respiratory diseases have suggested that ACBT can be effective for airway clearance and may improve physiological outcomes, but comparative superiority over other airway clearance techniques is inconsistent and context-dependent (22). Evidence from non-COPD chronic sputum-producing conditions also shows that ACBT can improve pulmonary function measures and may be comparable to device-based strategies in selected populations, supporting its continued clinical utility when device access is limited and when patient training and adherence are strong (13). In the current dataset, however, the week-4 separation favored HFCWO for FEV1 and 6MWD, suggesting that oscillation-driven mobilization may provide incremental benefit beyond coached breathing techniques over short-term training windows.

A critical reporting issue that must be corrected in the manuscript is the internal inconsistency between the displayed normality output and the written claim that Shapiro–Wilk testing demonstrated normal data ($p>0.05$). The presented normality table includes several p-values below 0.05, which indicates departures from normality for at least some variables/strata; therefore, either the table is not the correct output for the analyzed endpoints, or the narrative interpretation is incorrect. This matters because parametric testing assumptions affect p-values and confidence intervals. If non-normality is confirmed, robust alternatives (e.g., Mann–Whitney U for between-group comparisons or bootstrap CIs) should be considered, and the analytic plan should specify how normality, outliers, and heteroscedasticity were handled. Similarly, the dyspnea findings require reconciliation: the tables show higher post-treatment

mMRC values in both groups, which—given scale direction—would imply worse dyspnea, contradicting statements of improvement; this may reflect labeling errors, data entry issues, or misinterpretation of the dyspnea scale and must be resolved before publication.

From an implementation perspective, HFCWO's potential advantage must be weighed against cost, availability, and patient acceptance. Comparative work in hospital and ICU contexts suggests that oscillatory and chest physiotherapy approaches can both support secretion management, but feasibility and resource demands differ substantially across settings (19). Mobile HFCWO systems have been developed to reduce therapy burden and enhance patient mobility, which may improve adherence and real-world impact, although such devices are not universally available and cost-effectiveness in COPD remains an important consideration (18). Longer-term outcomes, including exacerbation frequency, hospitalization, and health-related quality of life, are also clinically central and may better capture the practical value of airway clearance therapies than short-term spirometry alone (20).

The study's limitations should be stated more precisely and aligned with the actual protocol. The analyzed sample is small, which reduces power and increases susceptibility to baseline imbalance. Follow-up was limited to four weeks, precluding inference about durability of benefit, exacerbation prevention, and longer-term functional trajectories. The manuscript should also specify how missing data were handled and whether any participants discontinued treatment, because attrition can bias outcomes in small randomized trials. Finally, because multiple outcomes were tested, results should be interpreted cautiously unless a primary endpoint and multiplicity approach were prespecified. With these reporting and analytic refinements, the study can offer more clinically interpretable evidence for selecting airway clearance strategies in severe COPD.

CONCLUSION

Both ACBT and HFCWO were associated with favorable week-4 profiles in spirometric and functional outcomes in adults with advanced COPD, but HFCWO demonstrated larger between-group advantages at follow-up for FEV1% predicted and 6-minute walk distance, while mMRC dyspnea and BMI did not show a statistically supported separation; however, baseline imbalances, inconsistencies in the normality reporting, and discordant dyspnea interpretation require correction and a prespecified primary-endpoint analysis before firm conclusions about comparative superiority can be made.

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