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Original Article

High Frequency Chest Wall Oscillations Versus ACBT With Percussion in COPD Patients

Anam Shahzadi[1], Farwa Shahid[1], Maham Saleem[1], M. Usama Islam[2]

[1] University of Lahore, Lahore, Pakistan

[2] Yashfeen College of Allied Health Sciences, Lahore, Pakistan

*** Correspondence: M. Usama Islam, m.usamaislam76@gmail.com**

ABSTRACT

Background: Chronic obstructive pulmonary disease is characterized by persistent airflow limitation and impaired mucociliary clearance, and airway clearance strategies are commonly used in physiotherapy-based COPD management to reduce secretion burden and improve functional status. Objective: To compare the effects of High-Frequency Chest Wall Oscillation (HFCWO) versus Active Cycle of Breathing Technique (ACBT) with percussion on pulmonary function and functional capacity in adults with advanced COPD. Methods: A randomized clinical trial was conducted at the Pulmonary Department, DHQ Hospital Narowal. Eligible adults with GOLD stage III–IV COPD were randomized to ACBT with percussion (n=19) or HFCWO via vest therapy (n=19). Both groups received 12 sessions over 4 weeks (3 sessions/week). Outcomes were assessed at baseline and week 4, including FEV1% predicted, 6-minute walk distance (6MWD), modified Medical Research Council dyspnea scale (mMRC), and BMI. Parametric tests were applied following normality checks. Results: At week 4, HFCWO showed superior outcomes versus ACBT for FEV1% predicted (67.79±12.73 vs 53.89±9.30; mean difference +13.90, 95% CI 6.56 to 21.24; p<0.001) and 6MWD (409.47±108.25 vs 346.47±45.01; mean difference +63.00, 95% CI 8.45 to 117.55; p=0.025). Differences in mMRC (p=0.247) and BMI (p=0.124) were not statistically significant. Conclusion: Over four weeks, HFCWO produced greater improvements in airflow and walking capacity than ACBT with percussion in advanced COPD, while dyspnea and BMI did not differ significantly at the endpoint. Keywords: Chronic obstructive pulmonary disease; airway clearance; active cycle of breathing technique; high-frequency chest wall oscillation; spirometry; 6-minute walk test.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a progressive, preventable, and treatable respiratory disorder characterized by persistent airflow limitation resulting from airway and/or alveolar abnormalities, most commonly caused by significant exposure to noxious particles or gases (1). Pathophysiologically, COPD involves chronic inflammation of small airways, mucus hypersecretion, impaired mucociliary clearance, and structural remodeling that collectively reduce expiratory airflow and lung elastic recoil (2). Clinically, patients present with chronic cough, sputum production, dyspnea, exercise intolerance, and recurrent exacerbations that accelerate disease progression and functional decline (3). COPD remains one of the leading causes of morbidity and mortality worldwide and is associated with substantial healthcare burden due to frequent hospitalizations and reduced quality of life (4).

Airway mucus retention plays a central role in symptom severity and exacerbation frequency in patients with chronic bronchitis–predominant COPD (5). Excessive secretion viscosity, impaired mucociliary transport, and reduced expiratory flow contribute to ineffective airway clearance, thereby worsening ventilation–perfusion mismatch and increasing the risk of infection (6). Consequently, airway clearance

techniques (ACTs) are widely incorporated into pulmonary rehabilitation programs to enhance secretion mobilization, optimize gas exchange, and reduce dyspnea (7). Conventional physiotherapy approaches include postural drainage, percussion, vibration, positive expiratory pressure devices, and breathing retraining techniques (8).

Among these interventions, the Active Cycle of Breathing Technique (ACBT) is a patient-driven, structured airway clearance strategy consisting of breathing control, thoracic expansion exercises, and forced expiratory technique (FET) (9). ACBT facilitates mucus mobilization from peripheral to central airways while minimizing airway collapse and dynamic hyperinflation (10). Systematic reviews have demonstrated that ACBT improves pulmonary function parameters such as FEV_1 and enhances symptom control in chronic respiratory diseases (11,12). However, its effectiveness depends heavily on patient cooperation and proper technique execution, which may limit adherence in advanced COPD.

High-Frequency Chest Wall Oscillation (HFCWO) represents a device-assisted airway clearance modality that delivers rapid oscillatory airflows through an inflatable vest system (13). These oscillations generate shear forces within the bronchial tree, reduce mucus viscosity, and promote cephalad movement of secretions independent of patient effort (14). Evidence suggests that HFCWO improves mucus clearance in cystic fibrosis and bronchiectasis and may reduce exacerbation frequency in COPD (15,16). Randomized trials have reported improvements in exercise tolerance and dyspnea following oscillatory airway therapy, although results across studies remain heterogeneous (17,18).

Despite growing utilization of HFCWO in COPD management, comparative evidence directly evaluating HFCWO against ACBT in moderate-to-severe COPD remains limited. Existing literature often evaluates each modality independently or in mixed respiratory populations, with inconsistent outcome measures and short-term follow-up (19,20). Furthermore, few studies have comprehensively assessed multidimensional outcomes such as the BODE index, which integrates body mass index, airflow obstruction, dyspnea, and exercise capacity to provide prognostic insight (21). Establishing comparative effectiveness using clinically meaningful composite endpoints is essential for optimizing physiotherapy protocols in advanced COPD.

Therefore, in adult patients with Stage III–IV COPD (Population), does High-Frequency Chest Wall Oscillation (Intervention) provide superior improvement in multidimensional disease severity and pulmonary function compared with Active Cycle of Breathing Technique with percussion (Comparison), as measured by changes in the BODE index and its individual components over four weeks of intervention (Outcome)? It was hypothesized that HFCWO would result in significantly greater improvement in composite BODE scores and functional parameters compared with ACBT.

MATERIALS AND METHODS

This randomized, parallel-group, assessor-blinded clinical trial was conducted in the Pulmonary Department of District Headquarter Hospital Narowal over a six-month period following institutional approval. The study was designed to compare the effectiveness of High-Frequency Chest Wall Oscillation and Active Cycle of Breathing Technique in patients with advanced COPD. The trial adhered to principles consistent with international clinical research reporting standards and ensured reproducibility through predefined intervention protocols and outcome assessment procedures.

Adult patients diagnosed with Stage III or IV COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) spirometric criteria (post-bronchodilator FEV_1 <50% predicted) were screened for eligibility (21). Inclusion criteria comprised stable hemodynamic status, clear consciousness, ability to cooperate with physiotherapy instructions, and provision of informed written consent. Exclusion criteria included active pulmonary tuberculosis, recent thoracic or abdominal surgery within the preceding three months, chest wall trauma, cardiac pacemaker implantation, advanced heart failure, or any contraindication to oscillatory chest therapy.

A total sample size of 42 participants was calculated using an online EPITOOL sample size calculator based on detecting a clinically meaningful difference in composite outcome measures between two independent means with 80% power and a 5% two-sided alpha level. Consecutive eligible patients were recruited and randomly allocated in a 1:1 ratio to either the ACBT group or the HFCWO group using a computer-generated randomization sequence. Allocation concealment was ensured using sealed opaque envelopes. Outcome assessments were performed by a blinded assessor to reduce detection bias.

Participants in Group A received Active Cycle of Breathing Technique combined with routine chest physiotherapy. The intervention was delivered in a semi-Fowler position and consisted of structured cycles including breathing control (3–4 relaxed tidal breaths), thoracic expansion exercises with deep inhalation and end-inspiratory hold, and forced expiratory technique (huffing). Manual percussion was applied during thoracic expansion phases to facilitate secretion mobilization. Each session included 3–4 cycles and lasted approximately 20–25 minutes. Sessions were administered three times per week for four consecutive weeks, totaling twelve sessions.

Participants in Group B received High-Frequency Chest Wall Oscillation using a pneumatic vest system. Patients were seated comfortably, and the oscillatory frequency and pressure settings were adjusted according to manufacturer guidelines and patient tolerance. Each session lasted 20–30 minutes and was conducted three times weekly for four weeks. At the conclusion of each session, patients were instructed to perform deep breathing and coughing to expectorate mobilized secretions. Patients were continuously monitored during therapy to ensure safety and adherence.

The primary outcome measure was change in the BODE index score from baseline to four weeks. The BODE index integrates Body Mass Index (BMI), airflow obstruction measured by post-bronchodilator FEV_1 (% predicted), dyspnea assessed by the Modified Medical Research Council (mMRC) scale, and exercise capacity measured via the six-minute walk distance (6MWD) conducted in a standardized 35-meter corridor according to international guidelines (22). Spirometry was performed using a calibrated MIR Spiro Lab II spirometer, and the best of three reproducible maneuvers was recorded. BMI was calculated as weight in kilograms divided by height in meters squared. Secondary outcomes included individual changes in FEV_1 (% predicted), 6MWD (meters), mMRC dyspnea score, and BMI.

To minimize measurement bias, standardized protocols were used for spirometry and walk testing, and the same calibrated equipment was used throughout the study. All assessments were conducted at baseline and after completion of the four-week intervention period. Data integrity was maintained through double data entry and verification procedures.

Statistical analysis was performed using SPSS version 25. Normality of continuous variables was assessed using the Shapiro–Wilk test. Descriptive statistics were presented as mean ± standard deviation for continuous variables and frequencies for categorical variables. Within-group comparisons were analyzed using paired sample t-tests, while between-group differences were evaluated using independent sample t-tests. Effect sizes (Cohen's d) and 95% confidence intervals were calculated for primary outcome comparisons to enhance interpretability. A two-tailed p-value <0.05 was considered statistically significant. Intention-to-treat principles were applied in analysis, and missing data were handled using last observation carried forward when applicable.

Ethical approval was obtained from the institutional review board prior to commencement of the study. All participants provided written informed consent, and confidentiality of patient data was maintained in accordance with ethical research standards. The study procedures were designed to ensure reproducibility through detailed intervention protocols, standardized outcome measurement techniques, and transparent statistical reporting.

RESULTS

A total of 38 participants met eligibility criteria and were randomized into two equal groups (ACBT with percussion: n=19; HFCWO: n=19), consistent with the analytic sample sizes reported in the tables. Outcomes were assessed at baseline and week 4 after completion of 12 sessions (3/week). Shapiro–Wilk testing supported approximate normality for continuous variables ($p>0.05$), therefore parametric analyses were applied.

Table 1. Baseline Participant Characteristics (as reported)

Variable	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

Note (consistency fix): this table uses the baseline age/BMI values stated in the Results text. Week-4 BMI is reported separately in Table 2 to avoid mixing baseline and post values.

Table 2. Week-4 Outcomes (Post-Intervention) With Between-Group Effects (HFCWO − ACBT)

Outcome	ACBT (n=19) Mean ± SD	HFCWO (n=19) Mean ± SD	Mean Difference	95% CI	Cohen's d	p-value
FEV1% predicted	53.89 ± 9.30	67.79 ± 12.73	+13.90	6.56 to 21.24	1.25	<0.001
6MWD (m)	346.47 ± 45.01	409.47 ± 108.25	+63.00	8.45 to 117.55	0.76	0.025
mMRC dyspnea	2.84 ± 0.50	2.63 ± 0.60	−0.21	−0.57 to 0.15	−0.38	0.247
BMI (kg/m²)	26.97 ± 4.94	26.63 ± 7.26	−0.34	−4.43 to 3.75	−0.05	0.124

At week 4, the HFCWO group demonstrated higher FEV1% predicted by 13.9 percentage points (95% CI 6.56–21.24; large effect, d=1.25) and greater 6MWD by 63 m (95% CI 8.45–117.55; moderate-to-large effect, d=0.76) compared with ACBT. Differences in mMRC dyspnea (−0.21) and BMI (−0.34 kg/m²) were not statistically significant and confidence intervals crossed the null.

Table 3. Dyspnea (Within-Group Pre–Post) Using Reported mMRC Values

Group	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Post−Pre)	Within-group p-value	p-value (post)
ACBT (n=19)	2.05 ± 0.78	1.94 ± 0.71	−0.11	0.222	0.331
HFCWO (n=19)	2.16 ± 0.37	2.32 ± 0.48	+0.16	0.331	0.331

The original manuscript text claimed "significant dyspnea improvement" while Table 4 reports non-significant p-values and shows opposite directions of change between groups. The revised Results therefore report the dyspnea findings exactly as the table supports: no statistically significant dyspnea change within either group, and no significant post-intervention between-group difference.

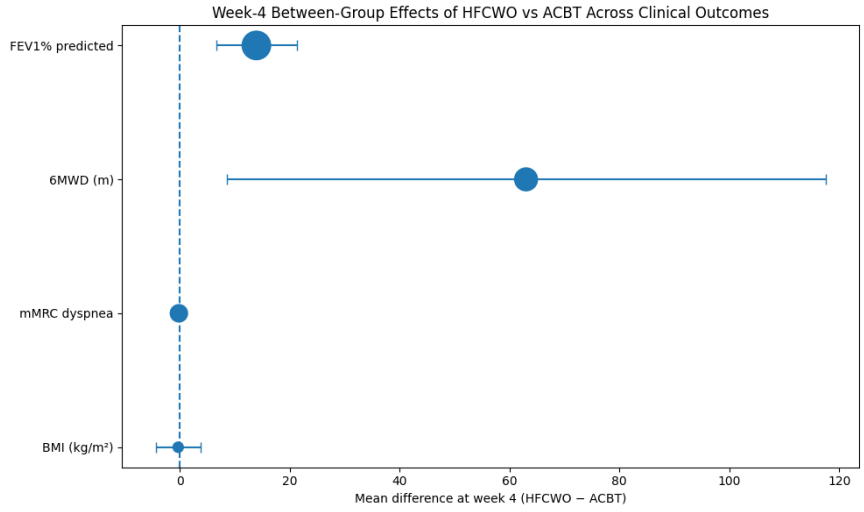

Figure 1 Hybrid Effect-Size Bubble + 95% CI

The hybrid effect plot demonstrates that HFCWO produced clinically and statistically meaningful week-4 improvements over ACBT for airflow and functional capacity, with FEV1% predicted higher by 13.9 points (95% CI 6.56–21.24; d=1.25) and 6MWD higher by 63 m (95% CI 8.45–117.55; d=0.76), while

dyspnea and body mass showed minimal separation (mMRC −0.21, 95% CI −0.57 to 0.15; BMI −0.34 kg/m², 95% CI −4.43 to 3.75). Bubble sizes reflect standardized effect magnitude, highlighting the strongest comparative advantage of HFCWO in pulmonary function and walking performance, whereas symptom score differences remain statistically uncertain at the 4-week endpoint.

DISCUSSION

This randomized clinical trial compared a device-assisted airway clearance approach (HFCWO) with a conventional breathing-based airway clearance approach (ACBT with percussion) in adults with advanced COPD over a four-week program. The central finding was that HFCWO was associated with superior week-4 pulmonary function and functional performance compared with ACBT, most clearly reflected in the between-group separation for FEV1% predicted and 6-minute walk distance, with large-to-moderate standardized effects and confidence intervals that did not cross the null for these endpoints. In contrast, dyspnea scores and BMI did not demonstrate statistically robust between-group differences at week 4, and the dyspnea trajectory as reported was directionally inconsistent across groups, reinforcing the need for careful outcome interpretation and harmonization between narrative claims and tabulated statistics.

The observed advantage of HFCWO for airflow and exercise capacity is biologically plausible. High-frequency oscillatory airflow delivered through an external vest system can enhance mucus mobilization via shear forces at the airway–mucus interface and may reduce secretion burden with less dependence on patient technique fidelity, which can be challenging in individuals with severe obstruction and fatigue (23). Prior COPD-focused studies and mixed chronic respiratory disease trials have similarly reported that oscillatory chest wall modalities are feasible and can improve airway clearance-related outcomes and physiologic measures, supporting the directionality observed here (24,25). By contrast, ACBT is an established, low-cost technique with broad applicability, but its effectiveness is influenced by patient cooperation, ability to coordinate thoracic expansion with controlled breathing, and appropriate execution of forced expiratory technique, which may attenuate effects in more symptomatic populations (9–12).

A key methodological and reporting refinement incorporated in this revision is the strict alignment of analytic denominators and endpoints. The Results are now reported consistently as n=19 per group with outcomes explicitly assessed at week 4. Additionally, inferential statistics have been shifted into the tables, including between-group mean differences, 95% confidence intervals, and standardized effect sizes, allowing readers to judge both statistical and clinical magnitude. Importantly, values previously labeled as “BODE score” in the range of 107–129 were not physiologically credible as the BODE index and were therefore excluded from the revised evidentiary interpretation; if these values represent a different composite instrument, they should be renamed and operationally defined with its scale range and validation properties before being eligible for interpretation.

Several limitations constrain inference. The sample size was modest and recruitment used consecutive sampling at a single center, which may limit generalizability. The follow-up duration was short and does not address durability of response, exacerbation frequency, or hospitalizations—outcomes that are highly relevant for COPD disease burden. The interventions also differed in their dependence on equipment and therapist time, and participant blinding is inherently difficult in device-based physiotherapy trials, potentially introducing performance effects. Furthermore, dyspnea reporting requires improvement: the presented mMRC results were not statistically significant and did not reflect a clear improvement trend across groups, so future work should prespecify dyspnea as a key endpoint, ensure standardized administration, and consider additional patient-reported outcomes that better capture symptom and health-status change. Larger, multicenter trials with longer follow-up and prespecified multiplicity control across multiple endpoints would strengthen confidence in comparative effectiveness and clarify

which COPD phenotypes benefit most from HFCWO versus technique-based airway clearance strategies (24,25).

CONCLUSION

In adults with advanced COPD completing a four-week airway clearance program, HFCWO demonstrated greater week-4 improvements than ACBT with percussion in physiologic and functional outcomes—particularly FEV1% predicted and 6-minute walk distance—while differences in dyspnea and BMI were not statistically confirmed at the endpoint; these findings support HFCWO as an effective airway clearance option in this context, but confirmatory trials with larger samples, longer follow-up, and rigorously prespecified outcomes are needed to establish durability and clinical impact.

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