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EFFECTIVENESS OF ACTIVE CYCLE OF BREATHING TECHNIQUE (ACBT) WITH AND WITHOUT ACAPELLA IN IMPROVING AIRWAY CLEARANCE, DYSPNEA, AND PULMONARY FUNCTION IN COPD PATIENTS: A RANDOMIZED CONTROLLED TRIAL

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Abstract

Background: Chronic Obstructive Pulmonary Disease (COPD) is a progressive inflammatory condition of the respiratory system, characterized by chronic bronchitis, airway thickening, and emphysema. Acapella, a handheld device with both resistive and vibratory properties, aids in airway clearance by loosening and mobilizing secretions. Research suggests that Active Cycle of Breathing Techniques (ACBTs) can be beneficial for COPD patients by improving lung function and facilitating secretion clearance. This study aims to evaluate the effects of ACBT with and without Acapella on airway clearance, dyspnea, and pulmonary function in COPD patients.

Objective: To assess the impact of ACBT alone versus ACBT combined with Acapella on airway clearance, dyspnea, and pulmonary function tests in COPD patients.

Methods: This randomized controlled trial was conducted at Aziz Bhatti Shaheed Teaching Hospital and National Hospital Gujrat. A total of 54 participants were randomly assigned to two groups after obtaining informed consent. Baseline assessments included a questionnaire evaluating dyspnea and sputum production, along with pulmonary function tests. One group performed ACBTs alone, while the other used ACBTs in combination with the Acapella device. The supervised intervention lasted for four weeks. Data was analyzed using SPSS 25.

Results: Within-group analysis revealed significant improvements in the control group for forced vital capacity (FVC) (p=0.034), forced expiratory volume in one second (FEV1) (p=0.014), dyspnea

(p=0.001), other symptoms (p=0.005), and the affective dimension of the multi-dimensional profile (p=0.001). The treatment group, which used Acapella, demonstrated even greater improvements in FVC (p=0.001), FEV1 (p=0.005), dyspnea (p=0.011), well-being (p=0.001), and the affective dimension (p=0.014). Between-group comparisons showed significant differences in post-treatment values for FVC (p=0.023), FEV1 (p=0.004), dyspnea (p=0.003), and other symptoms (p=0.005).
Conclusion: The combination of Acapella with ACBTs is more effective than ACBTs alone in improving airway clearance, dyspnea, and pulmonary function in COPD patients.

Keywords: COPD, Active Cycle of Breathing Technique, Acapella, airway clearance, dyspnea, pulmonary function tests, sputum diary, FEV1, FVC, randomized controlled trial

Introduction

Chronic Obstructive Pulmonary Disease (COPD) is the fourth leading cause of death globally, responsible for over three million deaths annually. The increasing morbidity and mortality rates associated with COPD have made it a significant global health priority. COPD is a progressive inflammatory disease of the respiratory system, characterized by chronic bronchitis, airway thickening, and emphysema. The severity and recurrence of exacerbations contribute to disease progression, leading to irreversible airway obstruction. This obstruction prevents effective expiration, resulting in small airway collapse and lung hyperinflation. The earliest symptom is chronic cough, typically linked to smoking or environmental exposures. As the disease advances, dyspnea becomes a primary concern, significantly impairing quality of life and leading to disability and depression. Additional symptoms include wheezing, chest tightness, weight loss, and anorexia in later stages (1).

Diagnosis of COPD relies on spirometry, with a post-bronchodilator forced expiratory volume in one second (FEV1)/forced vital capacity (FVC) ratio of less than 0.7, confirming airflow obstruction. Spirometry serves as a critical tool in assessing disease progression, healthcare utilization, exacerbation frequency, and mortality risk. A diagnosis is established when a patient presents with chronic cough, sputum production, and an FEV1/FVC ratio below 70%, along with an FEV1 less than 80% of the predicted value and a history of risk factor exposure (2).

Biomarkers such as plasma fibrinogen and C-reactive protein (CRP) levels have been associated with increased COPD risk, with CRP playing a key role in stratifying patients into low, medium, or high-risk categories. Alpha-1 antitrypsin deficiency is another critical factor, as its reduction in plasma correlates with higher disease susceptibility (3).

Due to persistent respiratory symptoms and airflow limitation, COPD remains a life-threatening condition, ranking just after stroke, ischemic heart disease, and lower respiratory infections in global mortality rates. In 2016 alone, COPD caused approximately three million deaths worldwide. Among the bacterial pathogens contributing to COPD exacerbations, Gram-negative *Chlamydophila pneumoniae* has been implicated. Additionally, poor oral hygiene and increased carotid artery intima-media thickness are linked to a higher disease burden. Managing COPD requires a multidisciplinary approach, with a strong emphasis on self-care and physiotherapy-based interventions. Airway clearance techniques (ACTs) play a crucial role in symptom management, as excessive secretions contribute to airway obstruction, recurrent infections, dyspnea, fatigue, and reduced quality of life. Several ACTs have been developed, including the active cycle of breathing technique (ACBT), positive expiratory pressure therapy, conventional chest physiotherapy, and intrapulmonary percussive ventilation (4).

Air pollution is a significant factor in COPD pathogenesis, with both chronic exposure and acute exacerbations contributing to disease progression. Indoor and outdoor pollutants vary in type, toxicity, concentration, and exposure patterns, influencing disease severity (5). COPD patients frequently experience acute exacerbations, which can manifest suddenly or develop over several days, leading to rapid deterioration in health. Hospitalization rates are high, with 24–27% of patients experiencing a second exacerbation within 30 days, making disease management challenging (6).

These exacerbations, characterized by increased sputum production, airway inflammation, and worsening dyspnea, significantly impact quality of life, accelerate lung function decline, and increase mortality risk. Many patients do not report or seek treatment for exacerbations, leading to further complications. Recurrent exacerbations are a major concern, as they predict future episodes, with every fifth hospitalized COPD patient at risk of readmission within a month. The primary goal in COPD management is to prevent and effectively treat exacerbations (7). Additionally, COPD is associated with systemic effects such as muscle wasting, depression, reduced fat-free mass, osteopenia, and chronic infections (8).

The Global Initiative for Chronic Obstructive Lung Disease (GOLD) classifies COPD into four stages, with stages III (severe) and IV (very severe) associated with frequent exacerbations. More than 80% of exacerbations are triggered by bacterial, viral, or fungal infections, while the remaining 20% are attributed to other factors (9). A decline in FEV1 is a key prognostic indicator, affecting both large and small airway function, alveolar gas exchange, and overall respiratory effort (10).

ACTs are designed to facilitate mucus clearance by applying external forces and modifying lung volume, pressure, and airflow dynamics. While various ACTs differ in application, their primary goal remains the same: improving airway clearance (11). ACBT, widely used for secretion clearance, aims to enhance quality of life and slow disease progression (12). This technique combines breathing control, thoracic expansion exercises, and forced expiratory maneuvers (huffing) to mobilize and remove airway secretions. Effective implementation of ACBT reduces infection recurrence, prevents airway damage, and improves lung function (1). The forced expiratory technique (FET), an essential component of ACBT, involves controlled huffing followed by relaxed breathing to facilitate mucus clearance (13).

Although ACBT can be performed in various positions, optimal results are achieved when combined with gravity-assisted postural drainage. However, some patients find ACBT labor-intensive (14). Recent advancements in airway clearance have introduced oscillatory positive expiratory pressure (OPEP) devices like Acapella, which facilitate mucus clearance more efficiently. The Acapella device, developed by DHD Healthcare, is available in two versions: blue (for expiratory flow <15 L/min for 3s) and green (for expiratory flow ≥15 L/min for 3s) (15).

Acapella is a handheld airway clearance device that combines resistive and vibratory properties to enhance secretion mobilization. It functions by generating oscillatory PEP, which increases functional residual capacity (FRC) and improves pulmonary pressures. The device contains a metal bar and a magnet, which create oscillations by disrupting and restoring airflow. This mechanism not only facilitates secretion clearance but also strengthens respiratory muscles, preventing atrophy (16).

The Acapella device provides both resistance and vibration during exhalation. The resistive feature maintains airway patency, allowing air to bypass secretions and aid their movement. The vibratory function loosens mucus, promoting upward mobilization (17). Acapella-based airway clearance reduces airway damage by efficiently mobilizing secretions from distal airways to the central airways for easier expectoration. Patients can independently use the device in any position, reducing the burden on therapists and improving compliance (18).

Acapella features a five-level adjustable dial at the rear, allowing users to modify frequency, wave amplitude, and resistance. At level 5, magnets are positioned closer together, increasing resistance, while at levels 1–2, magnets are farther apart, lowering resistance (19). For enhanced airway clearance and bronchodilation, Acapella can be used in conjunction with nebulized therapy. Its effectiveness remains consistent across different positions, making it a practical and user-friendly device for COPD management (20). The simplicity and efficiency of Acapella improve patient adherence to airway clearance regimens (21).

While previous research has extensively explored the pharmacological management of COPD, this study takes a non-pharmacological approach by investigating the combined effects of ACBT and Acapella on airway clearance, dyspnea, and pulmonary function tests. By integrating these physiotherapy techniques, this study aims to provide valuable insights into optimizing COPD management strategies.

Materials and Methods

Study Design

A randomized controlled trial was conducted.

Setting and Duration

The study took place at Aziz Bhatti Shaheed Teaching Hospital and National Hospital, Gujrat, over 10 months.

Sample Size and Selection

A total of 54 COPD patients (27 per group) were included using non-probability convenient sampling, with a 10% attrition rate.

Inclusion Criteria:

- Age 45-75 years, both genders
- Mentally stable, diagnosed COPD patients

Exclusion Criteria:

- Neurological conditions, arrhythmias, heart failure
- Previous heart or lung surgery

Study Groups

- **Group A:** Active Cycle of Breathing Technique (ACBT)
- **Group B:** ACBT with Acapella

Data Collection Tools

- **Sputum Diary:** Assessed dyspnea, sputum volume, and patient well-being
- **Dyspnea-MDP Scale:** Evaluated breathing discomfort and emotional response
- **Pulmonary Function Tests (PFTs):** Assessed lung function

Data Collection Procedure

Participants were randomly allocated into two groups. Both received supervised ACBT (with or without Acapella) for 4 weeks, three sessions per week, with 20 repetitions in two sets. PFTs and questionnaires were recorded post-treatment.

Data Analysis

Data was analyzed using SPSS v21. Mean ± SD was used for numerical data. Normality was tested via the Shapiro-Wilk test.

- **Wilcoxon T test:** Within-group analysis
- **Mann-Whitney test:** Between-group analysis
- Significance level: $P < 0.05$

Result

	Number	Mean	SD
Groups	50	1.5000	0.50508
Age	50	2.8400	1.82231

Table 1: Descriptive statistics of the groups and age of the patients

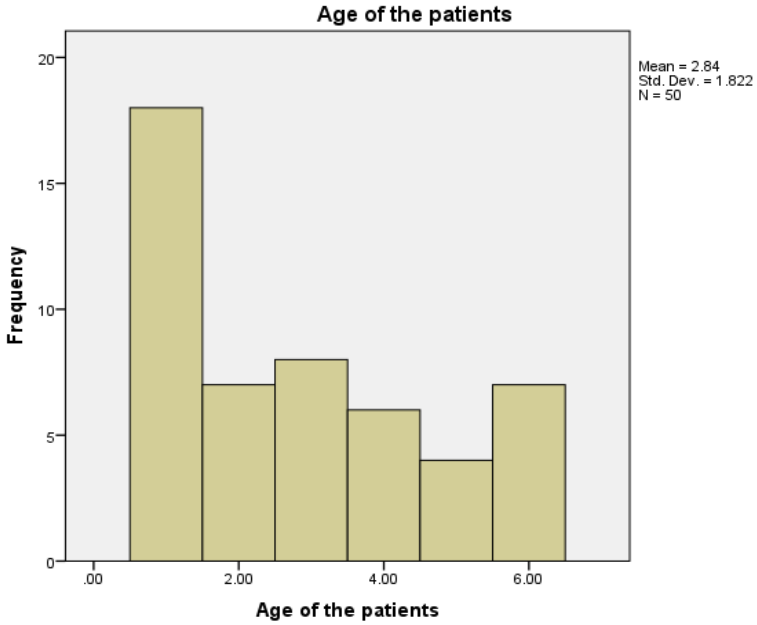

Figure 1: Age of the patients

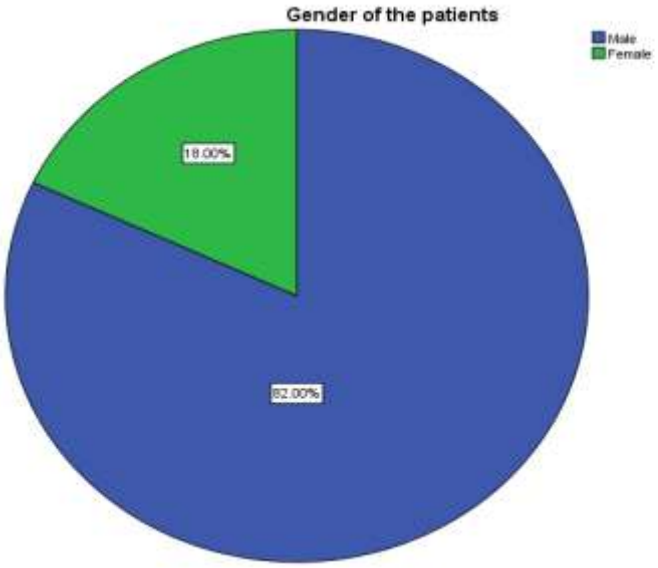

Figure 2: Gender of the patients

Variables	Statistic	Df	P-value
Week 1 Forced vital capacity	.936	50	.015
Week 1 forced expiratory volume in 1 second	.944	50	.018
Week 1 Dyspnea level in sputum diary	.832	50	.000
Week 1 sputum volume in sputum diaryz	.879	50	.000
Week 1 sputum color in sputum diary	.864	50	.000
Week 1 level of well-being in sputum diary	.773	50	.000
Week 1 other symptoms in sputum diary	.850	50	.000
Week 1 Sensory Qualities of multi- dimensional profile	.865	50	.000
Week 1 Affective dimension 1 of multi-dimensional profile	.412	50	.000
Week 1 Affective dimension 2 of multi-dimensional profile	.916	50	0.02

Table 2: Test of normality, Shapiro-wilk

Variable		Mean+std deviation	Median IQR	z-value	p-value
Forced vital capacity	Pre	54.3028+9.70416	54.2850	-2.121	.034
	Post	54.4630+9.69481	54.2850		
Forced expiratory volume in 1 second	Pre	61.8516+9.68562	60.1600	-2.460	.014
	Post	62.0524+9.85582	60.1650		
Dyspnea level in sputum diary	Pre	2.6400+.70000	2.5000	-3.464	.001
	Post	2.1200+.88129	2.0000		
Sputum volume in sputum diary	Pre	3.000+. 95743	3.0000	.000	1.00
	Post	3.000+.95643	3.0000		
Sputum color in sputum diary	Pre	2.7600+.96954	3.0000	.000	1.00
	Post	2.7600+.96944	3.0000		
Level of well-being in sputum diary	Pre	2.6400+.81035	2.5000	-1.000	.317
	Post	2.6800+.748	2.5000		
Other symptoms in sputum diary	Pre	2.2000+1.0801	2.0000	-2.807	.005
	Post	1.7200+.97980	1.0000		
Sensory Qualities of multi-dimensionaI profile	Pre	2.7600+1.3317	3.0000	.000	1.000
	Post	2.7600+1.33167	3.0000		
Affective dimension 1 of multi- dimensiona I profile	Pre	1.8400+.3742	2.0000	.000	1.000
	Post	1.8400+.37417	2.0000		
Affective dimension 2 of multi- dimensiona I profile	Pre	2.7600+.9256	3.0000	-3.207	.001
	Post	2.2800+1.02144	2.0000		

Table 3: Wilkoxon test of Control Group

Variable	Mean ±Standard Deviation	Median IQR	Z-value	P-value
Forced Vital Capacity	Pre:45.2292±14.2881	49.5800	-3.819	.001
	Post: 45.2380 ±14.2899	49.5900		
Forced Expiratory Volume in 1 Second	Pre: 50.2016 ±15.7209	52.6200	-2.831	.005
	Post: 50.2072±15.7220	52.6200		
Dyspnea Level in Sputum Diary	Pre: 3.2800±0.73711	3.0000	-2.530	.011
	Post: 2.9600 ±0.84063	3.0000		
Sputum Volume in Sputum Diary	Pre: 3.6000 ±0.57735	4.0000	.000	1.000
	Post: 3.6000±0.57635	4.0000		
Sputum Color in Sputum Diary	Pre: 2.8800 ± 0.83267	3.0000	.000	1.000
	Post: 2.8800 ± 0.83167	3.0000		
Level of Well-being in Sputum Diary	Pre: 3.2800 ± 0.73711	3.0000	-5.000	.001
	Post: 2.2800 ± 0.73611	2.0000		
Other Symptoms in Sputum Diary	Pre: 2.6000 ± 0.86603	3.0000	-1.134	.257
	Post: 2.4000 ± 0.86603	3.0000		
Sensory Qualities of Multi-dimensional Profile	Pre: 3.5600 ± 1.47422	4.0000	.000	1.000
	Post: 3.5600 ± 1.47322	4.0000		
Affective Dimension 1 of Multi-dimensional Profile	Pre: 1.8800 ± 0.3316	2.0000	-1.000	.317
	Post: 1.8400 ± 0.37417	2.0000		
Affective Dimension 2 of Multi-dimensional Profile	Pre: 3.0400 ± 1.27410	3.0000	-2.449	.014
	Post: 2.8000± 1.35401	3.0000		

Table 4: Wilkoxon test of Treatment Group

Variables		Mean rank		Sum of ranks		Median IQR	Z-value	p-value
		Acapella with ACBT	ACBT	Acapella with ACBT	ACBT			
FVC	pre	20.88	30.12	522.00	753.00	51.9550	-2.241	.025
	post	20.80	30.20	520.00	755.00	51.9600	-2.280	.023
FEV1	pre	19.84	31.16	501.00	774.00	57.9850	-2.649	.008
	post	20.52	30.48	496.00	779.00	58.3100	-2.746	.004
Dyspnea level in sputum diary	pre	31.10	19.90	777.50	497.50	3.0000	-2.893	.004
	post	31.38	19.62	784.50	490.50	2.0000	-2.986	.003
Sputum volume in sputum diary	pre	30.60	20.40	765.00	510.00	3.0000	-2.665	.008
	post	30.60	20.40	765.00	510.00	3.0000	-2.665	.008
Sputum color in sputum diary	pre	26.04	24.96	651.00	624.00	3.0000	-276	.783
	post	26.04	24.96	651.00	624.00	3.0000	-276	.783
Level of well-being in sputum diary	pre	30.76	20.24	769.00	506.00	3.0000	-2.702	.007
	post	22.66	28.34	566.50	708.50	2.0000	-1.494	.135
Other symptoms in sputum diary	pre	29.28	21.72	732.00	543.00	2.0000	-1.952	.051
	post	31.04	19.96	776.00	499.00	2.0000	-2.834	.005
Sensory qualities of multi-dimension profile	pre	29.68	21.32	742.00	533.00	3.5000	-2.083	.037
	post	29.68	21.32	742	533	3.5	-2.083	0.037
Affective dimension 1 of multi-dimension dyspnea profile Affective dimension 1 of multi-dimension dyspnea profile	pre	26	25	650	625	2	-0.403	0.687
	post	25.5	25.5	637.5	637.5	2	0	1
Affective dimension 2 of multi-dimension dyspnea profile Affective dimension 2 of multi-dimension dyspnea profile	pre	27.48	23.52	687	588	3	-0.999	0.318
	post	28.36	22.64	709	566	2	-1.431	0.152

Table 5: Mann Whitney Test

The descriptive statistics for the groups and patient age were presented, with the mean and standard deviation for groups being 1.5000 and 0.50508, respectively. For the patients' age, the mean and standard deviation were 2.8400 and 1.82231, based on a sample size of 50 (Table 1). Gender distribution showed 82% male and 18% female patients (Figure 2).
The Shapiro-Wilk test was applied to the pre-assessment values of pulmonary function tests (PFTs), sputum diary, and the multidimensional dyspnea profile (MDP). With p-values below 0.05, the data was found to be non-normally distributed for several variables, including Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), dyspnea level, sputum volume and color, level of well-being, and multidimensional profile dimensions. Consequently, non-parametric tests were used (Table 2).
In Table 3, the pre- and post-treatment mean and standard deviations for FVC, FEV1, dyspnea level, sputum volume, sputum color, level of well-being, other symptoms, and multidimensional dyspnea profiles in the control group are provided. For the control group, pre-treatment scores for FVC and FEV1 were 54.3028±9.70416 and 61.8516±9.68562, respectively. After treatment, there were slight improvements in FVC and FEV1, and reductions in dyspnea level, well-being, and other symptoms. The Z-values and p-values indicate that significant changes were observed in several variables, particularly in dyspnea level, other symptoms, and FEV1, with p-values less than 0.05 for most.
Table 4 presents similar data for the treatment group. Pre-treatment values were lower for FVC and FEV1 compared to the control group, but post-treatment improvements in FVC, FEV1, dyspnea level, and other symptoms were observed. The Z-values and p-values indicate significant changes in several areas, particularly in FVC, FEV1, dyspnea level, and well-being, with p-values below 0.05.
Table 5 shows the pre- and post-treatment mean ranks, sum of ranks, and p-values for the variables in both groups. In the treatment group, the mean ranks for variables like FVC, FEV1, and dyspnea level remained stable, with some significant changes observed in the rank sums for dyspnea and well-being. The control group showed less change in ranks, with significant shifts in the ranks for dyspnea level and well-being.
In conclusion, the results highlight significant improvements in several clinical measures for both groups, particularly in dyspnea levels and symptoms, with the treatment group showing more pronounced changes.

Discussion

A sample of 54 patients with Chronic Obstructive Pulmonary Disease (COPD) was chosen for a randomized controlled trial (RCT) to evaluate the effectiveness of Active Cycle of Breathing Techniques (ACBT) with and without the acapella device on airway clearance, dyspnea, and pulmonary function tests (PFTs). However, only 50 participants completed the study. The participants were divided into two groups: Group 1 received ACBT, while Group 2 received ACBT with acapella. The sample included both male and female patients, with 40% male and 10% female. The age range of the participants was 45-75 years.

The study found significant improvements after the treatment with ACBT plus acapella, with notable changes in Forced Vital Capacity (FVC) = 0.023, Forced Expiratory Volume in 1 second (FEV1) = 0.004, and dyspnea levels = 0.003. Although previous studies have assessed the effects of ACBT and acapella on airway clearance, dyspnea, and PFTs in various diseases, further research is needed to explore these effects on a larger scale and over a longer duration.

Comparing the present study to one by P. Senthil and colleagues in 2015, which examined the efficacy of ACBT with acapella in bronchiectasis, the findings are similar. In their study, 30 individuals were randomly assigned to either an ACBT group or an ACBT with acapella group. Their results indicated significant improvements in FEV1 ($p < 0.000$) and FVC ($p < 0.010$), supporting the present study's findings of improved FVC ($p = 0.023$) and FEV1 ($p = 0.004$) (22).

A 2016 study by Nesma M. Allam and colleagues investigated the combined effect of acapella and breathing techniques for managing complications after upper abdominal surgeries. In this study, 60 patients aged 20-50 years were divided into two groups, receiving three sessions per week for four weeks. The results showed significant improvements in FVC ($p < 0.05$) and FEV1 ($p < 0.001$) after using acapella and breathing exercises. While sputum expectoration showed no significant changes, this study supports the present findings, with improvements in FVC ($p = 0.025$) and FEV1 ($p = 0.008$) after treatment (23).

In 2020, Ibrahim Bingol and colleagues compared conventional chest physiotherapy with oscillatory positive expiratory pressure (OPEP) devices, such as acapella, in patients with primary ciliary dyskinesia. They found significant improvements in FEV1 ($p = 0.018$) and FVC ($p = 0.007$) in the acapella group. Exacerbation rates were similar between both groups, but comfort and compliance were better in the OPEP group. This study also aligns with the present research, as both FEV1 and FVC showed significant improvements (FVC = 0.023 and FEV1 = 0.008) following the combination of ACBT and acapella (24).

Mohamed Shamakh and colleagues, in a 2020 study, compared acapella and hand-held PEP devices in moderate COPD patients. They found that treatment groups (ACBT with PEP and ACBT with acapella) showed improvements in spirometry values, dyspnea, walking distance, and quality of life compared to the control group (ACBT). Although there was no significant difference between the PEP and acapella groups in terms of FEV1 (0.619) and 6-Minute Walk Test (6MWT) (0.659), both treatment groups showed significant improvements compared to the control group, which further supports the current study's findings of improved FEV1 ($p = 0.004$) and dyspnea ($p = 0.003$) (25).

Conclusion:

In conclusion, this study demonstrates the significant benefits of combining Active Cycle of Breathing Techniques (ACBT) with the Acapella device in managing Chronic Obstructive Pulmonary Disease (COPD). The results show notable improvements in Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and dyspnea levels. These findings are consistent with previous studies, further supporting the efficacy of ACBT with Acapella in enhancing airway clearance and pulmonary function. The study underscores the importance of non-pharmacological interventions in COPD management and encourages further research to explore long-term effects and broader applications in clinical settings.

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