JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

Vol. 4 Issue 18, 2026
Open Access | DOI: 10.61919/j8tepe51

Original Article

Blow Bottle Technique Along With Percussion and Diaphragmatic Breathing in Patients With Community Acquired Pneumonia

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Received: 07 August 2026	Revised: 03 September 2026	Accepted: 18 September 2026	Published: 30 September 2026

HOW TO CITE

Fatima Ahmad et al. 2026. Blow Bottle Technique Along With Percussion and Diaphragmatic Breathing in Patients With Community Acquired Pneumonia. Journal of Health, Wellness and Community Research. 4, 18 (Sep. 2026), 1–10.
DOI:https://doi.org/10.61919/j8tepe51

ARTICLE INFORMATION

Author Contributions	Concept: FA; Design: FA; Data Collection: FA; Analysis: FA; Drafting: FA.
Ethical Approval	The study was approved by research ethical board of the University of Lahore, Lahore, Pakistan
Informed Consent	Written informed consent was obtained from all participants
Conflict of Interest	The authors declare no conflict of interest.
Funding	No external funding.
Data Availability	Available from the corresponding author on reasonable request.
AI Declaration	No generative AI was used for conceptualization, analysis, or content generation. AI use was limited to language refinement, and the authors remain fully responsible for the accuracy, originality, validity, and integrity of the manuscript's content.

ABSTRACT

Background: Community-acquired pneumonia may impair ventilation, airway clearance, pulmonary function, and respiratory symptoms. Positive expiratory pressure generated through blow bottle breathing may provide additional benefit when combined with conventional respiratory physiotherapy. Objective: To compare the effects of blow bottle technique added to percussion and diaphragmatic breathing with percussion and diaphragmatic breathing alone in patients with community-acquired pneumonia. Methods: This randomized clinical trial included 28 patients at The University of Lahore Teaching Hospital, Lahore, allocated equally to Group A (percussion plus diaphragmatic breathing) or Group B (blow bottle technique plus percussion and diaphragmatic breathing). Treatment was administered twice daily for one week. FVC, FEV1, FEV1/FVC ratio, PEF, and Breathlessness, Cough and Sputum Scale (BCSS) scores were assessed at baseline and post-treatment. Data were analyzed using IBM SPSS Statistics version 26.0, with $p<0.05$ considered statistically significant. Results: Baseline outcomes were comparable between groups. Group B demonstrated greater changes in pre-bronchodilator FVC (between-group difference 0.281 L; 95% CI 0.243–0.318; $p<0.001$), FEV1 (0.297 L; 95% CI 0.256–0.338; $p<0.001$), and PEF (56.786 L/min; 95% CI 50.423–63.148; $p<0.001$). Total BCSS reduction was also greater in Group B by 1.786 points (95% CI 0.863–2.708; $p<0.001$). Conclusion: Adding blow bottle therapy to percussion and diaphragmatic breathing produced greater short-term improvements in pulmonary function and respiratory symptoms than percussion and diaphragmatic breathing alone. Keywords: Community-acquired pneumonia; blow bottle technique; positive expiratory pressure; percussion; diaphragmatic breathing; pulmonary function; BCSS.

INTRODUCTION

Community-acquired pneumonia (CAP) is an acute infection of the pulmonary parenchyma acquired outside a hospital or healthcare facility and remains an important cause of respiratory morbidity. The inflammatory response associated with pneumonia can result in alveolar filling with inflammatory cells and exudate, impaired ventilation and gas exchange, cough, sputum production, breathlessness, and reduced respiratory function (1,2). Clinical presentation varies according to disease severity, age, comorbidities, and the causative organism, while diagnosis is generally based on compatible clinical findings supported by radiological and other investigations when indicated

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(1,2). In addition to appropriate medical management, supportive interventions aimed at improving ventilation, secretion clearance, and respiratory mechanics may be important, particularly in patients who experience excessive bronchial secretions, ineffective airway clearance, or impaired lung expansion.

Respiratory physiotherapy has therefore been used as an adjunct to medical management in patients with pneumonia and other respiratory disorders. Its principal objectives include facilitating mobilization and clearance of retained secretions, promoting lung expansion, improving ventilation, and reducing the respiratory effort associated with ineffective breathing patterns. Nevertheless, evidence regarding chest physiotherapy in adults with pneumonia remains heterogeneous. A Cochrane review evaluating chest physiotherapy in adults with pneumonia reported uncertainty regarding its effects on major clinical outcomes and emphasized the need for better-quality evidence regarding specific techniques and patient groups (3). This uncertainty is particularly relevant because respiratory physiotherapy encompasses several distinct interventions that may not produce equivalent physiological or clinical effects.

Chest percussion is a commonly applied airway-clearance technique in which rhythmic manual clapping is used to facilitate mobilization of bronchial secretions. Clinical studies have reported potential respiratory benefits of chest physiotherapy and percussion in patients with pneumonia and other pulmonary conditions. Mohamed et al. observed improvement in respiratory status following chest percussion among infants with pneumonia, while Wibowo and Pramusinta reported beneficial effects of chest physiotherapy combined with thoracic expansion exercises in patients with pneumonia (4,5). Chest physical therapy has also been associated with a lower occurrence of pneumonia in patients with inhalation injury, suggesting that appropriate airway-clearance interventions may have an important supportive role in selected respiratory populations (6). However, differences in age groups, disease severity, treatment protocols, and outcome measures limit direct application of these findings to adults with community-acquired pneumonia.

Positive expiratory pressure (PEP) techniques represent another approach to airway clearance. During PEP therapy, resistance is applied during expiration, generating positive pressure within the airways and potentially assisting expiratory airflow, secretion mobilization, and maintenance of airway patency. The blow bottle technique is a simple form of PEP therapy in which the patient expires through a tube submerged in water. An integrative review of PEP-bottle therapy reported that this technique has been used in patients with pulmonary disorders as a low-cost method for supporting airway clearance and respiratory function (7). More recent evidence evaluating blowing devices and respiratory physiotherapy strategies has also suggested potential improvements in selected respiratory outcomes, although substantial heterogeneity exists across devices, protocols, populations, and outcome measures (8). Thus, the physiological rationale for blow bottle therapy is plausible, but its clinical effect depends on the population and treatment protocol in which it is applied.

Previous interventional studies provide additional support for investigating blow bottle therapy. Khar et al. compared Acapella with blow bottle PEP in post-COVID-19 patients and evaluated airway-clearance-related outcomes including peak expiratory flow and functional capacity (9). Afzal et al. compared percussion alone with percussion combined with blow bottle therapy in patients with chronic obstructive pulmonary disease and reported greater improvement in several respiratory outcomes when blow bottle therapy was added to percussion (10). In postoperative patients, Anjum et al. also evaluated blow bottle breathing against another breathing technique and demonstrated that structured breathing interventions can influence postoperative pulmonary outcomes (11). Although these studies support further evaluation of blow bottle breathing, their populations differ substantially from patients with CAP, and their findings cannot be assumed to represent the response of adults with acute community-acquired pneumonia.

Diaphragmatic breathing is another respiratory exercise intended to encourage diaphragmatic recruitment, promote a slower and more efficient breathing pattern, and reduce unnecessary accessory-muscle activity. Diaphragmatic breathing has been investigated in several clinical populations and has demonstrated potential effects on respiratory mechanics and functional outcomes (12). Yoon et al., for example, reported improvement in pulmonary function and walking endurance following diaphragmatic and pursed-lip breathing exercises in patients with chronic stroke (13). In children with lower respiratory tract infection, diaphragmatic breathing was also associated with improvement in selected clinical respiratory outcomes (14). Although these populations differ from

adults with CAP, these findings provide a physiological basis for incorporating diaphragmatic breathing within a combined respiratory physiotherapy programme.

Evidence specific to pneumonia suggests that active respiratory rehabilitation strategies may be beneficial, although the optimum combination of techniques remains uncertain. Ahmad et al. compared postural drainage with positive expiratory pressure in patients with community-acquired pneumonia and reported improvement in selected respiratory outcomes following physiotherapy intervention (15). Similarly, combined physiotherapy approaches incorporating breathing exercises and other active respiratory interventions have been investigated in patients with pneumonia, supporting the potential role of active participation in respiratory rehabilitation (16). However, existing studies vary considerably in intervention content, disease severity, treatment duration, and outcome selection, making it difficult to determine whether adding blow bottle PEP to commonly used techniques such as percussion and diaphragmatic breathing provides an additional therapeutic benefit in adults with CAP.

This uncertainty represents the principal knowledge gap addressed by the present study. While percussion may assist secretion mobilization and diaphragmatic breathing may promote more efficient ventilation, the addition of blow bottle PEP may provide an additional expiratory-pressure component that could further facilitate airway clearance and improve respiratory function. Direct evidence comparing percussion plus diaphragmatic breathing with the same treatment supplemented by blow bottle therapy in patients with community-acquired pneumonia remains limited. Evaluating this combination is particularly relevant in settings where inexpensive, simple, and readily available respiratory rehabilitation strategies are desirable.

Accordingly, the present randomized clinical trial was conducted to determine the comparative effects of blow bottle technique added to percussion and diaphragmatic breathing in patients with community-acquired pneumonia. Participants receiving percussion and diaphragmatic breathing alone were compared with those receiving blow bottle technique in addition to percussion and diaphragmatic breathing. Treatment effects were evaluated using pulmonary function outcomes, including forced vital capacity (FVC), forced expiratory volume in one second (FEV1), the FEV1/FVC ratio, and peak expiratory flow (PEF), together with respiratory symptoms assessed through breathlessness, cough, sputum, and total Breathlessness, Cough and Sputum Scale scores. The study hypothesized that the addition of the blow bottle technique would result in greater short-term improvement in pulmonary function and respiratory symptoms than percussion and diaphragmatic breathing alone.

MATERIAL AND METHODS

This randomized clinical trial was conducted at The University of Lahore Teaching Hospital, Lahore, over a period of nine months following approval of the research synopsis. The study evaluated whether adding the blow bottle technique to percussion and diaphragmatic breathing produced greater short-term improvement in pulmonary function and respiratory symptoms than percussion and diaphragmatic breathing alone in patients with community-acquired pneumonia. Community-acquired pneumonia was considered pneumonia acquired outside a healthcare facility and diagnosed clinically by the treating physician in accordance with the clinical context of the study population (1,2). The final study sample comprised 28 participants, with 14 participants allocated to each treatment group.

Patients admitted to the hospital with a diagnosis of community-acquired pneumonia were screened for eligibility. Both male and female patients aged 40–50 years were considered for inclusion. Eligible participants were required to have mild-to-moderate impairment of pulmonary function, including an FEV1/FVC ratio greater than 60%, and to be clinically suitable for participation in chest physiotherapy. Patients with severe pneumonia requiring acute intensive management, admission to the intensive care unit, or oxygen support were excluded. Additional exclusion criteria included severe chronic obstructive pulmonary disease, heart failure, malignancy, neurological disorders such as stroke or severe dementia that could interfere with participation, pregnancy or lactation, and receipt of respiratory treatments such as nebulization or chest physiotherapy during the 48 hours preceding enrolment. The eligibility criteria were intended to identify clinically stable patients able to perform the respiratory interventions safely and consistently.

Participants were recruited using a convenience sampling technique. After eligibility screening and enrolment, treatment allocation was performed using sealed opaque envelopes. Envelopes labeled 0 corresponded to Group A and envelopes labeled 1 corresponded to Group B. Participants were not informed of the intervention protocol

delivered to the alternate group. Before treatment, demographic and clinical information was collected, and baseline pulmonary-function and respiratory-symptom measurements were recorded. All participants received an explanation of the study procedures and intervention techniques before treatment commenced.

Pulmonary function was assessed using digital spirometry. The principal spirometric outcomes were forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, and peak expiratory flow (PEF). Measurements included pre-bronchodilator and post-bronchodilator values for FVC, FEV1, FEV1/FVC ratio, and PEF. These parameters were selected to characterize changes in ventilatory capacity, expiratory airflow, and overall pulmonary function during the intervention period. Respiratory symptoms were assessed using the Breathlessness, Cough and Sputum Scale (BCSS), which consists of three symptom domains scored from 0 to 4, with higher scores indicating greater symptom severity. Breathlessness, cough, sputum, and the summed total BCSS score were recorded at baseline and after treatment.

Before the allocated group-specific treatment, participants were instructed in diaphragmatic breathing under physiotherapist supervision. Patients were positioned comfortably in sitting or semi-Fowler's position according to clinical tolerance and were instructed to place one hand over the abdomen to monitor abdominal movement during breathing. They inhaled slowly through the nose, allowed the abdomen to expand, briefly held the breath, and then exhaled slowly through the mouth. Diaphragmatic breathing was used to encourage controlled ventilation, promote lung expansion, and reduce excessive reliance on accessory respiratory muscles. The anatomical and biomechanical basis of deep diaphragmatic breathing has been described in respiratory rehabilitation literature (12).

Group A received chest percussion combined with diaphragmatic breathing. Patients were positioned in sitting, semi-Fowler's, or side-lying positions according to comfort and clinical condition. Chest percussion was performed by the physiotherapist using cupped hands to apply rhythmic clapping over the appropriate chest or upper-back region for approximately 2–3 minutes. The patient was subsequently encouraged to cough effectively to assist removal of mobilized respiratory secretions. This was followed by supervised diaphragmatic breathing for approximately 3 minutes. The complete treatment protocol was administered twice daily for one week.

Group B received the blow bottle technique in addition to the same percussion and diaphragmatic-breathing programme. Blow bottle therapy was performed using a water-filled plastic bottle and a tube placed into the water. Participants formed a seal around the tube with their lips and exhaled through the tube with moderate effort to generate bubbles, thereby producing expiratory resistance consistent with the principle of positive expiratory pressure therapy. PEP-bottle therapy has been described as a simple and low-cost respiratory intervention intended to assist airway clearance and secretion mobilization in patients with pulmonary disorders (7). Participants performed repeated expiratory efforts through the tube, followed by huffing and effective coughing to facilitate secretion clearance. The blow bottle component was followed by chest percussion using the same procedure applied in Group A and subsequently by supervised diaphragmatic breathing. The combined intervention was administered twice daily for one week.

Outcome measurements were obtained before initiation of treatment and repeated after completion of the one-week intervention period. The same principal outcomes were evaluated at both time points. Pulmonary-function assessment included pre- and post-bronchodilator FVC, FEV1, FEV1/FVC ratio, and PEF, while respiratory symptoms were assessed using individual and total BCSS scores. The physiotherapist supervised the respiratory exercises and intervention procedures to improve adherence to the intended treatment technique and to maintain consistency of administration across sessions.

Data were checked for missing entries, recording errors, and internal inconsistencies before statistical analysis. Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were summarized using means and standard deviations, while categorical variables were presented as frequencies and percentages. Sex distribution between groups was assessed using the chi-square test. Distributional assumptions for continuous outcomes were assessed using the Shapiro–Wilk test. For normally distributed continuous data, within-group pre-treatment and post-treatment comparisons were performed using paired-samples t-tests, while between-group comparisons were performed using independent-samples t-tests. When equality of variances was not satisfied, Welch's t-test was used. For variables that did not satisfy normality assumptions, within-group

comparisons were planned using the Wilcoxon signed-rank test and between-group comparisons using the Mann–Whitney U test.

Treatment effects were evaluated using both within-group changes and between-group comparisons. In addition to comparing post-treatment values between groups, change scores from baseline to post-treatment were calculated for pulmonary-function and BCSS outcomes and compared between Group A and Group B. For FVC, FEV1, FEV1/FVC ratio, and PEF, an increase represented improvement, whereas for BCSS breathlessness, cough, sputum, and total scores, a reduction represented symptomatic improvement. Statistical significance was set at $p < 0.05$, and effect estimates were reported with 95% confidence intervals where applicable. Statistical analyses were performed using IBM SPSS Statistics version 26.0.

The study was conducted in accordance with the ethical principles prescribed by the Institutional Research Ethics Board of The University of Lahore and the principles of the Declaration of Helsinki. Written informed consent was obtained from participants before enrolment. Participants were informed about the purpose and procedures of the study, the voluntary nature of participation, and their right to withdraw without affecting their routine patient–physiotherapist relationship or clinical care. Confidentiality and privacy of participant information were maintained throughout the study, and participants were informed about the nature of the physiotherapy interventions before treatment.

RESULTS

Twenty-eight participants were included in the analysis, with 14 participants in each treatment group. The mean age was 44.93 ± 6.11 years in Group A and 45.36 ± 6.18 years in Group B, with no evidence of a baseline difference between groups ($p = 0.855$). Group A included 8 males (57.1%) and 6 females (42.9%), whereas Group B included 6 males (42.9%) and 8 females (57.1%); sex distribution was also comparable between groups ($p = 0.450$) (Table 1).

Baseline pulmonary-function measures were similar between the two groups, with no between-group differences in pre- or post-bronchodilator FVC, FEV1, FEV1/FVC ratio, or PEF (all $p > 0.80$ except the FEV1/FVC comparisons, which were likewise non-significant). Following the one-week intervention, improvement in pulmonary function was greater in Group B across all measured outcomes (Table 2). Pre-bronchodilator FVC increased by 0.188 ± 0.042 L in Group A and by 0.469 ± 0.054 L in Group B, corresponding to a between-group difference in change of 0.281 L (95% CI 0.243 to 0.318; $p < 0.001$; Hedges' $g = 5.64$). Pre-bronchodilator FEV1 increased by 0.212 ± 0.039 L and 0.509 ± 0.063 L, respectively, with a between-group difference of 0.297 L (95% CI 0.256 to 0.338; $p < 0.001$; Hedges' $g = 5.50$).

Table 1. Baseline demographic characteristics of participants

Characteristic	Group A (n = 14)	Group B (n = 14)	p-value
Age, years, mean ± SD	44.93 ± 6.11	45.36 ± 6.18	0.855
Male, n (%)	8 (57.1)	6 (42.9)	0.450
Female, n (%)	6 (42.9)	8 (57.1)	—

Values are mean ± SD or n (%). Age was compared using an independent-samples t-test; sex distribution was compared using the chi-square test. SD, standard deviation.

Table 2. Baseline, post-treatment, and change in pulmonary-function outcomes

Outcome	Group A baseline mean ± SD	Group B baseline mean ± SD	Baseline p-value	Group A post-treatment mean ± SD	Group B post-treatment mean ± SD	Group A change mean ± SD	Group B change mean ± SD	Between-group difference in change, B − A	95% CI	p-value	Hedges' g
Pre-BD FVC, L	2.65 ± 0.30	2.68 ± 0.32	0.837	2.84 ± 0.28	3.14 ± 0.33	0.188 ± 0.042	0.469 ± 0.054	0.281	0.243 to 0.318	<0.001	5.64
Pre-BD FEV1, L	2.03 ± 0.24	2.05 ± 0.26	0.848	2.24 ± 0.24	2.56 ± 0.27	0.212 ± 0.039	0.509 ± 0.063	0.297	0.256 to 0.338	<0.001	5.50
Pre-BD FEV1/FVC, %	76.54 ± 0.99	76.52 ± 0.99	0.970	78.89 ± 2.13	81.44 ± 2.27	2.350 ± 2.067	4.921 ± 2.393	2.571	0.834 to 4.309	0.005	1.12
Pre-BD PEF, L/min	317.86 ± 44.81	321.93 ± 47.54	0.817	353.14 ± 46.87	414.00 ± 48.84	35.286 ± 5.327	92.071 ± 10.284	56.786	50.423 to 63.148	<0.001	6.73
Post-BD FVC, L	2.72 ± 0.30	2.75 ± 0.32	0.825	2.91 ± 0.27	3.22 ± 0.33	0.189 ± 0.053	0.473 ± 0.057	0.284	0.242 to 0.327	<0.001	5.01
Post-BD FEV1, L	2.09 ± 0.25	2.11 ± 0.27	0.845	2.31 ± 0.23	2.62 ± 0.27	0.224 ± 0.046	0.516 ± 0.064	0.293	0.250 to 0.336	<0.001	5.09
Post-BD FEV1/FVC, %	76.73 ± 0.97	76.69 ± 1.05	0.911	79.46 ± 2.11	81.57 ± 2.40	2.736 ± 2.117	4.886 ± 2.499	2.150	0.351 to 3.949	0.021	0.90

Post-BD PEF, L/min	342.21 ± 48.60	346.86 ± 51.64	0.808	376.93 ± 47.35	441.14 ± 48.64	34.714 ± 7.426	94.286 ± 13.117	59.571	51.291 to 67.852	<0.001	5.43

Positive change values indicate improvement. Between-group differences are expressed as Group B minus Group A, so positive values favor Group B. Baseline comparisons used independent-samples t-tests. Within-group changes were derived from paired observations, and between-group change scores were compared using independent-samples t-tests as reported in the manuscript. Hedges' g was calculated from the reported group-specific change-score means and standard deviations, with positive values favoring Group B. BD, bronchodilator; CI, confidence interval; FEV1, forced expiratory volume in one second; FVC, forced vital capacity; PEF, peak expiratory flow; SD, standard deviation.

Table 3. Baseline, post-treatment, and change in BCSS outcomes

Outcome	Group A baseline mean ± SD	Group B baseline mean ± SD	Baseline p-value	Group A post-treatment mean ± SD	Group B post-treatment mean ± SD	Group A reduction mean ± SD	Group B reduction mean ± SD	Between-group difference in reduction, B − A	95% CI	p-value	Hedges' g
BCSS breathlessness, points	2.43 ± 0.51	2.36 ± 0.50	0.712	1.43 ± 0.51	0.79 ± 0.70	1.000 ± 0.555	1.571 ± 0.514	0.571	0.156 to 0.987	0.009	1.04
BCSS cough, points	3.00 ± 0.68	2.93 ± 0.62	0.773	1.93 ± 0.27	1.21 ± 0.80	1.071 ± 0.616	1.714 ± 0.469	0.643	0.218 to 1.068	0.005	1.14
BCSS sputum, points	2.50 ± 0.52	2.43 ± 0.51	0.717	1.43 ± 0.51	0.79 ± 0.70	1.071 ± 0.616	1.643 ± 0.497	0.571	0.137 to 1.006	0.012	0.99
Total BCSS, points	7.93 ± 1.49	7.71 ± 1.14	0.673	4.79 ± 0.98	2.79 ± 1.12	3.143 ± 1.512	4.929 ± 0.730	1.786	0.863 to 2.708	<0.001	1.46

Positive reduction values indicate improvement. Between-group differences are expressed as the reduction in Group B minus the reduction in Group A, so positive values favor Group B. Between-group change-score comparisons used independent-samples t-tests as reported in the manuscript. Hedges' g was calculated from the reported reduction-score means and standard deviations. BCSS, Breathlessness, Cough and Sputum Scale; CI, confidence interval; SD, standard deviation.

The pre-bronchodilator FEV1/FVC ratio increased by 2.350 ± 2.067 percentage points in Group A compared with 4.921 ± 2.393 percentage points in Group B. The between-group difference in improvement was 2.571 percentage points (95% CI 0.834 to 4.309; p = 0.005; Hedges' g = 1.12). A particularly large separation between groups was observed for pre-bronchodilator PEF, which increased by 35.286 ± 5.327 L/min in Group A and 92.071 ± 10.284 L/min in Group B. The resulting between-group difference in change was 56.786 L/min (95% CI 50.423 to 63.148; p < 0.001; Hedges' g = 6.73).

Post-bronchodilator outcomes showed a similar pattern. FVC improvement was 0.189 ± 0.053 L in Group A and 0.473 ± 0.057 L in Group B, yielding a between-group difference of 0.284 L (95% CI 0.242 to 0.327; p < 0.001; Hedges' g = 5.01). The corresponding difference in FEV1 improvement was 0.293 L (95% CI 0.250 to 0.336; p < 0.001; Hedges' g = 5.09). Improvement in the post-bronchodilator FEV1/FVC ratio was also greater in Group B, with a between-group difference of 2.150 percentage points (95% CI 0.351 to 3.949; p = 0.021; Hedges' g = 0.90). Post-bronchodilator PEF increased by 34.714 ± 7.426 L/min in Group A and 94.286 ± 13.117 L/min in Group B, producing a between-group difference of 59.571 L/min (95% CI 51.291 to 67.852; p < 0.001; Hedges' g = 5.43).

Respiratory symptom scores were also similar between groups at baseline, with no evidence of differences in breathlessness, cough, sputum, or total BCSS scores (all p > 0.67). After treatment, reductions in all BCSS domains were greater in Group B (Table 3). Breathlessness decreased by 1.000 ± 0.555 points in Group A and 1.571 ± 0.514 points in Group B, corresponding to an additional reduction of 0.571 points in Group B (95% CI 0.156 to 0.987; p = 0.009; Hedges' g = 1.04). The between-group difference in cough-score reduction was 0.643 points (95% CI 0.218 to 1.068; p = 0.005; Hedges' g = 1.14), while the difference in sputum-score reduction was 0.571 points (95% CI 0.137 to 1.006; p = 0.012; Hedges' g = 0.99).

The total BCSS score decreased from 7.93 ± 1.49 to 4.79 ± 0.98 in Group A and from 7.71 ± 1.14 to 2.79 ± 1.12 in Group B. The mean reduction was 3.143 ± 1.512 points in Group A compared with 4.929 ± 0.730 points in Group B, resulting in a between-group difference in symptom reduction of 1.786 points (95% CI 0.863 to 2.708; p < 0.001; Hedges' g = 1.46). Overall, the between-group change analysis showed consistently larger improvements in Group B for all

pulmonary-function and BCSS outcomes, with the largest standardized differences observed for PEF, FVC, and FEV1 change.

DISCUSSION

The present randomized clinical trial found that both treatment groups improved over the one-week intervention period, but participants who received the blow bottle technique in addition to percussion and diaphragmatic breathing demonstrated consistently greater improvements in pulmonary-function measures and respiratory symptoms than those who received percussion and diaphragmatic breathing alone. The between-group differences were evident for FVC, FEV1, FEV1/FVC ratio, PEF, and all BCSS domains, indicating that the addition of a positive expiratory pressure component may have provided an incremental short-term benefit beyond the effects of percussion and diaphragmatic breathing alone. These findings address the study objective by suggesting that the combined intervention may be more effective for short-term respiratory rehabilitation in clinically stable patients with community-acquired pneumonia, although the small sample and brief follow-up require cautious interpretation.

The greater improvement observed in FVC and FEV1 in Group B is consistent with the physiological rationale of positive expiratory pressure therapy. PEP-bottle therapy produces resistance during expiration and may help maintain airway patency, facilitate movement of secretions toward larger airways, and support more effective ventilation (7). A systematic review of blowing devices and related respiratory physiotherapy strategies similarly reported that such interventions may improve selected respiratory outcomes, although substantial heterogeneity in treatment devices, protocols, patient groups, and measured endpoints limits certainty regarding their effects (8). The present findings therefore support the possibility that adding blow bottle breathing to conventional respiratory physiotherapy may enhance short-term functional improvement, while also reinforcing the need for standardized treatment protocols and larger comparative trials.

The observed improvement in expiratory airflow is also broadly consistent with previous blow bottle studies conducted in other respiratory populations. Khar et al. compared Acapella and blow bottle PEP in patients with post-COVID-19 respiratory impairment and demonstrated that both approaches could be used as airway-clearance strategies, although differences between devices were not consistently significant across time points (9). Afzal et al. reported greater improvement in selected respiratory measures when blow bottle therapy was combined with percussion in patients with chronic obstructive pulmonary disease compared with percussion alone (10). Although these populations differ from patients with acute community-acquired pneumonia, the direction of these findings is compatible with the present observation that adding expiratory resistance to percussion and breathing exercises may enhance airway clearance and expiratory performance.

The improvement in PEF was particularly marked in the group receiving blow bottle therapy. This may reflect a combination of improved secretion mobilization, reduced airway obstruction from retained mucus, and repeated active expiratory effort during the blow bottle procedure. However, these mechanisms were not directly measured in the present study and should therefore be considered plausible explanations rather than demonstrated physiological effects. Previous research on vibrating or positive expiratory pressure approaches has shown potential benefits in secretion clearance and respiratory recovery. Sun et al. reported shorter sputum-production duration and better radiographic outcomes among children receiving vibrating PEP therapy for refractory Mycoplasma pneumoniae pneumonia compared with controls (17). The age group, disease characteristics, and intervention differ considerably from the present trial, but the findings support the broader physiological concept that positive expiratory pressure can contribute to airway-clearance management in selected patients with pulmonary infection.

The FEV1/FVC ratio also improved in both groups, with a greater change in Group B. The improvement observed in Group A indicates that percussion combined with diaphragmatic breathing itself may have contributed to respiratory recovery. Diaphragmatic breathing is intended to promote diaphragmatic recruitment and a more efficient breathing pattern, while percussion may facilitate mobilization of retained secretions. Previous studies have reported improvement in respiratory and functional outcomes after diaphragmatic breathing in different clinical populations (12,13). Fargaly et al. also observed favorable respiratory changes after diaphragmatic breathing in children with lower respiratory tract infection (14). Although these findings cannot be directly generalized to

adults with CAP, they support the inclusion of diaphragmatic breathing as an active component of respiratory rehabilitation.

The symptom findings provide additional clinical context to the spirometric results. Breathlessness, cough, sputum, and total BCSS scores improved in both groups but showed greater reductions in Group B. The combination of expiratory resistance, secretion mobilization through percussion, effective coughing, and controlled diaphragmatic breathing may have contributed collectively to these changes. The BCSS was originally developed primarily for symptom assessment in obstructive airway disease, and therefore its application to patients with acute community-acquired pneumonia should be interpreted with caution. Nevertheless, the consistent direction of change across individual symptom domains and the total score suggests that participants receiving the combined intervention experienced greater short-term symptomatic improvement alongside the measured changes in pulmonary function.

The present findings also align in part with evidence more directly related to pneumonia. Ahmad et al. compared positive expiratory pressure with postural drainage in patients with community-acquired pneumonia and reported improvement in selected respiratory outcomes following both physiotherapy approaches (15). The current study extends this comparison by evaluating the addition of blow bottle PEP to a background programme of percussion and diaphragmatic breathing rather than comparing two independent airway-clearance techniques. Similarly, Hassan et al. reported improvement in respiratory and physiological outcomes among patients with acquired pneumonia receiving structured respiratory training, supporting the potential contribution of active breathing interventions as adjuncts to conventional management (18). However, differences in treatment devices, clinical severity, outcome measures, and treatment settings limit direct quantitative comparison.

Evidence from broader pneumonia rehabilitation research also supports the use of combined active physiotherapy approaches. Rutkauskienė et al. evaluated early mobilization, breathing exercises, and chest wall oscillation in patients with bilateral pneumonia and found that active multimodal respiratory rehabilitation could improve selected clinical outcomes (16). Likewise, Saleh et al. reported improvements in pulmonary function and diaphragmatic excursion following diaphragm-focused manual interventions in patients with severe pneumonia (19). These studies differ substantially from the present trial in both severity and intervention content, but collectively suggest that respiratory rehabilitation strategies targeting ventilation, diaphragmatic function, and airway clearance may have a supportive role during recovery from pneumonia.

At the same time, the present results should be interpreted in the context of the wider evidence base, which remains uncertain. The Cochrane review of chest physiotherapy for pneumonia in adults concluded that available evidence is insufficient to establish consistent benefit for major outcomes such as mortality, cure rate, or length of hospital stay (3). This is important because the current study assessed short-term physiological and symptom outcomes rather than major clinical outcomes. Improvement in spirometry or symptom scores should therefore not be interpreted as evidence that blow bottle therapy reduces mortality, prevents complications, shortens hospitalization, or improves long-term recovery. Instead, the present findings support a more limited conclusion that the addition of blow bottle therapy was associated with greater short-term improvement in the outcomes specifically measured in this trial.

The study has several strengths. It used a comparative randomized design, evaluated both objective pulmonary-function measures and patient-reported respiratory symptoms, applied the interventions over the same treatment period, and examined between-group changes rather than relying solely on within-group statistical significance. Reporting both pre- and post-bronchodilator pulmonary-function measures also provided a broader description of respiratory performance. The consistency of the treatment effect across multiple pulmonary and symptom outcomes strengthens the internal pattern of the findings.

Several limitations should nevertheless be considered. The sample consisted of only 28 participants from a single hospital, limiting statistical precision and generalizability. The intervention lasted one week and there was no longer-term follow-up, so persistence of the observed improvements is unknown. Participants and treating therapists could not realistically be blinded to the use of the blow bottle technique, creating potential performance bias, and assessor blinding was not established. The study evaluated numerous related outcomes without a clearly identified primary endpoint, increasing the potential for multiplicity-related inflation of statistical findings. The magnitude of several standardized effects was unusually large and should be interpreted cautiously, particularly

given the small sample and low variability of some reported change scores. In addition, concomitant medical treatments for pneumonia were not characterized in sufficient detail to determine whether treatment differences could have contributed to outcome variability. The use of BCSS in patients with community-acquired pneumonia rather than its principal obstructive-airway-disease context is another measurement limitation. Finally, outcomes such as oxygen saturation, length of hospital stay, complications, readmission, quality of life, and longer-term functional recovery were not assessed.

From a clinical perspective, the blow bottle technique has practical advantages because it is inexpensive, simple, and does not require specialized commercial equipment. These characteristics may make it attractive as an adjunctive airway-clearance strategy in rehabilitation settings with limited resources. However, implementation should depend on appropriate patient selection, standardized technique, supervision, infection-control procedures, and clinical monitoring. The present findings justify further evaluation in adequately powered trials using clearly prespecified primary outcomes, standardized PEP protocols, appropriate blinding of outcome assessment where feasible, and clinically important endpoints in addition to spirometry and symptom scores.

CONCLUSION

In this randomized clinical trial of patients with community-acquired pneumonia, both percussion combined with diaphragmatic breathing and the same treatment supplemented with the blow bottle technique were associated with improvement over one week; however, the addition of the blow bottle technique produced greater short-term improvements in FVC, FEV1, FEV1/FVC ratio, PEF, and BCSS respiratory symptom scores. These findings suggest that blow bottle therapy may be a useful adjunct to percussion and diaphragmatic breathing for short-term respiratory rehabilitation in appropriately selected patients with community-acquired pneumonia, although the small single-center sample and short follow-up limit the extent to which the findings can be generalized.

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