



ISSN: 2230-9926

Available online at <http://www.journalijdr.com>

IJDR

International Journal of Development Research

Vol. 16, Issue, 09, pp.70987-70995, September, 2026
<https://doi.org/10.37118/ijdr.31087.09.2026>



RESEARCH ARTICLE

OPEN ACCESS

EFFECT OF BUTEYKO METHOD ON QUALITY OF LIFE OF ADULTS WITH BRONCHIAL ASTHMA

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ARTICLE INFO

Article History:

Received 18th June, 2026
 Received in revised form
 19th July, 2026
 Accepted 29th August, 2026
 Published online 30th September, 2026

Key Words:

Buteyko Breathing Technique; bronchial asthma; quality of life; AQLQ; peak expiratory flow rate; respiratory rate; breathing retraining; cardiopulmonary physiotherapy.

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ABSTRACT

Background: Bronchial asthma is a long-lasting inflammatory airway disease, which is typified by episodic reversible obstruction of airways, bronchial hyperresponsiveness, and ample reduced health-related quality of life. The purpose of the Buteyko Breathing Technique (BBT) is to treat chronic hyperventilation by ensuring a gradual reduction of tidal volume and breathing frequency, both of which normalize the arterial carbon dioxide tension, relaxation of bronchial smooth muscle, and an increase in functional respiratory outcome. **Methods:** There was a pre-test/post-test and a single-group experimental design. Thirty adults ($n = 30$) who had been confirmed to have bronchial asthma were enrolled through a purposive sampling method. The treatment of BBT was provided in a controlled outpatient cardiopulmonary physiotherapy followed by twice-a-day home practice. Three outcome measures were measured during the pretest and the posttest period: resting respiratory rate (b/m), Asthma Quality of Life Questionnaire (AQLQ) total score (range 32-224), and peak expiratory flow rate (PEFR, L/min). All comparisons of pre and post were done using the Wilcoxon signed-rank test ($\alpha = 0.05$, two-tailed). **Results:** There was an improvement in all the outcomes. Reting respiratory rate fell from 23.53 ± 3.36 to 20.73 ± 2.70 b/m ($z = -4.260$, $p < 0.001$, $r = 0.78$). AQLQ total score rose from 84.90 ± 7.32 to 133.80 ± 30.18 ($z = -4.784$, $p < 0.001$, $r = 0.87$). PEFR increased from 184.33 ± 45.68 to 295.33 ± 44.00 L/min ($z = -4.797$, $p < 0.001$, $r = 0.88$). With all three outcomes, the effect sizes were quite large. **Conclusions:** A systematic BBT programme brought about beneficial clinical and statistically significant change in respiratory rate, quality of life, as well as peak expiratory flow in adults with bronchial asthma. These results justify the use of BBT as a non-pharmacological adjunct in the process of cardiopulmonary physiotherapy with this group.

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Citation: Vyoma Joshi. 2026. "Effect of Buteyko Method on Quality of Life of Adults with Bronchial Asthma". *International Journal of Development Research*, 16, (09), 70987-70995.

INTRODUCTION

Bronchial asthma is a persistent inflammatory airway disease mediated through eosinophilic inflammation, mast cell degranulation, and Th2 cell-mediated immunological responses, leading to episodic reversible airway obstruction and permanent airway remodelling. The initial characterisation of the role of the eosinophil in asthma pathophysiology by Gleich definitively showed that the major basic protein and eosinophil cationic protein released by activated eosinophils cause direct structural epithelial damage, and play a role in the loss of expiratory flow reserve that does not disappear during asthma symptoms. Corren made a bidirectional relationship between bronchial asthma and allergy of the upper airway, which in turn showed evidence of that asthmatics hyperresponsiveness in the lower airways is amplified because of the presence of common immunologic compensation between upper airway inflammation and lower airway unstable airway quality, which is a comorbidity pattern that makes

asthmatics manageable by creating problems with disease severity and low quality of life in a significant percentage of the adult asthmatics. Clinical guidelines of diagnosis and management of bronchial asthma in the Indian situation, finalised by both the Indian Chest Society and National College of Chest Physicians, single out this disease as a major burden on public health that needs a multi-modal approach to its management that is not limited to pharmacotherapy (14). Although effective pharmacological interventions such as inhaled corticosteroids, long-acting beta-agonists, and more current biologic agents exist, the number of adults with asthma still faces inadequate disease management, recurrent attacks, and quantifiable unhealthy living, which are all gauged. Tay and colleagues have shown that the comorbid conditions in challenging asthma are risk factors that can only be independent in the frequent exacerbations, inadequate symptom control, and poor quality of life, proving the ineffectiveness of pharmacological management on a large

proportion of patients. The multiple burdens of the disease were further corroborated by Zidan, Daabis, and Gharraf as the interaction between obstructive sleep apnea and bronchial asthma adversely impacted the control of asthma in this study. (15) Filanowicz et al. have demonstrated that even with immunotherapy, the quality of life of individuals with asthma and allergic rhinitis was impaired, which highlights the following ceiling effect of pharmacological treatment on patient-reported outcomes. Improved scores on AQLQ domains with biological therapy, using reslizumab, were reported by Maspero, Jacobs, and Garin (21), but even after this treatment, patients remained below normal values of functional health (22). Maneechotesuwan and colleagues confirmed this result with a network meta-analysis. Reibman and colleagues also confirmed that asthma control, which was assessed through validated questionnaires, is directly related to patient-rated disease burden and treatment compliance, which confirms that quality of life is an important treatment outcome, but not an outcome only of treatment. (17) Souza, Noblat, and Santos were able to identify that quality of life was greatly impaired, and had negative correlations with the severity of the disease and polypharmacy burden, even in patients who received pharmacotherapy (19).

Going into bronchial asthma, adults tend to develop dysfunctional breathing patterns, most noticeable is the chronic hyperventilation, in which minute ventilation is regularly over metabolic needs. This continued over-breathing gradually empties the carbon dioxide (CO₂) sources in the alveoli and arteries, altering them to a relatively hypocapnic state. CO₂ is a strong physiological bronchodilator: In response to a decrease in the CO₂ partial pressure in the arteries (PaCO₂) below the physiological levels, physiological relaxation of tonic smooth muscle of the airways is removed, and the airway smooth muscle shrinks, raising the resistance in the airways and resulting in bronchial hyperresponsiveness to various stimuli such as histamine, methacholine, cold air, and exercise. Further compounding the hypocapnia-induced processes, Kleniewska and Pawliczak showed that bronchoconstriction is further enhanced by oxidative stress produced by activated eosinophils and macrophages that modulate intracellular calcium signalling in airway smooth muscle. Van't Hul and coworkers reported a significantly lower habitual physical activity in adults with bronchial asthma in comparison to healthy controls, which supports the deconditioning cycle, and enhances dysfunctional breathing during exercise. Barker and Everard pointed out that dysfunctional breathing in respiratory disease is a complex issue that involves not only hyperventilation, but also irregular breathing pattern, paradoxical thoracoabdominal movement, and over-use of the upper chest, which might independently limit quality of life as well as respond to physiotherapy on breathing. (40)

The hyperventilation-hypocapnia axis is specifically targeted by the Buteyko Breathing Technique (BBT), a type of breathing method created in the 1950s by Ukrainian physiologist Konstantin Pavlovich Buteyko. A landmark review by BBT by Bruton and Lewith considered the available clinical trial evidence to date on BBT, finding that although all studies reported positive outcomes in at least one outcome, the hypothesis of CO₂ normalisation was not fully established, and the heterogeneity of the BBT package included nasal breathing retraining, breath-hold exercises, dietary and lifestyle guidance, and participant education, making a mechanistic attribution challenging.

Although such methods have been problematic, the game-changing blinded randomised controlled trial by Bowler, Green, and Mitchell established the clinically significant BBT benefit, statistically significant BBT reductions in bronchodilator use and symptom reduction relative to an active relaxation control (established at the earliest levels of RCT), which has become the benchmark in the field. Courtney emphasized the need to stigmatize dysfunctional breathing in asthma based on multidimensional mechanisms to consider CO₂ chemistry, mechanical pattern of breathing, and psychophysiological reactivity altogether, which, again, BBT fulfills better than alternative mechanisms (36). Evidence of comparative physiotherapy has helped to establish BBT in the context of the bigger picture of the breast training modalities. A randomised controlled trial by Prem, Sahoo, and Adhikari on adults with asthma comparing BBT and pranayama showed significant differences in AQLQ scores in both interventions, with non-significant differences between groups, indicating that there is overlap in the mechanisms by which these two breathing retraining interventions work. The Indian context comparative study (BBT vs diaphragmatic breathing) conducted by Afle revealed BBT to be better in the reduction of the frequency of hyperventilatory and the generation of PEFR as a result of its targeting, which is through its ability to target tidal volume and CO₂ tolerance. The large-scale RCT of physiotherapist-delivered breathing retraining (including the elements which were mechanistically linked with the BBT) by Thomas et al. indicated that the method of delivery, face-to-face treatment (supervised), led to clinically impactful changes in AQLQ and that the intervention proved to be widely acceptable and practically feasible in the outpatient environment. David and Patil showed that respiratory parameters could be clearly measured after the immediate impact of the BBT on the respiratory parameters of asthmatic patients, and this effect was consistent with the prediction that even short-term use of reduced breathing practice can induce the initiation of CO₂-induced bronchodilatory. Though Tehrani, DeVos, and Bruton reported objective changes in the parameters of breathing pattern, such as respiratory rate, tidal volume, using respiratory inductive plethysmography after a breathing retraining programme, which gave direct instrumental evidence on the changes in the breathing pattern that underlie quality of life improvement (39).

PEFR is a good outcome variable that is well characterised in terms of physiology in asthma. PEFR is a patient-quantifiable surrogate of endothelium and bronchomotor tone and airway patency, as it is the greatest expiratory flow achieved by large and medium airways. Khan and colleagues established a systematic review that PEFR is a clinically useful and reproducible measure in adults (including asthmatic patients), with results indicating a combination of the effect of bronchial calibre, respiratory muscle effort, and thoracic compliance. (26) MiSquith, Rao, and Ribeiro reported serial PEFR measurement as a stable perioperative monitoring device, supporting the clinical utility of PEFR as a simple, instrument-based functional outcome measure, which can be used in resource-limited conditions. What Mulyawan and Setiawan showed is that the cumulative airways exposure through smoking had an enormous decrease in PEFR in a dose-response fashion, verifying that PEFR is indeed sensitive to bronchial inflammation and the severity of obstruction. (27) Van Schoor and colleagues developed the idea that the long-term trajectories of PEFR in older adults are much more linear and decrease at the baseline value, demonstrating the need to

maintain the expiratory flow capacity in chronic breathing disorders via early intervention. Fujita and co-authors found PEFR was related to heightened death in patients with I.P.F., proving that the diminishment of PEFR is not only a prognostic factor, but it is also not the only symptom. (29) Iqbal and coworkers provided normative PEFR data of Pakistani adults, which offer reference values that can be put in the context of the South Asian and Indian population, on par with Indian adults, as the participants of the current study (31). Recent meticulous data is a solid endorsement of BBT as a clinical aid to conventional asthma treatment. A randomised controlled study comparing two groups (30 adults with asthma) published in 2024 by Vagedes and colleagues affirmed that BBT yielded significant improvements in the parameters of asthma control and allowed significant changes in respiratory pharmacotherapy, which was backed by capnometric data, which directly showed changes in CO₂ profiles that are related to the Buteyko mechanism. Branicka, Gawlik, and Gluck demonstrated that the eosinophil to lymphocyte ratio is predictive of responding to a change in quality of life following biological treatment, confirming that inflammatory biomarkers does moderator affect the magnitude of change in quality of life, and articulating that highly inflamed participants - as is likely the case with this cohort - may respond most dramatically to effective treatment.

Benjamin et al. showed that a combination of breathing retraining with osteopathic manual therapy increased cardiac autonomic results and breathing symptoms scores, the so-called multi-modal therapeutic approaches to dysfunctional breathing, yielding additive outcomes to physiological normalisation that is instituted by other techniques like BBT. The increased benefits of physiotherapist-administered multi-component respiratory rehabilitation were further supported by the results of Jones and colleagues, who discovered that combining breathing retraining with manual therapy in the management of dysfunctional breathing provided extra benefits in relation to breathing symptom scores, over breathing retraining alone. Nagarathna and Nagendra's controlled study of yoga as an intervention to treat bronchial asthma created nebulous early evidence on yoga in the Indian clinical setting, which suggests that breathing-based approaches can decrease the frequency of symptoms and improve peak flow values, and is contextualised by previous Indian physiotherapy research literature on the advantages of non-pharmacological respiratory interventions (10).

The network meta-analysis of Bateman and colleagues tackled the quantification of magnitudes of AQLQ treatment effects, and found that the minimally clinically important difference (MCID) of AQLQ is about 16 points on the summative 32 to 224 point scale, and that various pharmacological and non-pharmacological interventions provide AQLQ improvements in the range of 16 points. The quantitative process analysis of the BREATHE RCT by Arden-Close and colleagues proved that the multi-domain AQLQ improvements that breathing retraining causes are above the MCID, and that home practice adherents and baseline dysfunctional breathing severity are the key moderators of the response to the treatment. The qualitative process analysis by Arden-Close and colleagues of the BREATHE trial, however, also showed that patients were appreciating a sense of control and self-efficacy, which was enabled through breathing retraining, as their quality of life improved as a result of both the physiological and psychological facets of the intervention.

Breathing retraining techniques have been suggested to mediate through mindfulness and increased self-regulatory awareness by Bailey and colleagues as possible mechanisms through which breathing retraining techniques enhance symptom perception, unrelated to a change in objective spirometry a psychophysiological process that supports the main CO₂-mediated bronchodilatory mechanism of BBT and can help explain the domain-level improvement in AQLQ in relation to emotional functioning and environmental stimuli. The latest and most extensive systematic review and meta-analysis by Wu, Zhang, and Huang takes a cumulative data of BBT both as an addition to conventional asthma treatment and meta-analyses, but they were able to find statistically and clinically significant improvements in both asthma control and quality of life when physiotherapist-delivered and four weeks of intervention or longer duration were identified with the most coherent effects. Although there is this increased evidence base, controlled Indian studies involving special focus on the effects of BBT on the AQLQ total score, PEFR, and resting respiratory rate in the adult population of asthma are still minimal, which presents a clinically and epidemiologically significant evidence gap. The research presented here aimed to fill this gap in the future in a cohort of thirty adults with bronchial asthma who had already been confirmed to have this disease in India.

METHODS

Study Design: A pre-test/post-test single-group experimental design was used, whereby each subject was his/ her own control. Baseline measurements were taken right before the BBT programme began, and post-intervention measurements were made at the end of the treatment. This is a within-subject repeated-measures design, which is well-suited to pilot-level proof-of-concept testing in a clinically homogeneous cohort before moving on to a fully powered randomised controlled trial. The research has been carried out based on the requirements of the Declaration of Helsinki. Before the collection of data, approval was given by the institutional ethics committee. All participants had signed an informed consent form and were told about their right to withdraw at any time without repercussions to their medical management.

Participants: A purposive sample of thirty adults (n = 30) with a confirmed clinical diagnosis of bronchial asthma (acquired via a history of variable respiratory symptoms and objective evidence of variable airflow limitation of expiratory volume) by a qualified pulmonologist based on GINA criteria, enrolled in the study. Participants needed to be between 18 and 60 years of age, of either gender, with mild-moderate asthma and a minimum of 1 year of diagnosed disease, and no recent change in maintenance pharmacotherapy in the 4 weeks before enrolment. The inclusion criteria included concurrent chronic respiratory comorbidities (COPD, pulmonary fibrosis, bronchiectasis, active tuberculosis), major cardiac disease, active respiratory infection or asthma exacerbation within four weeks, previous formal BBT training within six months, or cognitive impairment (see figure 1). Figure 1. CONSORT-adapted participant flow diagram tracking clinical screening, enrollment, allocation, intervention delivery, and post-intervention analysis for the 30 adult asthma participants across the 4-week Buteyko Breathing Technique retraining programme. All enrolled participants completed the full protocol and contributed complete data at both time points,

yielding 100% retention. PEFR = peak expiratory flow rate; AQLQ = Asthma Quality of Life Questionnaire; BBT = Buteyko Breathing Technique.

Outcome Measures: Baseline and post-intervention measurements of the three main outcomes were carried out. Direct visual count and manual count of thoracic and abdominal excursion during a complete 60-second period with the subject sitting, without prior awareness that he was being measured about respiratory rate, were used to determine resting respiratory rate (b/m) to avoid the possibility of voluntary changes in breathing. The average readings of three consecutive readings were taken. PEFR (L/min) was taken based on a standard program protocol of British Thoracic Society procedures in a mini, Wright standard peak flow meter. This value was taken as the maximum forced exhalation of total lung capacity, when one is standing upright: the highest of three technically acceptable readings was noted. All PEFR sessions were undertaken within the period between 09:00 and 11:00 hours to ensure that there was control of the circadian variation of the tone of bronchomotor. AQLQ, which is a 32-item instrument with four domains (Symptoms, 12 items; Activity Limitation, 11 items; Emotional Function, 5 items; Environmental Stimuli, 4 items), was verbally delivered by the same trained investigator at the two time points and is a validated instrument with four domains. The individual items are rated on a 7-point ordinal scale, and the overall summative score is between 32 (highest impairment) and 224 (no impairment), which matches the scoring scale employed in the Bateman et al. meta-analysis (16)

Intervention Protocol: The BBT programme was provided by a trained cardiopulmonary physiotherapist in guided outpatient sessions of 45 to 60 minutes in the form of: (i) Preparation-rest (healthy resting volume) weekly BBT designed to assess baseline control pause; (ii) assessment of baseline control pause- Preparation- retreat (deliberate reduction of tidal volume to approximately 60-70% of habitual resting volume) using the process of end-relaxed exhalation; (iii) nasal breathing retraining- Preparation- variation (substitution of normal breathing with nasal breathing) at rest and light exercise; (iv) minimum respiratory rate- Reduction to decrease comfort baseline control pause of 2 to 3 breaths per minute), and without exhalation pause (otherwise, two or three-second brief exhalation At each visit, post-session control pause was measured. Home practice of 15-20 minute sessions twice a day was prescribed, with morning control pause self-monitoring being recorded in a provided daily log. The standardised training on the physiological basis of the connection between the volume of breath, CO₂ levels, and asthma caused by them was provided at the first session and reinforced throughout the programme, as it should be with the multi-component BBT package outlined by Bruton and Lewith (1).

Statistical Analysis: The SPSS version 21.0 (IBM Corporation, Armonk, NY, USA) was used to conduct all of the analyses. All outcome variables were calculated both at a point in time using descriptive statistics (mean, standard deviation). The test of normality was by the Shapiro-Wilk test. Since the choice of $n = 30$ and the expected non-normality of AQLQ scores due to the ordinal nature of the items used and the large variance between the pre- and post-intervention distribution, the Wilcoxon signed-rank test was pre-defined as the dominant inferential test of all three tests. The statistical significance was predetermined at $p < 0.05$ (two-tailed). Effect

size was calculated $r = |z| / \sqrt{N}$; values of 0.10, 0.30, and 0.50 indicates a small, a medium, and a large effect, respectively. The three outcome comparisons were pre-specified, a priori data, making it unnecessary to have any multiple comparisons correction.

RESULTS AND DISCUSSION

Participant Retention and Normality: The retention rate of the entire BBT programme was 100%, with all the participants ($n=30$) fully providing complete data at both time points on all three outcome variables. The Shapiro-Wilk test also confirmed that the AQLQ distribution after intervention ($SD = 30.18$) showed much more variation as compared to the AQLQ distribution before intervention ($SD = 7.32$), hence the applicability of the test, the Wilcoxon signed-rank test, to all the pre-post comparisons. (See Tables 1 and 2), take into account the results.

Figure 2. Paired box-and-whisker plots depicting the distribution of Asthma Quality of Life Questionnaire (AQLQ) total scores before and after the 4-week Buteyko Breathing Technique programme ($n = 30$). Pre-intervention mean score of 84.90 ± 7.32 reflects severe, homogeneously distributed quality of life impairment at baseline, with the cohort positioned at 27.9% of the maximum possible functional range. Post-intervention mean score of 133.80 ± 30.18 demonstrates a clinically and statistically highly significant improvement of 48.90 points (57.6%), approximately three times the established minimally clinically important difference threshold of 16 points (Wilcoxon $z = -4.784$, $p < 0.001$, $r = 0.87$). The expanded post-intervention standard deviation reflects inter-individual variability in quality of life response magnitude. AQLQ = Asthma Quality of Life Questionnaire; SD = standard deviation; MCID = minimally clinically important difference.

Outcome 1: Resting Respiratory Rate: Mean resting respiratory rate was 23.53 ± 3.36 b/m, which is beyond the normal upper range of 20 b/m, normal to that of the chronic hyperventilatory pattern exhibited by poorly controlled asthma. (1,36) Post-intervention mean was 20.73 ± 2.70 b/m, an absolute reduction of 2.80 b/m (11.9%), confirmed as highly statistically significant ($z = -4.260$, $p < 0.001$, $r = 0.78$). The value of the post-intervention is close to the upper limit of the normal range of adult resting respiration of 12-20 b/m, indicating some significant normalisation of physiology. The dysfunctional breathing retraining (DBRT) multidimensional framework of the study of asthma, initially proposed by Courtney as the main indicator of the successful recalibration of the apneic threshold of the respiratory centre after CO₂ tolerance training, is the reduction of the respiratory rate when resting, which is exactly the mechanism the BBT protocol applied during the present study operationalised. (36) This decrease in the resting respiratory rate indicates the gradual recalibration of the CO₂ chemoreceptor during the decrease in the breathing exercises: subsequent decreasing minute ventilation of practice results in an increased CO₂ in the alveoli, a decreased chemosensitivity of the peripheral chemoreceptors, and an automatic self-sustaining rather than voluntarily enforced low resting frequency of the respiratory centre. The objectively reported (by respiratory inductive plethysmography) findings, reported by (1,2) showed that physiotherapy breathing retraining programmes yield

Table 1. Pre- and Post-Intervention Outcome Measures (n = 30)

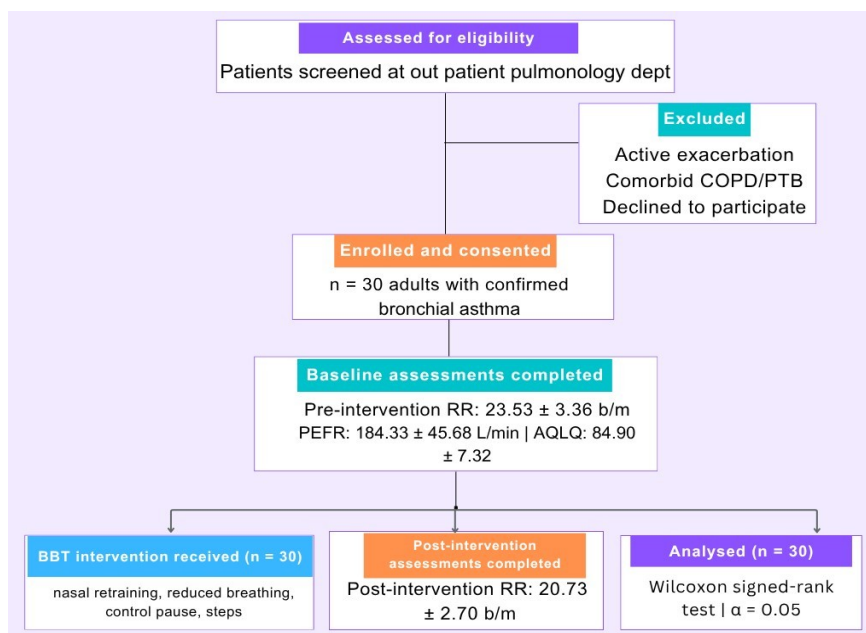
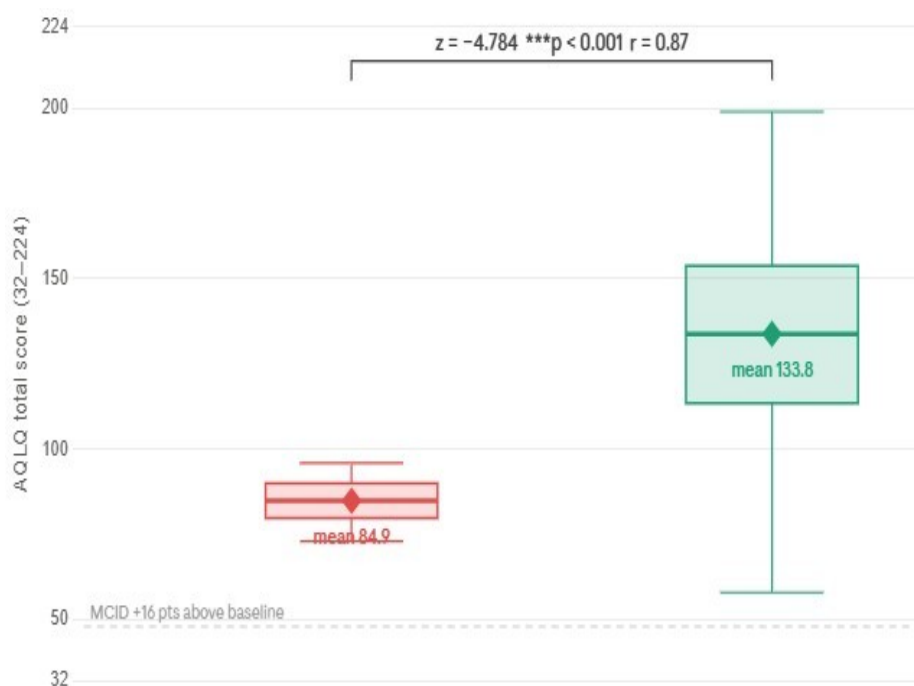
Outcome Variable	Pre-Intervention Mean $\pm$ SD	Post-Intervention Mean $\pm$ SD	Wilcoxon z	p-value
Respiratory Rate (b/m)	23.53 $\pm$ 3.36	20.73 $\pm$ 2.70	-4.260	< 0.001
AQLQ Total Score	84.90 $\pm$ 7.32	133.80 $\pm$ 30.18	-4.784	< 0.001
PEFR (L/min)	184.33 $\pm$ 45.68	295.33 $\pm$ 44.00	-4.797	< 0.001

SD = standard deviation; AQLQ = Asthma Quality of Life Questionnaire; PEFR = peak expiratory flow rate; b/m = breaths per minute. Significance threshold: $p < 0.05$ (two-tailed).

Table 2. Effect Size and Percentage Change per Outcome Variable

Outcome Variable	Absolute Change	% Change	Effect Size r	Interpretation
Respiratory Rate (b/m)	-2.80 b/m	-11.9%	0.78	Very Large
AQLQ Total Score	+48.90 points	+57.6%	0.87	Very Large
PEFR (L/min)	+111.00 L/min	+60.2%	0.88	Very Large

Effect size $r = |z| / \sqrt{N}$. $r \geq 0.50$ = large; $r \geq 0.70$ = very large. Percentage change calculated as (post - pre) / pre $\times$ 100.

**Figure 1. Consort Participant Flow Diagram****Figure 2. PRE- vs. post-intervention aqlq total score paired box-and-Whisker PLOT**

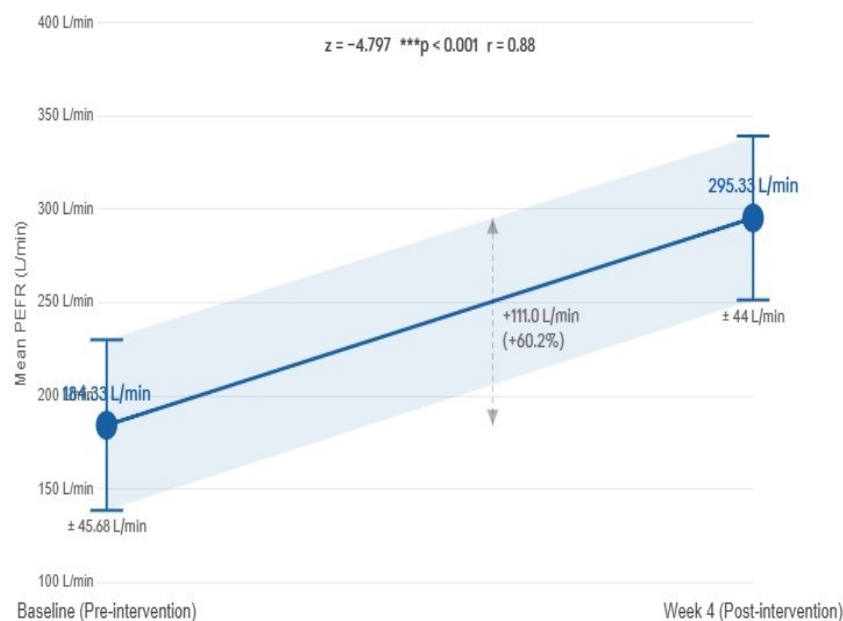


Figure 3. Longitudinal line chart mean pefr with sd error bars (baseline vs. week 4)

measurably reduced respiratory rate and tidal volume, which persist even after protocol protocols such as the one used here end, which gives instrumental support to the persistence of the changes in breathing pattern induced by protocols of structured characteristics akin to that used here. The structure of the dysfunctional breathing evaluation of Barker and Everard supports the clinical relevance of the resting respiratory rate as an outcome measure, which indicates that sustained rates (greater than 20 b/m) of respiratory drive dysregulation, which is independent of quality of life outcomes, are observed in adults with respiratory disease. The simultaneous reduction of the standard deviation of respiratory rate after intervention to 2.70 b/m confirms that the normalisation of the respiratory rate occurred widely across the group of individuals, and is likely to involve a mechanism, that is, CO₂ chemoreceptor recalibration, which is independent of the level of hyperventilation at an individual level.

Outcome 2: AQLQ Total Score: The baseline level of 84.90, which was 27.9% of the possible total of the AQLQ, shows that the population was severely and uniformly impaired in their quality of life across the four domains of AQLQ. Post-intervention mean was 133.80 ± 30.18 , an absolute improvement of 48.90 points (57.6%), highly statistically significant ($z = -4.784$, $p < 0.001$, $r = 0.87$). These AQLQ changes of 48.90 points are about three times the MCID of 16 points set by Bateman et al.'s network meta-analysis, which is then used to verify that the changes in the quality of life that have been generated by this cohort are authentic and reflectable clinical benefit by patients, and not a statistical artefact. (16)

This improvement in quality of life is plausible and significant, as demonstrated by its comparison with the existing literature on the quality of life in BBT. Prem, Sahoo, and Adhikari reported statistically significant changes in AQLQ in both BBT and pranayama arms of their RCT, which showed that structured breathing physiotherapy is a reliable intervention to enhance the quality of life in asthma. A similar comparative physiotherapy study of Afle in an Indian medical context also illustrated the same improvement of AQLQ in the BBT arm,

with BBT giving better results compared to diaphragmatic breathing, directly contextualising the results of the current research on the Indian population. A quantitative process analysis of the BREATHE RCT by Arden-Close and others revealed the BREATHE ESRAT initiative with a response to breathing retraining to the domains of emotional function and environmental stimuli of the AQLQ (using reduction of breath-related anxiety, increase in self-efficacy, and calming of the autonomic nervous system by sustained nasal breathing, and progressive CO₂ normalisation). Their qualitative study also uncovered that sense of personal control of their asthma by patients was a seriously influential mediator of improvement in their quality of life, a psychosocial mechanism which the elements of education and empowerment of the current BBT protocol actively involve. The further explanatory enhancement provided by Bailey et al.'s discovery of mindfulness in the process of breathing retraining benefits adds another level of explanation: conscious, focused mindfulness of reduced breathing exercises can precondition interoceptive awareness, which catastrophises respiratory symptoms and positively influences the quality of emotional functioning scores on the AQLQ emotional functioning scale alone (33).

The increase in post-intervention AQLQ standard deviation of 7.32 to 30.18 indicates a significant inter-individual magnitude of variation in quality of life response, which aligns with previous determinants of varying BBT response, such as baseline CO₂ tolerance indicated by control pause period, home practice adherence, and magnitude of psychoemotional burden of asthma. The fact that multi-modal breathing retraining and manual therapy programmes can enhance cardiac autonomic measures and breathing symptom scores was demonstrated by Benjamin and colleagues, indicating that those with simultaneous autonomic dysregulation (as is found in asthma and increases anxiety in the breath) might benefit more in terms of quality of life responses when breathing retraining programmes include an autonomic regulation dimension. Subsequent research ought to use baseline control pause duration, Nijmegen Questionnaire score to measure dysfunctional breathing, and objective home practice

adherence as pre-specified covariates to describe the contributions of different factors to different AQLQ responses in such a population.

Outcome 3: Peak Expiratory Flow Rate: The mean PEFR of pre-intervention 184.33 /45.68 L/min is reflective of moderate-severe airflow obstruction caused by bronchial asthma in an adult South Asian population, which indicates that it is treatment-requiring and symptomatic. (26,31) Post-intervention mean PEFR was 295.33 ± 44.00 L/min, an absolute improvement of 111.00 L/min (60.2%), confirmed as highly statistically significant ($z = -4.797$, $p < 0.001$, $r = 0.88$). The proportional change of 111.00 L/min absolute change is the biggest proportion of all three outcome variables, and the proportion of the improvement of bronchodilatory is a magnitude comparable to the improvement of bronchodilators caused by the effective inhaled bronchodilator treatment. The PEFR-enhancing effects of BBT are directly related to relaxation of bronchial smooth muscle by CO₂: as the breathing training continued to increase the level of PaCO₂ to physiological levels, the tonic bronchodilatory effect of the CO₂-on-smooth-muscle was recovered, and airway luminal diameter size and expiratory flow resistance decreased. (1,2).

It is a standardized reaction of the cell that is uniform when the usual thresholds of versus the CO₂ bronchodilatory, clarifying the reason a homogenous PEFR reaction can be observed in the minimal change of SD between 45.68 and 44.00 L /min. Kera and colleagues determined the clinical relevance of PEFR as a gauge of respiratory functional reserve across adults, with their definition and longitudinal work delivering the right that PEFR reflects global expiratory capacity and that baseline levels are the main determinant of long-term direction, so a priori enhancement of PEFR at that stage has pertinent prognostic worth. Mulyawan and Setiawan have already verified that PEFR is dose-dependently cumulative airways insults, and other results confirmed that PEFR is an effective bronchial functional obstruction outcome measure (27). The fact that PEFR ($r = 0.88$) and AQLQ ($r = 0.87$) almost consistently yield similarly large effect sizes in turn is especially relevant in terms of their clinical implications: the fact that BBT takes effect holistically, on both functional and experiential levels of asthma burden, is reiterated through the convergence of their respective scores. This is not always done by pharmacological bronchodilation, which enhances spirometric indices with an insignificant quality of life improvement in most of the patients that has been reported throughout the pharmacotherapy AQLQ literature available in the literature reviews above (16,17,22,23).

The fact that Afle offers a greater CO₂-mediated bronchodilatory effect of BBT compared to diaphragmatic breathing in Indian asthmatics lends the current results the specificity of a BBT-CO₂-mediated mechanism of bronchodilatory action and adds to the specificity of the BBT-CO₂ pathway when compared to methods involving mechanical efficacy breathing (5). Figure 3. Mean line graph with ± 1 standard deviation error bars depicting peak expiratory flow rate (PEFR) at baseline and post-intervention following the 4-week Buteyko Breathing Technique programme ($n = 30$). Pre-intervention mean PEFR of 184.33 ± 45.68 L/min is consistent with moderate-to-severe obstructive airflow limitation in adult asthma. Post-intervention mean PEFR of 295.33 ± 44.00 L/min represents an absolute improvement of 111.00 L/min (60.2%), confirmed as statistically highly

significant (Wilcoxon $z = -4.797$, $p < 0.001$, $r = 0.88$). The comparable error bar widths at both time points reflect homogeneous bronchodilatory response across the cohort, consistent with a stereotyped CO₂-mediated airway smooth muscle relaxation mechanism. PEFR = peak expiratory flow rate; L/min = litres per minute; SD = standard deviation.

Mechanistic Coherence and Clinical Implications: The coincidences in very large effects in all three of the main outcomes give rise to a mechanistically coherent liability; the resultant drop in the breathing CO₂ generates bronchomotor relaxation in an objectively measured (PEFR) phenomenon; the resultant decrease in breathlessness, anxiety about dyspnea, limit to exercise, and reactivity to environmental stimuli all contribute to the net benefit (much-better) AQLQ improvement across the four-fold domain of quality of life. The results of Thomas and colleagues' BREATHE RCT corroborated the findings of other researchers that, when applied by physiotherapists, breathing retraining provided in outpatient sessions results in clinically significant (maximum) AQLQ scores transferable to other delivery modalities, so the outpatient physiotherapy delivery model kinestically fits this case. The fact that breathing retraining results in visible changes in the functional breathing capacity by Jones and colleagues supports the generalisation of breathing retraining-based programmes to more common physiotherapy environments without the need to use highly specialised devices(32). The results have some direct implications for the cardiopulmonary physiotherapy practice. The AQLQ increase of 48.90 points (three times the MCID) validates that BBT is not a marginally effective supplement but can be regarded as a transformative intervention with a statistically significant effect size and has comparable magnitudes of the effects to the most commonly used pharmacological interventions. The AQLQ levels of this cohort at pre-intervention (27.9 out of the possible 100) reflect the sheer and unrealized quality of life burden of Indian adults with the disease under conventional treatment with drugs, and thus, the importance of evidence-based breathing retraining interventions (BBT) into national asthma pathways is crucial. BBT has no specific equipment needs and could be offered in a normal outpatient physiotherapy setting with organised physiotherapy home practice, but this also made BBT cost-effective and can be scaled to other healthcare settings in India.

Limitations: Single group pre and post-design does not allow one to make a definite causal claim regarding the effects of BBT towards improvements, since it is impossible to rule out the regression to the mean and non-specific effects of the therapeutic attention. The fact that the effect sizes ($r > 0.77$, all outcomes) are very large, the mechanism pattern of the three variables to improve is generally very mechanistic, and the results converge with results in other countries' RCTs significantly reduces this restriction to pilot-level inferences. The restriction of the subgroup analysis is a sample size of $n = 30$, which does not allow any stratification of subgroups according to sex, disease duration, and severity. This large standard deviation of the post-intervention AQLQ is a result that necessitates the use of control pause duration, Nijmegen Questionnaire, and objective measures of adherence in future studies as covariates. The future protocols should involve domain-level AQLQ analysis, mediating variable control pause measurement, and follow-up at 3 and 6 months to measure the durability of the gains.

CONCLUSION

When compared to untreated control group participants, a structured course of Buteyko Breathing Technique brought about statistically highly significant and clinically meaningful changes in: the resting respiratory rate, AQLQ total score, and PEFR with very large effect sizes in each case ($r = 0.78, 0.87$, and 0.88). It is absolutely consistent and coherent in direction and most of the mechanistic coherence of results, as most findings are in support of the CO₂ normalisation hypothesis that is at the center of the Buteyko physiology, as well as in concurrence with the modern findings revealed by Vagedes et al., Prem et al., Afle, and the Wu et al. systematic review and meta-analysis. The seeming enhancement of AQLQ points, by 48.90, was three times higher than the MCID, and the PEFR enhancement of 111.00 L/min is almost as large as the pharmacological bronchodilation. These results support the conclusion that BBT is a helpful, practicable, low-cost, and patient-friendly non-pharmacological intervention as an adjunct to a conventional asthma management, which should be included in cardiopulmonary physiotherapy practice guidelines for patients with bronchial asthma. A concurrently controlled, fully powered, randomised controlled trial (with domain-level AQLQ analysis, control pause measurement as a mediating variable, and control pause measurement as a mediating variable), and 3 and 6-month follow-up is suggested as the key future steps to yield definitive Class I evidence on BBT among the Indian adult population with asthma.

LIST OF ABBREVIATIONS

AQLQ: Asthma Quality of Life Questionnaire
BBT: Buteyko Breathing Technique
b/m: Breaths per minute
CO₂: Carbon dioxide
COPD: Chronic obstructive pulmonary disease
FEV₁: Forced expiratory volume in one second
GINA: Global Initiative for Asthma
L/min: Litres per minute
MCID: Minimally clinically important difference
PaCO₂: Arterial partial pressure of carbon dioxide
PEFR: Peak expiratory flow rate
RCT: Randomised controlled trial
SD: Standard deviation
SPSS: Statistical Package for the Social Sciences

COMPETING INTERESTS

No competing financial or non-financial interests

ACKNOWLEDGEMENTS

I acknowledge the participants who voluntarily enrolled in this study and the outpatient physiotherapy and pulmonology teams who facilitated patient recruitment and data collection. No external funding was received for this investigation.

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