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Impact of diaphragmatic stretching versus respiratory training on pulmonary function and exercise tolerance in adults with asthma: a comparative quasi-experimental study

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Abstract

An estimated 262 million people live with asthma globally, and control remains inadequate for a large share of them despite pharmacotherapy. Diaphragmatic stretching and respiratory training have each shown promise as nonpharmacological adjuncts, but they have rarely been compared directly. In a two-arm quasi-experimental study at a private hospital outpatient department in Lahore, Pakistan, 100 adults with clinically stable mild-to-moderate asthma were enrolled consecutively and assigned alternately to diaphragmatic stretching or respiratory training (50 per arm); both arms attended supervised 30-minute sessions three times weekly across 14 weeks. Forced expiratory volume in one second (FEV1; primary outcome), forced vital capacity (FVC), six-minute walk test (6MWT), Asthma Control Test (ACT), and University of California, San Diego Shortness of Breath Questionnaire (UCSD SOBQ) were assessed at baseline and at 14 weeks. All five outcomes improved within both groups ($p < 0.001$). Between-group comparisons of changes in scores favored diaphragmatic stretching throughout: an FEV1 of 0.20 L (95% CI of 0.07 to 0.33), an FVC of 0.20 L (0.10 to 0.30), a 6MWT of 39.9 m (27.6 to 52.2), an ACT of 1.98 points (1.16 to 2.80), and a UCSD SOBQ of −5.08 points (−6.33 to −3.83); all $p \leq 0.003$, and analysis of covariance adjusted for baseline values yielded concordant results. More participants reached the predefined minimal clinically important difference (MCID) with diaphragmatic stretching for FEV1 (60% vs 32%), FVC (58% vs 36%), the 6MWT (70% vs 14%), the ACT (54% vs 22%), and the UCSD SOBQ (60% vs 2%). Compared with respiratory training, diaphragmatic stretching therefore improved pulmonary function, exercise tolerance, and asthma-related symptoms more. Because allocation was not randomized and the groups differed at baseline, confirmation in randomized controlled trials is needed.

Keywords

Asthma; Breathing exercises; Exercise tolerance; Respiratory function tests; Respiratory muscles; Respiratory therapy; Diaphragm

1. Introduction

Asthma is a long-term airway disorder in which inflammation, narrowing of the bronchi, and excess mucus act together to restrict airflow and produce the familiar symptoms of wheezing, breathlessness, and cough [1,2]. It is among the most common chronic lung conditions and has a heavy clinical and economic burden, with an estimated 262 million people affected worldwide [3,4]. Although drug therapy—mainly bronchodilators and inhaled corticosteroids—remains the cornerstone of management, a large proportion of patients continue to have inadequately controlled disease. That shortfall has directed growing interest toward nonpharmacological adjuncts intended to bolster lung mechanics, increase functional capacity and ease day-to-day living for those with the disease [5,6,7].

In particular, diaphragmatic stretching and respiratory training through nonpharmacological approaches have shown promise as interventions that can improve asthma patients' pulmonary function and exercise tolerance [8]. Patients with asthma often develop dysfunction of their diaphragm as well as altered breathing patterns, both of which lead to ineffective ventilation and worsened dyspnea [9]. Techniques that release tension in the diaphragm and the surrounding fascia are intended to increase diaphragmatic strength, flexibility, and excursion and thereby to improve ventilation by allowing deeper and more controlled breathing [10]. This can decrease airway resistance, improve gas exchange, and relieve symptoms such as wheezing. It also helps move patients away from shallow, chest-based breathing to diaphragmatic, abdominal breathing, improving overall respiratory mechanics [11,12].

In contrast, respiratory training aims to strengthen respiratory muscles, including the diaphragm and intercostal muscles, and to optimize breathing patterns. Maneuvers of this kind, such as pursed-lip and diaphragmatic breathing, lower airway resistance, ease dyspnea and extend exercise tolerance by building strength and coordination in the respiratory musculature [13,14]. By engaging in slower, deeper breaths, respiratory training decreases the perception of breathlessness, especially with exertion, and enhances aerobic work. This results in increased endurance, improved adherence, and reduced exercise-induced bronchoconstriction [15,16].

Asthma imposes a psychological and physical burden in addition to impairing respiratory function; interventions such as diaphragmatic stretching and respiratory training are therefore of increasing interest. Stress is a recognized trigger of asthma attacks, and many patients are also highly anxious because of their reduced capacity for physical labor or exercise [17]. By promoting relaxation and greater control over breathing, diaphragmatic stretching may reduce the stress and anxiety that can precipitate an asthma attack when a patient is emotionally or physically strained. Respiratory training is an additional aid because it makes patients more comfortable and confident in managing symptoms while they are engaged in physical exertion, which may reduce episodes of panic and support better mental health [18].

Although diaphragmatic stretching and respiratory training have each shown promise for improving pulmonary function and exercise tolerance in patients with asthma, direct head-to-head evaluation within a single population remains scarce, and the relative benefit of a diaphragm-focused technique over general respiratory-muscle training remains unclear. The mechanisms by which these interventions influence day-to-day asthma symptoms are also not fully understood, and evidence on their effects on exercise tolerance under real-life conditions is limited. To help address this gap, the present study aimed to compare the effects of diaphragmatic stretching and respiratory training on pulmonary function, exercise tolerance, asthma control, and shortness of breath in adults with mild-to-moderate asthma. The specific objectives were to quantify the change in each outcome within each group after a 14-week program and to determine whether the two approaches differ in terms of the magnitude of improvement. We hypothesized that both interventions would improve the measured outcomes and that diaphragmatic stretching would result in greater gains than respiratory training would.

2. Methods

2.1. Study design

This was a two-arm comparative quasi-experimental study with pre- and postintervention assessments. Participants were enrolled consecutively and assigned alternately to one of two intervention groups according to their order of presentation.

2.2. Ethics approval

The Ethics Review Committee of Hussain Memorial Hospital approved the protocol (No. HMH-23-ERC-51), and institutional permission to recruit participants was granted by the same hospital, at which all participants were enrolled. Written informed consent preceded enrollment in every case, and the work adhered to the Declaration of Helsinki. Data were collected over eight months between January and August 2024.

2.3. Study setting

The study was carried out in Lahore, the provincial capital of Punjab, the most populous province of Pakistan. Participants were recruited from the outpatient department of Hussain Memorial Hospital, a private hospital in the city that provides outpatient, inpatient, and intensive care services together with round-the-clock diagnostic and emergency coverage. Patients were approached at the time of routine outpatient visits.

2.4. Participant recruitment

Adults aged 18 to 65 years for whom a physician had confirmed asthma under the 2023 GINA recommendations [19] were eligible. The diagnosis rested on a consistent history of fluctuating respiratory symptoms alongside documented variability in expiratory airflow, taken as present where postbronchodilator forced expiratory volume in one second (FEV1) increased by ≥ 12% and ≥ 200 mL above baseline, which is consistent with the GINA diagnostic criteria. Participants were required to have clinically stable mild-to-moderate asthma, with no recent acute exacerbation and a stable prescribed asthma treatment regimen at enrollment. Asthma severity was classified during clinical assessment according to the GINA treatment step required to maintain symptom control.

Participants were excluded if they had severe asthma, chronic obstructive pulmonary disease (COPD), or other significant respiratory or cardiovascular comorbidities that could independently affect pulmonary function or exercise tolerance. Pregnant or lactating women and individuals unable or unwilling to participate in the prescribed intervention and follow-up assessments were also excluded.

Although the predefined eligibility age range was 18–65 years, the observed age range of the enrolled participants was 30–65 years. This was not an additional exclusion criterion; rather, it reflected the age distribution of patients who met the eligibility criteria in the study setting during the recruitment period.

Participants were instructed to continue their prescribed asthma treatment unchanged across the 14-week intervention, and the protocol introduced no deliberate alteration to routine medication. However, detailed baseline medication types and inhaled corticosteroid doses were not systematically recorded in the study dataset. Consequently, potential differences in inhaled corticosteroid exposure between groups could not be formally assessed or adjusted for in the analysis. This issue was therefore considered a potential source of residual confounding and has been acknowledged as a limitation of the study.

2.5. Sampling technique and sample size

Participants were recruited consecutively from the outpatient department of the study hospital as they presented and met the inclusion and exclusion criteria. They were then allocated alternately, in order of presentation, to two treatment groups of 50 patients each: one group received the diaphragmatic stretching technique, and the other received respiratory training. Because allocation was not random, baseline characteristics were compared between the groups and are reported below. In the absence of directly comparable data, a moderate between-arm difference in the change in FEV1 was assumed (Cohen's d = 0.60). A priori calculation in G*Power 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) indicated that 45 participants per arm would satisfy 80% power at a two-sided α of 0.05; this was rounded up to 50 per arm to absorb attrition, giving a total of 100.

2.6. Study instruments

Study instruments were selected to assess pulmonary function, exercise tolerance, asthma control, and shortness of breath. Baseline sociodemographic and clinical characteristics were recorded using a structured data-collection form.

Spirometry followed American Thoracic Society/European Respiratory Society (ATS/ERS) technical standards on an MIR Spirobank II Smart portable spirometer (MIR Medical International Research, Rome, Italy), calibrated to the manufacturer’s specifications ahead of each testing session. Testing was performed seated with a nose clip in place and standardized verbal prompts guiding every maximal forced expiratory maneuver. Three or more maneuvers were obtained per participant and screened for acceptability and repeatability against the ATS/ERS criteria. The highest technically acceptable FEV1 and forced vital capacity (FVC) values were retained for analysis. FEV1 and FVC were recorded as absolute values. Spirometry was performed without routine bronchodilator administration so that the FEV1 and FVC reflected prebronchodilator function at both assessment points; bronchodilator responsiveness testing was used only to support the diagnosis at screening. Participants were instructed to avoid short-acting bronchodilator use for at least 4 hours before testing. These procedures were based on the ATS/ERS 2019 technical standard for spirometry [20].

Exercise tolerance was gauged by a six-minute walk test (6MWT) under the standardized ATS protocol along a straight, 30-meter-long indoor corridor. Each participant walked without pause for six minutes at the quickest pace they could sustain, receiving the encouragement scripted in that protocol. The distance covered was logged in meters. Greater 6MWT distances indicate better functional exercise capacity [21].

Asthma control was assessed using the five-item Asthma Control Test (ACT). The total ACT score ranged from 5 to 25, with higher scores indicating better asthma control. The ACT was administered in its validated form as described by Nathan et al. [22].

Breathlessness was quantified with the University of California, San Diego Shortness of Breath Questionnaire (UCSD SOBQ): 24 items, each rated 0 to 5, for a range of 0–120. Larger totals indicate more severe dyspnea, so a decrease in score signals relief. Approximately 5 points was taken as the minimum clinically important difference (MCID) [23], a threshold established in patients with fibrotic interstitial lung disease and COPD rather than asthma and adopted here for an asthma-specific value.

Participants also maintained a study-specific diary to document adherence to the prescribed intervention and any adverse effects experienced during the study period. The diary and interview schedule were pilot tested before the main study commenced to assess the clarity, feasibility, and ease of completion. Adherence was expressed as the share of prescribed sessions attended, and adverse events were logged by occurrence, type and severity and by whether they prompted interruption or withdrawal. These diary records were not collated into the study analysis dataset and could not be retrieved for the present analysis; therefore, adherence and adverse events are not reported.

2.7. Data collection

The screening was performed jointly by a researcher and a physician, who reviewed each patient's medical history, carried out a physical examination, and reviewed the relevant investigations to confirm eligibility against the inclusion and exclusion criteria. Candidates first received a brief Urdu-language information sheet, setting out the purpose of the work, its likely benefits and risks, ethics approval and safeguards protecting confidentiality. Once written informed consent had been obtained, a brief face-to-face interview lasting 10 to 15 minutes was conducted in the patient's local language. Assessment was performed at baseline and again at the completion of the 14-week program so that the two interventions could be weighed against each other before and after treatment.

2.8. Interventional protocol

Diaphragmatic stretching intervention was performed by a trained physiotherapist and was designed to promote diaphragmatic excursion, improve lung expansion, and enhance respiratory muscle function. Every 30-minute session comprised 10 sets of 5 repetitions separated by 2-minute rests. The intensity of the stretching progressively increased weekly, as tolerated by the participants. The intervention was administered three times per week for 14 weeks, with the physiotherapist supervising and delivering the stretching technique during each session. Exercise intensity progressed according to the participants' tolerance and response [24,25,26].

In the respiratory training group, the intervention combined pursed-lip breathing with inspiratory muscle training. Each session lasted 30 minutes, matching the session duration of the diaphragmatic stretching group. Sessions were performed three times per week for 14 weeks under the supervision of the same trained physiotherapist, who monitored technique, recorded adherence, and ensured appropriate progression.

A threshold loading device (Threshold IMT) delivered the inspiratory muscle training, starting resistance being fixed at 30% of each participant's maximal inspiratory pressure (MIP). MIPs were assessed using a calibrated respiratory pressure meter, and the highest technically acceptable value was used to determine the initial training load. The resistance was reassessed weekly and progressively increased by 5% of the MIP, as tolerated by the participant, to provide progressive respiratory muscle loading. Each session ran to 10 sets of 6 repetitions, again with 2 minutes of rest. Pursed-lip breathing was incorporated to improve breathing efficiency and reduce shortness of breath.

The inspiratory muscle training load was individualized and progressively adjusted according to participants' tolerance and performance during follow-up sessions [15,27,28,29].

Both interventions included educational sessions to reinforce asthma management techniques and encourage adherence. Throughout the 14 weeks, progress in pulmonary function, exercise tolerance, and overall asthma control was monitored at the supervision visits, and the outcome measures reported below were formally assessed at baseline and at 14 weeks [30].

2.9. Statistical analysis

Descriptive statistics are summarized as frequencies and percentages for categorical variables and as the means with standard deviations for continuous variables. The distribution of continuous variables was checked with the Shapiro–Wilk test before analysis; the within-person differences were normally distributed for every group and outcome except for asthma control in the respiratory training group (Shapiro–Wilk $p = 0.022$) and FEV1 in the diaphragmatic stretching group (Shapiro–Wilk $p = 0.013$), which were analyzed by the Wilcoxon signed-rank test. Group comparisons of categorical data were performed using the Pearson chi-square test without continuity correction, with Fisher's exact test given alongside 2 × 2 tables. Changes within each arm were tested by paired t tests or Wilcoxon signed-rank tests, and differences between arms were tested by independent-samples t tests or Mann–Whitney U tests, according to distribution. Because the within-person changes in the ACT score in the respiratory training group and in the FEV1 in the diaphragmatic stretching group were not normally distributed, the corresponding between-arm comparisons were rerun nonparametrically as a sensitivity check. Baseline comparability of the outcome variables was tested before the between-group analyses. The primary between-group comparison was of the within-person change scores; because allocation was not randomized and the groups differed at baseline, posttreatment values were additionally compared by analysis of covariance with the corresponding baseline value as a covariate for sensitivity analysis. Thresholds for the minimal clinically important difference (MCID) were set in advance: a gain of ≥ 0.20 L in FEV1 and in FVC, ≥ 30 m in six-minute walk distance, ≥ 3 points on the ACT and a fall of ≥ 5 points on the UCSD SOBQ. Effect sizes appear as Cohen’s dz within arms and as Cohen’s d for the between-arm difference in change scores. Responder proportions are given for every outcome. FEV1 served as the primary outcome and anchored the sample size calculation, with the other four being secondary. Significance was two-sided at $p < 0.05$. Analysis was carried out in IBM SPSS Statistics, version 26 (IBM Corp., Armonk, NY, USA). This study is reported in line with the TREND statement for nonrandomized interventional studies.

3. Results

3.1. Patients’ sociodemographic and baseline clinical characteristics

The mean age in the diaphragmatic stretching arm was 48.68 years (SD = 10.80), spanning 30 to 65 years (Table 1); the respiratory training arm averaged 45.02 years (SD = 9.46) across a marginally closer 30 to 63 years. All 100 participants had complete data, with 50 valid cases in each group and no missing values. Age did not separate the arms (mean difference 3.66 years, 95% CI −0.37 to 7.69; Welch’s $t = 1.80$; $p = 0.075$).

Table 1 shows the sociodemographic characteristics of the diaphragmatic stretching and respiratory training groups (n = 100). Sex was balanced across the arms (Pearson chi-square $p = 0.181$; Fisher's exact $p = 0.265$): the diaphragmatic stretching group was 66% female and 34% male, whereas the respiratory training group was 78% female and 22% male. Geographic location differed between the groups (Pearson chi-square $p = 0.045$; Fisher's exact $p = 0.071$), with 58% of the diaphragmatic stretching group being from rural areas and 62% of the respiratory training group being from urban areas. Because the study was not randomized, this imbalance in geographic location was a confounder and was considered when the between-group comparisons were interpreted; it was not entered as a covariate because the adjusted analyses were specified to adjust for baseline outcome values only.

Neither employment status ($p = 0.915$) nor marital status ($p = 0.264$) separated the arms. Compared with the diaphragmatic stretching group, the respiratory training group included a greater proportion of married participants (40% vs 26%), although the gap was not significant. Disease duration was likewise comparable ($p = 0.915$), with 30% of participants in the diaphragmatic stretching group presenting with a disease duration of 1–5 years compared with 24% in the respiratory training group. Longer disease durations were similarly distributed in both groups (6–10 years, 40% vs 44%; 11–15 years, 20% vs 20%; >15 years, 10% vs 12%).

Table 1. Baseline sociodemographic and clinical characteristics of the participants by intervention group.

Variable		Diaphragmatic Stretching (n=50)	Respiratory Training (n=50)	Test Statistic	*p* Value
		Mean ± SD, n (%)	**Mean ± SD, n (%)**	**t/χ² (df)**	
Age (years)		48.68 ± 10.80	45.02 ± 9.46	1.80 (96.3)	0.075
Age range (years)		30–65	30–63	-	-
Sex	Male	17 (34)	11 (22)	1.79 (1)	0.181
	Female	33 (66)	39 (78)		
Geographical location	Urban	21 (42)	31 (62)	4.01 (1)	0.045
	Rural	29 (58)	19 (38)		
Employment status	Self-employed	16 (32)	18 (36)	0.18 (2)	0.915
	Employed	16 (32)	15 (30)		
	Unemployed	18 (36)	17 (34)		
Marital status	Married	13 (26)	20 (40)	3.98 (3)	0.264
	Unmarried	12 (24)	10 (20)		
	Separated/divorced	15 (30)	8 (16)		
	Widowed	10 (20)	12 (24)		
Disease duration	1–5 years	15 (30)	12 (24)	0.52 (3)	0.915
	6–10 years	20 (40)	22 (44)		
	11–15 years	10 (20)	10 (20)		
	> 15 years	5 (10)	6 (12)		
Baseline FEV1 (L)		2.90 ± 0.40	2.70 ± 0.30	2.80 (98)	0.006
Baseline FVC (L)		3.70 ± 0.50	3.60 ± 0.40	1.11 (98)	0.269
Baseline 6MWD (m)		450.04 ± 75.10	419.94 ± 70.01	2.07 (98)	0.041
Baseline ACT score		19.94 ± 2.97	17.98 ± 3.08	3.24 (98)	0.002
Baseline UCSD SOBQ score		18.06 ± 4.98	18.96 ± 4.99	−0.90 (98)	0.369

Independent-samples t test for continuous variables (Welch correction for age; hence, noninteger df) and Pearson chi-square test without continuity correction for categorical variables were used. Test statistics are given as t (df) or χ^2 (df). The identical *p* values for employment status and disease duration (0.915) arise from different χ^2 values (0.18 and 0.52, respectively). Abbreviations: ACT, Asthma Control Test; FEV1, Forced expiratory volume in one second; FVC, Forced vital capacity; SD, Standard deviation; UCSD SOBQ, University of California, San Diego Shortness of Breath Questionnaire; 6MWD, Six-minute walk distance.

3.2. Intervention outcomes

Table 2 outlines the outcomes measured 14 weeks after the application of two interventions—diaphragmatic stretching and respiratory training—in patients with asthma, together with the within-group changes over the 14-week program. At baseline, the two groups differed significantly in the FEV1 (2.90 vs 2.70 L, $p = 0.006$), ACT score (19.94 vs 17.98, $p = 0.002$) and six-minute walk distance (450.0 vs 419.9 m, $p = 0.041$) but not in the FVC ($p = 0.269$) or UCSD SOBQ score ($p = 0.369$); the comparison of change scores was therefore supplemented by an analysis of covariance adjusted for the corresponding baseline value.

In the diaphragmatic stretching group, the FEV1 increased by 0.30 L ($p < 0.001$), indicating improved airflow, and the FVC increased by 0.30 L ($p < 0.001$), indicating greater lung capacity. These gains were accompanied by a 49.96 m increase in the 6MWT ($p < 0.001$), reflecting improved exercise tolerance, and a 2.94-point increase in the ACT ($p < 0.001$), indicating better symptom control. The UCSD SOBQ score decreased by 6.08 points ($p < 0.001$), which is consistent with reduced dyspnea. Within-group effect sizes in this group were moderate to large for every outcome (Cohen's dz 0.72 for FEV1, 1.00 for FVC, 1.25 for the 6MWT, 1.21 for the ACT and −1.49 for the UCSD SOBQ).

Table 2. Pulmonary function, exercise tolerance, asthma control, and shortness of breath before and 14 weeks after treatment in the intervention group.

Variable	n	Diaphragmatic Stretching				Respiratory Training			
		Pre-treatment Mean ± SD	Post-treatment Mean ± SD	Mean Difference	*p* Value	Pre-treatment Mean ± SD	Post-treatment Mean ± SD	Mean Difference	*p* Value
FEV1 (L)	50	2.90 ± 0.40	3.20 ± 0.50	+0.30	< 0.001	2.70 ± 0.30	2.80 ± 0.40	+0.10	< 0.001
FVC (L)	50	3.70 ± 0.50	4.00 ± 0.60	+0.30	< 0.001	3.60 ± 0.40	3.70 ± 0.50	+0.10	< 0.001
6MWT (m)	50	450.04 ± 75.10	500.00 ± 79.99	+49.96	< 0.001	419.94 ± 70.01	430.00 ± 69.95	+10.06	< 0.001
ACT (score)	50	19.94 ± 2.97	22.88 ± 1.84	+2.94	< 0.001	17.98 ± 3.08	18.94 ± 2.99	+0.96	< 0.001
UCSD SOBQ (score)	50	18.06 ± 4.98	11.98 ± 4.06	−6.08	< 0.001	18.96 ± 4.99	17.96 ± 4.93	−1.00	< 0.001

The values are the means ± SDs. Within-group changes were tested by paired t tests or Wilcoxon signed-rank tests where within-person differences deviated from normality; significance was set at $p < 0.05$. The change scores are compared between the groups in Table 3. Abbreviations: ACT, Asthma Control Test; FEV1, Forced expiratory volume in one second; FVC, Forced vital capacity; SD, Standard deviation; UCSD SOBQ, University of California, San Diego Shortness of Breath Questionnaire; 6MWT, Six-minute walk test.

In the respiratory training group, the within-group improvements were also statistically significant but smaller in magnitude. The FEV1 and FVC each increased by 0.10 L ($p < 0.001$), the 6MWT distance increased by 10.06 m ($p < 0.001$), and the ACT score increased by 0.96 points ($p < 0.001$). The UCSD SOBQ score decreased by 1.00 points ($p < 0.001$), which was a smaller reduction than that seen with diaphragmatic stretching. Within-group effect sizes in this group were moderate throughout (Cohen's dz 0.50 for FEV1, 0.56 for FVC, 0.56 for the 6MWT, 0.59 for the ACT and −0.55 for the UCSD SOBQ). Comparisons of the change scores between groups favored diaphragmatic stretching for every outcome: an FEV1 mean difference of 0.20 L (95% CI 0.07 to 0.33; $p = 0.003$), an FVC of 0.20 L (95% CI 0.10 to 0.30; $p < 0.001$), a 6MWT of 39.90 m (95% CI 27.58 to 52.22; $p < 0.001$), an ACT of 1.98 points (95% CI 1.16 to 2.80; $p < 0.001$) and a UCSD SOBQ of −5.08 points (95% CI −6.33 to −3.83; $p < 0.001$). Analysis of covariance adjusted for baseline values yielded concordant results (adjusted mean differences: FEV1 0.22 L, 95% CI 0.09 to 0.36; FVC 0.19 L, 95% CI 0.09 to 0.29; 6MWT 41.58 m, 95% CI 29.03 to 54.13; ACT 2.76 points, 95% CI 2.06 to 3.47; UCSD SOBQ −5.34 points, 95% CI −6.46 to −4.22; all $p \leq 0.002$). The proportion of participants who reached the MCID was also greater with diaphragmatic stretching for FEV1 (60% vs 32%, $p = 0.005$), FVC (58% vs 36%, $p = 0.028$), the 6MWT (70% vs 14%, $p < 0.001$), the ACT (54% vs 22%, $p = 0.001$), and the UCSD SOBQ (60% vs 2%, $p < 0.001$). The between-group results are summarized in Table 3.

Table 3. Between-group comparisons of the response to diaphragmatic stretching versus respiratory training.

Outcome	Difference in Change Scores (95% CI)	*p* Value	Baseline-Adjusted Difference (95% CI)†	*p* Value	Cohen's d	Reached MCID, Diaphragmatic Stretching vs Respiratory Training n (%)	*p* Value
FEV1 (L)	0.20 (0.07 to 0.33)	0.003	0.22 (0.09 to 0.36)	0.002	0.61	30 (60) vs 16 (32)	0.005
FVC (L)	0.20 (0.10 to 0.30)	< 0.001	0.19 (0.09 to 0.29)	< 0.001	0.81	29 (58) vs 18 (36)	0.028
6MWT (m)	39.90 (27.58 to 52.22)	< 0.001	41.58 (29.03 to 54.13)	< 0.001	1.29	35 (70) vs 7 (14)	< 0.001
ACT (score)	1.98 (1.16 to 2.80)	< 0.001	2.76 (2.06 to 3.47)	< 0.001	0.96	27 (54) vs 11 (22)	< 0.001
UCSD SOBQ (score)	−5.08 (−6.33 to −3.83)	< 0.001	−5.34 (−6.46 to −4.22)	< 0.001	-1.61	30 (60) vs 1 (2)	< 0.001

Difference in change scores = mean change in the diaphragmatic stretching arm minus that in the respiratory training arm, by independent-samples t test (df = 98); positive values favor diaphragmatic stretching for FEV1, FVC, the 6MWT and the ACT, and negative values for the UCSD SOBQ. †Analysis of covariance on posttreatment values with the corresponding baseline value as a covariate. Cohen's d is derived from the difference in change scores. Responders were defined a priori as those whose FEV1 and FVC were ≥ 0.20 L, those whose ACT was ≥ 30 m, those whose ACT was ≥ 3 points and those whose SOBQ was ≥ 5 points; proportions were compared by Pearson's chi-square test. After the Mann–Whitney U test was performed, the left FEV1 ($p = 0.003$) and the ACT ($p < 0.001$) were used. Abbreviations: ACT, Asthma Control Test; CI, Confidence interval; FEV1, Forced expiratory volume in one second; FVC, Forced vital capacity; MCID, Minimal clinically important difference; SD, Standard deviation; UCSD SOBQ, University of California, San Diego Shortness of Breath Questionnaire; 6MWT, Six-minute walk test.

4. Discussion

This study compared the effects of diaphragmatic stretching and respiratory training on pulmonary function, exercise tolerance, asthma control, and shortness of breath in adults with asthma. All measured outcomes—FEV1, FVC, the 6MWT, the ACT, and the UCSD SOBQ—improved significantly from baseline to the end of the 14-week program in both groups ($p < 0.001$); thus, benefits were attached to each intervention. When the two approaches were compared, the magnitude of improvement differed, and every between-group difference favored diaphragmatic stretching, both in the change scores and after adjustment for baseline values.

Diaphragmatic stretching resulted in greater improvement in the FEV1 than respiratory training did (0.30 L, from 2.90 to 3.20 L, versus 0.10 L, from 2.70 to 2.80 L; mean difference 0.20 L, 95% CI 0.07 to 0.33). These findings suggest that a diaphragm-focused technique may increase lung function more effectively by promoting diaphragmatic excursion and increasing the volume of air that can be expelled. In people with COPD, Rocha et al. [31] reported gains in diaphragmatic mobility, inspiratory capacity and exercise capacity after a manual diaphragm release technique, although the effects on other outcomes, including spirometric volume, were small or not significant. Respiratory training was still beneficial but had a more modest effect, likely because it targeted overall respiratory muscle efficiency rather than the diaphragm specifically.

FVC improved with both interventions, but the increase was greater in the diaphragmatic stretching group (0.30 L, from 3.70 to 4.00 L) than in the respiratory training group (0.10 L, from 3.60 to 3.70 L). These findings indicate that diaphragmatic stretching may increase lung volume more than respiratory training does, possibly through greater diaphragmatic movement and chest expansion. Tsimouris et al. [24] registered a randomized controlled trial protocol to test whether diaphragm-directed manual therapy improves diaphragm function in adults with asthma; those results are awaited and will permit a more direct comparison with the present findings.

Both interventions improved exercise tolerance on the 6MWT, but the diaphragmatic stretching group improved more (49.96 m, from 450.04 to 500.00 m) than the respiratory training group did (10.06 m, from 419.94 to 430.00 m). A more efficient diaphragm may lower the work of breathing and the metabolic price of ventilation during exertion, which could plausibly contribute to the greater increase seen in the diaphragmatic stretching group, although no mechanistic measurements were made in this study. In a related context, Burge et al. [32] reviewed graded exercise therapy across serious respiratory illness and reported evidence of a benefit for fatigue, an outcome closely linked to exercise tolerance. Respiratory training, which targets general respiratory muscle strength, produced smaller effects, presumably because it is less specific to endurance.

Participants in the diaphragmatic stretching group improved their ACT score by a mean of 2.94 points (from 19.94 to 22.88) compared with 0.96 points (from 17.98 to 18.94) in the respiratory training group. These findings may indicate that diaphragmatic stretching relieves symptoms more directly by improving the efficiency of breathing and reducing airway resistance. In an overview of systematic reviews, Heredia-Rizo et al. [33] reported that mind–body exercises incorporating controlled breathing improved outcomes across chronic respiratory diseases, which is broadly consistent with the improvement in asthma control observed here. The smaller change in the respiratory training group is consistent with an intervention that strengthens the respiratory muscles in general but does not specifically target asthma control.

With respect to shortness of breath, the diaphragmatic stretching group showed greater improvement (the UCSD SOBQ score decreased from 18.06 to 11.98) than the respiratory training group did (from 18.96 to 17.96). These results suggest that diaphragmatic stretching may optimize respiratory mechanics and reduce breathing effort. Hudson-Colby et al. [34] described how breathing pattern disorders contribute to symptom burden in difficult-to-treat asthma, which is consistent with the reduction in breathlessness observed here, although their population was more severely affected than the mild-to-moderate cohort studied here was. Although the respiratory training group also improved, its reduction in shortness of breath was small, likely because the intervention was not specifically directed at dyspnea.

This study has several limitations. Allocation to the two groups was not randomized, and the groups differed at baseline in geographic location and in FEV1, asthma control, and walking distance. Changes in scores were backed by covariance analysis adjusted to baseline, and the conclusions were unchanged; however, residual confounding by unmeasured factors cannot be excluded. There was no untreated control group, so the improvements cannot be separated from natural variation or attention effects. The sample was drawn from the outpatient clinic of a single private hospital in one city. Patients who attend private facilities in Pakistan typically differ from those who use public tertiary-care services in socioeconomic position, health literacy, and access to maintenance therapy; thus, the findings may not be generalizable to public-sector or rural populations. Two of the five outcome measures, asthma control and shortness of breath, were self-reported and are therefore subject to reporting bias. The interventions were not blinded, and the study was not prospectively registered. No formal adjustment was made for testing five outcomes; every between-arm change score and baseline-adjusted comparison would survive a Bonferroni-corrected α of 0.01, although the difference in the proportion of FVC responders ($p = 0.028$) would not. Spirometric outcomes are reported as absolute volumes only; percentage-predicted values were not available for the present analysis, which limits comparisons with other cohorts. Adherence and adverse events were recorded in participant diaries during the study, but these records were not collated into the analysis dataset and could not be retrieved; therefore, neither outcome could be quantified. As a result, intervention fidelity cannot be demonstrated; the two groups cannot be shown to have received comparable exposure to their assigned protocols, and no comparative statement can be made about the safety of the two interventions. This is a material limitation of the present report rather than an omission from the manuscript, and any future trial of these interventions should collect and report both outcomes prospectively. The follow-up period also ended at 14 weeks; thus, the durability of the observed gains is unknown. Baseline asthma control in the diaphragmatic stretching arm already stabilized in the well-controlled band, and 13 of the 50 participants (26%) in that group reached the maximum ACT score of 25 after treatment, four of whom were already at that ceiling at baseline; thus, ceiling effects may have compressed the measured change in that outcome. Finally, although the improvements in the respiratory training group were statistically significant, they fell below the MCIDs commonly cited for the 6MWT, the ACT, and the UCSD SOBQ; thus, their clinical relevance is uncertain. The MCID thresholds applied throughout were themselves derived in other respiratory populations, chiefly COPD and interstitial lung disease, since values specific to asthma are unestablished for all five outcomes; the responder analyses should therefore be read as indicative rather than definitive. Future work should use randomized allocation, an adequately powered and more diverse sample, a control group, and, where possible, a blinded outcome assessment; the potential added value of combining diaphragmatic stretching with other therapies also warrants investigation.

5. Conclusions

In conclusion, both diaphragmatic stretching and respiratory training resulted in significant within-group improvements in pulmonary function, exercise tolerance, asthma control, and shortness of breath in adults with asthma, and diaphragmatic stretching resulted in significantly greater improvements across all five outcomes, most markedly in exercise tolerance and shortness of breath. These findings suggest that diaphragm-focused exercises are a promising component of asthma rehabilitation. Because allocation was not randomized and the groups differed at baseline, confirmation in adequately powered randomized controlled trials with longer follow-up periods is needed before firm practice recommendations can be made; in the interim, supervised diaphragmatic exercises may reasonably serve as an adjunct in rehabilitation programs for selected patients with mild-to-moderate asthma.

Abbreviations: ACT, Asthma Control Test; ATS, American Thoracic Society; COPD, Chronic obstructive pulmonary disease; ERS, European Respiratory Society; FVC, Forced vital capacity; MCID, Minimum clinically important difference; MIP, Maximal inspiratory pressure; UCSD SOBQ, University of California, San Diego Shortness of Breath Questionnaire; 6MWT, Six-minute walk test.

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Consent to publication: Not applicable.

Data availability: The data supporting this study's findings are available from the corresponding author, Bushra Ejaz, upon reasonable request.

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