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Respiratory Rehabilitation through Pranayama and Yogic Practice: Effects on Spirometric Indices, Inflammatory Biomarkers, and Quality of Life in Adults with Chronic Obstructive Pulmonary Disease

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ABSTRACT: Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disorder associated with substantial global morbidity and mortality, necessitating adjunctive non-pharmacological interventions. Pranayama, a yogic breathing practice, demonstrates therapeutic potential in pulmonary rehabilitation; however, evidence integrating pulmonary, haematological, and quality-of-life outcomes in GOLD-staged COPD remains limited. This study evaluated adjunctive efficacy of pranayama on pulmonary function, biomarkers, and quality of life. This prospective cohort study enrolled 100 GOLD Stage II and III COPD patients and were allocated into an intervention group receiving pranayama and yogic asana - Kapalabhati, Anuloma-viloma, Bhastrika, Sasangasana and Bhramari for 30 minutes daily alongside pharmacotherapy, and a control group receiving pharmacotherapy alone. Spirometric indices, SpO2, mMRC score, SGRQ, leucocyte counts, CRP, and creatine kinase were assessed at baseline and six weeks. The intervention group demonstrated significant improvements across all outcome domains compared to controls ($p = 0.0010$). FEV1 increased from 1.33 L to 1.89 L (+0.56 L), FVC from 2.03 L to 2.38 L (+0.35 L), FEV1/FVC ratio from 0.66 to 0.80 (+0.13), and PEFR from 3.24 L/min to 4.19 L/min (+0.95 L/min). Peripheral oxygen saturation improved from 90.9 to 92.1%, and mMRC dyspnea score declined from 2.48 to 0.76. SGRQ domains including symptoms, activity and impact showed substantial reduction. Total leucocyte count, neutrophil, eosinophil, C-reactive protein, and creatine kinase decreased while lymphocyte percentage increased, indicating a favourable immunomodulatory response. Six weeks of structured pranayama as an adjunct to pharmacotherapy conferred multidimensional clinical benefits across pulmonary function, dyspnea severity, health-related quality of life, haematological indices, and inflammatory biomarkers in GOLD Stage II and III COPD patients. Pranayama represents a safe, cost-effective, evidence-based rehabilitation that warrants integration into comprehensive COPD management protocols, particularly within resource-constrained healthcare settings.

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1. INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive, irreversible airway disorder characterised by persistent airflow limitation and significant dyspnea, with classical manifestations including chronic bronchitis and emphysema. Globally, COPD constitutes a substantial public health burden owing to its high morbidity, mortality, and healthcare utilization across diverse socioeconomic strata [1]. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) classifies disease severity into stages based on spirometric indices, particularly the FEV_1/FVC ratio, and endorses pulmonary rehabilitation as an integral component of COPD management [2]. Pharmacological regimens, while efficacious in symptom control, carry inherent limitations including adverse effects, economic burden, and incomplete resolution of functional impairment, thereby necessitating complementary non-pharmacological strategies [3].

Pranayama, the ancient Indian system of regulated yogic breathing, has garnered considerable scholarly attention as a safe, cost-effective, and accessible adjunct intervention for patients with obstructive lung disease. Derived from the Sanskrit terms 'prana' (vital life force) and 'ayama' (regulation or extension), pranayama encompasses diverse breathing modalities -including Kapalabhati, Anuloma-viloma, Bhastrika and Bhramari and each mechanistically targeting distinct components of respiratory physiology [4]. A study comprised of randomised controlled trial, demonstrated that pranayama improved exercise tolerance in patients with moderate-to-severe COPD, concluding that yoga breathing may serve as a feasible home-based alternative to formal pulmonary rehabilitation programmes [1]. These techniques collectively enhance diaphragmatic excursion, reduce airway resistance, improve pulmonary compliance, and augment ventilatory muscle strength, thereby favouring bronchodilation and optimised alveolar ventilation [5,6].

Extant literature corroborates the utility of pranayama in improving pulmonary function parameters specifically FEV_1, FVC, FEV_1/FVC ratio, and Peak Expiratory Flow Rate (PEFR). Nagarathna and Nagendra established the long-term efficacy of integrated yoga therapy, including pranayama, in improving peak flow rate and reducing medication dependence in patients with airway disease [7]. Another study further confirmed that expiratory pranayama exercises significantly improved FEV_1 and PEFR objectively in patients with mild-to-moderate bronchial asthma [8]. In a randomised controlled trial among coal miners with stable GOLD Stage II–III COPD, demonstrated statistically significant reductions in dyspnea and fatigue scores alongside meaningful improvements in peripheral capillary oxygen saturation (SpO2%), underscoring pranayama's rehabilitative potential [3].

Regarding health-related quality of life (HRQoL), a study demonstrated in a randomised controlled study that pranayama practice significantly improved spirometric indices, six-minute walk distance, and St. George's Respiratory Questionnaire (SGRQ) scores among COPD patients [5]. The systemic anti-inflammatory dimension of pranayama is equally compelling; elevated C-reactive protein and leucocyte counts are established biomarkers of systemic inflammation in COPD, correlating inversely with FEV_1 and predicting disease exacerbation risk [9]. In a systematic review corroborated the physiological and psychological benefits of pranayama across multiple clinical conditions [4]. Another review and meta-analysis, further reported robust effects of yoga - particularly yoga breathing techniques - on pulmonary function, exercise capacity, and quality of life in COPD patients [2].

Despite this growing body of international evidence, prospective analytical studies simultaneously examining the impact of pranayama on spirometric parameters, inflammatory biomarkers, and quality of life in COPD patients receiving optimised pharmacotherapy remain limited in the South Asian context [6]. The present study was therefore designed to evaluate the adjunctive therapeutic efficacy of a structured six-week pranayama intervention on pulmonary function indices, dyspnea grading, health-related quality of life, and biochemical markers among adults with GOLD Stage II and III COPD attending a tertiary care institution in Central Tamil Nadu, India.

2. MATERIALS AND METHODS

This study was conducted as a prospective analytical cohort study employing a two-group parallel design. The study was carried out at the Department of Respiratory Medicine, of tertiary care teaching hospital of Central Tamil Nadu. The study was conducted over a twelve-month period. Before initiating the work, ethical clearance was obtained from the Institutional Ethics Committee and the study was designed and conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Participants were eligible for inclusion if they fulfilled the following criteria: physician-confirmed stable COPD; age between 20 and 55 years of either gender; clinical stability for at least three months prior to recruitment; GOLD 2014 Stage II and III classification based on spirometric indices; sufficient cognitive capacity for spirometry manoeuvre execution; ability to ambulate without mechanical aid; willingness to complete all scheduled study assessments; and provision of written informed consent.

Participants were excluded if they had recently diagnosed COPD, active epilepsy, or concurrent airway infections; myocardial infarction, angioplasty, unstable angina, or cardiac surgery within the preceding six months; recent thoracic, abdominal, or cranial surgery; unexplained haemoptysis; severe hypertension; basal blood pressure exceeding 180/100 mmHg; resting pulse rate above 120 beats per minute; body mass index above 35 kg/m²; prior participation in any structured yoga programme; or intellectual disability.

Sample size was calculated by reference to the randomised controlled trial by Kaminsky et al. (2017), which examined the effect of yoga breathing (pranayama) on exercise tolerance in COPD patients [1]. Applying Cohen's formula with an effect size of 0.78 and a significance level (α) of 0.05 at 90% statistical power, a minimum sample of 108 participants was derived. After accounting for anticipated attrition and estimating that approximately 50% of eligible COPD patients would demonstrate clinically meaningful improvement with pranayama, a final enrolment target of 100 analysable participants was established.

Consecutive sampling was employed to recruit all eligible COPD patients attending the outpatient department of Respiratory Medicine who fulfilled the pre-specified inclusion criteria during the study period. Participants were subsequently allocated into two groups of 50 each - the intervention group and the control group based on their willingness to undertake the pranayama programme alongside their prescribed standard pharmacotherapy.

COPD was confirmed in all enrolled participants based on documented clinical history of reversible respiratory obstruction, supported by spirometric evidence of a post-bronchodilator FEV_1/FVC ratio below 0.70, with reversibility in FEV_1 or FVC of ≥12% or ≥200 mL from baseline, consistent with Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2024 diagnostic guidelines [10]. COPD severity was categorised into mild, moderate, severe, and very severe stages based on the percentage predicted FEV_1.

Baseline demographic and clinical data including age, gender, height, weight, body mass index and dyspnea grade were systematically recorded for all participants at enrolment. The intervention group received a structured 30-minute pranayama programme performed in a comfortable seated posture (Padmasana, Vajrasana, or Sukhasana), comprising five sequential techniques: Kapalabhati (three rounds of 20 inhalation–exhalation cycles); Anuloma-viloma alternate nostril breathing (five rounds at a 4:8 inhale-to-exhale count ratio); Bhastrika (three rounds of forceful inhalation–exhalation cycles); Sasangasana, a yogic asana performed in Vajrasana, wherein arms are raised overhead on inhalation and lowered to touch the forehead to the ground on exhalation, held for five seconds, and returned to the starting position over five rounds; and Bhramari (five rounds of humming exhalation with digital occlusion of ears and eyes). Pranayama practices outside the structured hospital sessions was monitored and documented on a weekly basis using practice charts. The study was conducted without blinding of participants or outcome assessors. Participant blinding was not feasible because the intervention involved a behavioural programme comprising breathing and yogic practices.

Pulmonary function tests including FEV_1, FVC, FEV_1/FVC ratio, and PEFR were measured using the Easy On-PC Spirometer (ndd Medical Technologies) in the upright seated position between 10:00 AM and Noon, with the best of three acceptable manoeuvres selected as the final value. Peripheral oxygen saturation (SpO_2) was recorded using a calibrated pulse oximeter [11]. Dyspnea severity was graded using the validated modified Medical Research Council (mMRC) dyspnea scale [12]. Health-related quality of life was evaluated using the St. George's Respiratory Questionnaire (SGRQ), which encompasses three validated domains including symptoms, activity and impact with scores ranging from 0 (no health impairment) to 100 (maximum impairment) [13]. Haematological parameters like total leucocyte count by haemocytometry and differential leucocyte count using Turk's fluid and Leishman's stain were analysed by trained laboratory personnel at a certified clinical laboratory. Serum C-reactive protein was quantified using a high-sensitivity latex CRP assay (Roche Diagnostics), and serum creatine kinase was measured by enzymatic procedure with absorbance recorded at 340 nm. All primary and secondary outcome assessments were conducted at baseline and after six weeks of intervention in both groups.

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Data were analysed using the Statistical Package for Social Sciences (SPSS), version 24.0. Descriptive statistics were computed for all demographic and clinical variables. Within-group pre-to-post comparisons were performed using paired Student's t-test for normally distributed data; the Kruskal–Wallis and Mann–Whitney U tests were applied for non-normal distributions. One-way analysis of variance was used for between-group comparisons. A p-value of less than 0.05 was considered statistically significant.

3. RESULTS AND DISCUSSION

The baseline demographic and clinical profile of the 100 study participants equally allocated between the intervention group (n = 50) and the control group (n = 50). The mean age was 44.22 years (± 5.63 years) in the intervention group compared to 45.08 years (± 5.26 years) in the control group (t = −0.790; p = 0.4320), with no statistically significant intergroup difference established. Similarly, no statistically significant differences were demonstrated for mean height (1.59 ± 0.10 m versus 1.60 ± 0.10 m; t = −0.544; p = 0.5880), mean weight (54.49 ± 5.99 kg versus 54.40 ± 6.89 kg; t = 0.069; p = 0.9450), or mean body mass index (21.53 ± 2.60 kg/m² versus 21.16 ± 2.33 kg/m²; t = 0.748; p = 0.4560) by independent samples t-test. Gender distribution assessed by chi-square revealed that females constituted the predominant subgroup in the intervention arm with 26 participants (52%), while males and females were equally represented in the control arm with 25 participants each (50%), with no statistically significant intergroup disparity (p = 0.331). The COPD severity distribution was likewise comparable across both groups (p = 0.9656), with moderate COPD representing the predominant severity stratum in the intervention arm with 21 participants (42%), thereby confirming satisfactory baseline therapeutic equipoise between the two study cohorts (Table 1).

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants Stratified by Pranayama Intervention and Control Groups

Parameter	Intervention Group (n = 50)	Control Group (n = 50)	Test Statistic	P Value
Age (years)	44.22 ± 5.63	45.08 ± 5.26	t = −0.790†	0.4320
Height (m)	1.59 ± 0.10	1.60 ± 0.10	t = −0.544†	0.5880
Weight (kg)	54.49 ± 5.99	54.40 ± 6.89	t = 0.069†	0.9450
BMI (kg/m²)	21.53 ± 2.60	21.16 ± 2.33	t = 0.748†	0.4560
Gender n (%)				
Male	22 (44.00%)	25 (50.00%)	2.2111‡	0.331
Female	26 (52.00%)	25 (50.00%)		
Transgender	2 (4.00%)	0 (0.00%)		
COPD Severity - n (%)				
Mild (GOLD I)	19 (38.00%)	20 (40.00%)	0.2698‡	0.9656
Moderate (GOLD II)	21 (42.00%)	20 (40.00%)		
Severe (GOLD III)	6 (12.00%)	7 (14.00%)		
Very Severe (GOLD IV)	4 (8.00%)	3 (6.00%)		

Data presented as Mean ± Standard Deviation for continuous variables; n (%) for categorical variables. †Independent samples t-test; ‡Chi square test. Abbreviations: BMI = Body Mass Index; COPD = Chronic Obstructive Pulmonary Disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease. P < 0.05 considered statistically significant.

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The comparative trajectory of spirometric parameters delineated forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC), across the six-week observation period, with within-group p-values reported separately for each cohort (Table 2). In the intervention group, the mean FEV_1 demonstrated a statistically significant increment from 1.33 litres (± 0.48 litres) at baseline to 1.89 litres (± 0.50 litres) post-intervention, representing a mean difference of +0.56 litres (p = 0.0010). In the control group, FEV_1 exhibited a comparatively marginal improvement from 1.20 litres (± 0.36 litres) to 1.27 litres (± 0.34 litres), yielding a mean difference of +0.07 litres (p = 0.0010). Correspondingly, the mean FVC in the intervention group increased significantly from 2.03 litres (± 0.68 litres) to 2.38 litres (± 0.52 litres; mean difference = +0.35 litres; p = 0.0010), substantially exceeding the control group improvement of +0.06 litres (1.90 ± 0.61 litres to 1.95 ± 0.59 litres; p = 0.0010). Although within-group pre-to-post changes attained statistical significance in both cohorts, the markedly superior magnitude of improvement in the pranayama intervention arm is indicative of enhanced broncho-dilatation, improved alveolar ventilation, and augmented respiratory muscle efficiency attributable to systematic pranayama practice.

Table 2: Comparative analysis of forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC) at baseline and after six weeks of intervention, with separate within-group p values for pranayama intervention and control groups

Parameter	Intervention				Control			
	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †
FEV_1 (Litres)	1.33 ± 0.48	1.89 ± 0.50	+0.56 L	0.0010	1.20 ± 0.36	1.27 ± 0.34	+0.07 L	0.0010
FVC (Litres)	2.03 ± 0.68	2.38 ± 0.52	+0.35 L	0.0010	1.90 ± 0.61	1.95 ± 0.59	+0.06 L	0.0010

Data presented as Mean ± Standard Deviation. †Paired Student's t-test applied independently for within-group pre-to-post comparison in each respective group. Mean Difference = Post-intervention value minus Baseline value. Abbreviations: FEV_1 = Forced Expiratory Volume in the first second; FVC = Forced Vital Capacity; SD = Standard Deviation. P<0.05 considered statistically significant.

Table 3 presents the pre- and post-intervention values for the FEV_1/FVC ratio, peak expiratory flow rate (PEFR), and peripheral oxygen saturation (SpO_2). In the intervention group, the mean FEV_1/FVC ratio demonstrated a statistically significant improvement from 0.66 (± 0.15) at baseline to 0.80 (± 0.12) post-intervention, representing a mean difference of +0.13 (p = 0.0010), in contrast to a marginal increment of +0.02 observed in the control group (0.65 ± 0.15 to 0.67 ± 0.14; p = 0.0040). The mean PEFR increased substantially in the pranayama cohort from 3.24 L/min (± 1.11 L/min) to 4.19 L/min (± 1.10 L/min), yielding a statistically significant mean difference of +0.95 L/min (p = 0.0010), compared to a negligible increase of +0.03 L/min in the control group (3.24 ± 0.87 L/min to 3.27 ± 0.87 L/min; p = 0.0020). Furthermore, the mean SpO_2 in the intervention group exhibited a statistically significant rise from 90.86% (± 1.77%) to 92.12% (± 1.67%; mean difference = +1.26%; p = 0.0010), while the control group demonstrated a negligible and statistically non-significant decline from 91.12% (± 1.76%) to 91.06% (± 2.07%; mean difference = −0.06%; p = 0.7540), thereby affirming the superior oxygenation and airflow benefit exclusively conferred by six weeks of structured pranayama practice.

Table 3: Comparative analysis of FEV_1/FVC ratio, peak expiratory flow rate (PEFR), and peripheral oxygen saturation (SpO_2) at baseline and after six weeks of intervention, with separate within-group p values for pranayama intervention and control groups

Parameter	Intervention				Control			
	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †
FEV_1/FVC Ratio	0.66 ± 0.15	0.80 ± 0.12	+0.13	0.0010	0.65 ± 0.15	0.67 ± 0.14	+0.02	0.0040

PEFR (L/min)	3.24 ± 1.11	4.19 ± 1.10	+0.95 L/min	0.0010	3.24 ± 0.87	3.27 ± 0.87	+0.03 L/min	0.0020
SpO_2 (%)	90.86 ± 1.77	92.12 ± 1.67	+1.26%	0.0010	91.12 ± 1.76	91.06 ± 2.07	−0.06%	0.7540 (NS)

Data presented as Mean ± Standard Deviation. †Paired Student's t-test applied independently for within-group pre-to-post comparison in each group. NS = Not Statistically Significant. Mean Difference = Post-intervention value minus Baseline value. Abbreviations: FEV_1 = Forced Expiratory Volume in the first second; FVC = Forced Vital Capacity; PEFR = Peak Expiratory Flow Rate; SpO_2 =Peripheral Oxygen Saturation; SD=Standard Deviation; P<0.05 considered statistically significant.

Patient-reported outcomes were encompassed dyspnea severity and health-related quality of life across both study cohorts, with independent within-group p-values enabling discrete intragroup assessment (Table 4). Within the intervention group, the mean modified Medical Research Council dyspnea score declined markedly from 2.48 (± 1.11) at baseline to 0.76 (± 0.77) post-intervention, representing a statistically significant mean difference of −1.72 (p = 0.0010). The control group exhibited a comparatively attenuated reduction from 2.36 (± 1.05) to 1.68 (± 1.15; mean difference = −0.68; p = 0.0010). Regarding St. George's Respiratory Questionnaire domain scores, the intervention group demonstrated a substantial reduction in the Symptoms score from 304.57 (± 86.92) to 168.25 (± 106.63; mean difference = −136.32; p = 0.0010), considerably exceeding the control group decrement of −65.65 points (318.51 ± 88.89 to 252.86 ± 70.20; p = 0.0010). Additionally, the Activity score in the pranayama arm declined from 545.35 (± 212.05) to 284.80 (± 155.42; mean difference = −260.55; p = 0.0010), while the Impact score decreased from 793.05 (± 367.05) to 418.14 (± 312.12; mean difference = −374.91; p = 0.0010). Corresponding control group reductions — Activity mean difference = −176.95 (p = 0.0010) and Impact mean difference = −270.12 (p = 0.0010) — though statistically significant, were markedly inferior in magnitude, collectively affirming the multidimensional superiority of pranayama in improving patient-reported quality of life beyond pharmacotherapy alone.

Table 4: Comparative assessment of dyspnea severity (mMRC Scale) and health-related quality of life (SGRQ domain scores) at baseline and after six weeks of intervention, with separate within-group p values for pranayama intervention and control groups

Parameter	Intervention				Control			
	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †
mMRC Dyspnea Score	2.48 ± 1.11	0.76 ± 0.77	−1.72	0.0010	2.36 ± 1.05	1.68 ± 1.15	−0.68	0.0010
SGRQ — Symptoms Score	304.57 ± 86.92	168.25 ± 106.63	−136.32	0.0010	318.51 ± 88.89	252.86 ± 70.20	−65.65	0.0010
SGRQ — Activity Score	545.35 ± 212.05	284.80 ± 155.42	−260.55	0.0010	480.91 ± 213.95	303.96 ± 183.89	−176.95	0.0010
SGRQ — Impact Score	793.05 ± 367.05	418.14 ± 312.12	−374.91	0.0010	755.73 ± 384.28	485.61 ± 297.42	−374.91	0.0010

Data presented as Mean ± Standard Deviation. †Paired Student's t-test applied independently for within-group pre-to-post comparison in each group. Mean Difference = Post-intervention value minus Baseline value. Lower mMRC and SGRQ scores denote superior clinical outcomes. Abbreviations: mMRC = modified Medical Research Council Dyspnea Scale; SGRQ = St. George's Respiratory Questionnaire; SD = Standard Deviation. P < 0.05 considered statistically significant.

Haematological response to six weeks of pranayama across both study cohorts, with within-group p-values were reported independently. Within the intervention group, the mean total leucocyte count demonstrated a statistically significant reduction from 12,478.00 cells/mm³ (± 1,232.77 cells/mm³) at baseline to 12,018.00 cells/mm³ (± 1,218.34 cells/mm³) post-

intervention, representing a mean difference of −460.00 cells/mm³ (p = 0.0010). Conversely, no statistically significant change was established in the control group, where the mean TLC marginally increased from 12,304.00 (± 1,385.05) to 12,330.00 cells/mm³ (± 1,408.90 cells/mm³; mean difference = +26.00; p = 0.5670). The mean neutrophil percentage in the intervention group declined substantially from 71.96% (± 16.28%) to 58.66% (± 3.43%; mean difference = −13.30%; p = 0.0010), with no statistically significant change in the control arm (59.22 ± 4.23% to 59.78 ± 5.18%; p = 0.3270). The mean eosinophil percentage decreased from 8.24% (± 2.00%) to 6.82% (± 1.49%; mean difference = −1.42%; p = 0.0010) in the pranayama group, contrasting with a marginal non-significant increase in controls (8.23 ± 2.09% to 8.38 ± 2.86%; p = 0.5330). Conversely, the mean lymphocyte percentage increased from 26.00% (± 4.75%) to 28.32% (± 3.83%; mean difference = +2.32%; p = 0.0010) in the intervention group, while demonstrating a statistically significant but directionally inverse decline from 27.50% (± 4.53%) to 25.68% (± 4.49%; mean difference = −1.82%; p = 0.0010) in the control group, collectively indicating a favourable immune-modulatory shift exclusively attributable to the pranayama intervention.

Table 5: Comparative analysis of total leucocyte count (TLC) and differential leucocyte count parameters at baseline and after six weeks of intervention, with separate within-group p values for pranayama intervention and control groups

Parameter	Intervention				Control			
	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †
Total Leucocyte Count - TLC (cells/mm³)	12478.00 ± 1232.77	12018.00 ± 1218.34	−460.00	0.0010	12304.00 ± 1385.05	12330.00 ± 1408.90	+26.00	0.5670 (NS)
Neutrophil (%)	71.96 ± 16.28	58.66 ± 3.43	−13.30%	0.0010	59.22 ± 4.23	59.78 ± 5.18	+0.56%	0.3270 (NS)
Eosinophil (%)	8.24 ± 2.00	6.82 ± 1.49	−1.42%	0.0010	8.23 ± 2.09	8.38 ± 2.86	+0.15%	0.5330 (NS)
Lymphocyte (%)	26.00 ± 4.75	28.32 ± 3.83	+2.32%	0.0010	27.50 ± 4.53	25.68 ± 4.49	−1.82%	0.0010

Data presented as Mean ± Standard Deviation. †Paired Student's t-test applied independently for within-group pre-to-post comparison in each group. NS = Not Statistically Significant (p > 0.05). Control group Lymphocyte change (p = 0.0010) was statistically significant but directionally inverse to the intervention group. Mean Difference = Post-intervention value minus Baseline value. Abbreviations: TLC = Total Leucocyte Count; SD = Standard Deviation. P < 0.05 considered statistically significant.

Table 6 documents the pre- and post-intervention concentrations of serum inflammatory and myocellular enzyme biomarkers, with within-group p-values reported independently for each cohort to enable discrete intragroup interpretation. Within the pranayama group, the mean serum C-reactive protein demonstrated a statistically significant reduction from 9.53 mg/L (± 5.86 mg/L) at baseline to 7.85 mg/L (± 5.43 mg/L) post-intervention, representing a mean difference of −1.68 mg/L (p = 0.0010). Conversely, the control group exhibited a marginal and statistically non-significant decline from 9.13 mg/L (± 5.70 mg/L) to 9.08 mg/L (± 6.08 mg/L; mean difference = −0.05 mg/L; p = 0.8390), indicating the absence of any meaningful anti-inflammatory benefit in the absence of yogic intervention. Regarding serum creatine kinase, a plasma biomarker of myocellular damage reflecting the work of breathing, the intervention group demonstrated a statistically significant reduction from 145.01 μ/L (± 105.24 μ/L) to 140.57 μ/L (± 104.48 μ/L; mean difference = −4.44 μ/L; p = 0.0010). Furthermore, the control group exhibited a paradoxical and statistically significant increase from 141.64 μ/L (± 100.47 μ/L) to 146.37 μ/L (± 104.34 μ/L; mean difference = +4.73 μ/L; p = 0.0020), attributable to progressive elevation of airway resistance and augmented respiratory muscle workload in the absence of pranayama practice, thereby underscoring the cytoprotective myocellular benefit conferred by the six-week structured yogic breathing intervention.

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Table 6: Comparative analysis of serum C-Reactive Protein (CRP) and serum Creatine Kinase (CK) levels at baseline and after six weeks of intervention, with separate within-group p values for pranayama intervention and control groups

Parameter	Intervention				Control			
	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †	Baseline (Mean ± SD)	Post-6 Weeks (Mean ± SD)	Mean Difference	p-value †
Serum C-Reactive Protein — CRP (mg/L)	9.53 ± 5.86	7.85 ± 5.43	−1.68 mg/L	0.0010	9.13 ± 5.70	9.08 ± 6.08	−0.05 mg/L	0.8390 (NS)
Serum Creatine Kinase — CK (μ/L)	145.01 ± 105.24	140.57 ± 104.48	−4.44 μ/L	0.0010	141.64 ± 100.47	146.37 ± 104.34	+4.73 μ/L	0.0020

Data presented as Mean ± Standard Deviation. †Paired Student's t-test applied independently for within-group pre-to-post comparison in each group. NS = Not Statistically Significant. Control group serum CK change (p = 0.0020) was statistically significant — representing a paradoxical increase indicating progressive myocellular stress. Mean Difference = Post-intervention value minus Baseline value. Abbreviations: CRP = C-Reactive Protein; CK = Creatine Kinase; SD = Standard Deviation. Reference range serum CRP: 0.1–20 mg/L (Roche Diagnostics, latex HS-CRP). P < 0.05 considered statistically significant.

The present prospective analytical cohort study was designed to evaluate the adjunctive therapeutic efficacy of a six-week structured pranayama and yogic asana intervention on pulmonary function, dyspnea severity, health-related quality of life, haematological indices, and biochemical inflammatory biomarkers among adults with GOLD Stage II and III chronic obstructive pulmonary disease (COPD). The intervention group demonstrated statistically significant improvements in forced expiratory volume in the first second (FEV_1; +0.56 L; p = 0.0010), forced vital capacity (FVC; +0.35 L; p = 0.0010), FEV_1/FVC ratio (+0.13; p = 0.0010), and peak expiratory flow rate (PEFR; +0.95 L/min; p = 0.0010), substantially exceeding gains observed in the control group across all parameters. These findings are strongly corroborated by Nagendra et al. (1986), who demonstrated highly significant improvements in peak expiratory flow rate in a 3–54-month prospective follow-up of 570 bronchial asthmatics undergoing integrated yoga therapy inclusive of pranayama, alongside substantial reduction in medication dependence [6].

Nagarathna and Nagendra (1985) similarly reported significantly greater peak flow rate improvement in the yoga group compared to matched pharmacotherapy controls in a study of 106 patients [7]. Behera (1998) further confirmed that yoga encompassing pranayama, asanas and relaxation significantly improved FVC, FEV_1, and PEFR while decreasing medication usage in chronic obstructive airway disease, findings directly paralleled by the current investigation's spirometric outcomes [14]. Fulambarker et al. (2012) additionally validated these observations, reporting improvements in FVC, FEV_1, and PEFR after yoga in COPD patients alongside decreased medication requirements [15].

The physiological mechanisms underpinning the observed pulmonary improvements are multifaceted. Joshi et al. (1992), in a rigorous six-week pranayama protocol involving 75 healthy volunteers (33 male, 42 female; mean age 18.5 years), demonstrated significant improvements in forced vital capacity, FEV_1 percentage, maximum voluntary ventilation, and PEFR, alongside a significantly lowered respiratory rate, establishing a foundational mechanistic basis for pranayama-induced ventilatory enhancement [16]. Madanmohan et al. (2008) further elucidated that pranayama stimulates pulmonary stretch receptors during lung inflation, induces smooth muscle relaxation within the tracheobronchial tree and larynx, and facilitates the release of prostaglandins and surfactant, collectively increasing pulmonary compliance and reducing airway resistance [17].

Complementing these pranayama techniques, Sasangasana, a forward-bending yogic asana performed in Vajrasana, wherein the arms are raised overhead on inhalation and the forehead is lowered to the ground on exhalation and held for five seconds over five rounds facilitated thoracic cage expansion, intercostal muscle stretching, and enhanced chest wall compliance, collectively augmenting the spirometric improvements observed in the intervention cohort. The significant PEFR increment

from 3.24 L/min to 4.19 L/min ($p = 0.0010$) in the present study is consistent with Shyam Karthik et al. (2014), who documented a statistically significant rise in PEFR following pranayama in medical students, and aligns with Saxena and Saxena (2009), who established that expiratory pranayama exercises significantly improved FEV_1 and PEFR in patients with mild-to-moderate bronchial asthma [8, 18].

The systematic review by Jayawardena et al. (2020), employing PEDro methodological quality criteria, provided meta-level corroboration for pulmonary function enhancement across diverse disease populations, authenticating the mechanistic underpinnings of the current results [4]. The significant improvement in peripheral oxygen saturation from 90.9 to 92.1% (mean difference = +1.26%; $p = 0.0010$) and the marked reduction in modified Medical Research Council dyspnea score from 2.48 to 0.76 (mean difference = −1.72; $p = 0.0010$) in the pranayama group align robustly with Ranjitha et al. (2016), who reported statistically significant reductions in Borg-scale dyspnea ($p < 0.001$) and improvements in peripheral capillary SpO_2% ($p < 0.001$) in GOLD Stage II–III COPD coal miners following twelve weeks of integrated yoga therapy [3].

The control group SpO_2 remained virtually unchanged (91.1 to 91.1%; $p = 0.7540$), confirming oxygenation benefit was exclusively attributable to pranayama. Gupta et al. (2014) similarly demonstrated that three months of pranayama produced marked improvement in dyspnea severity in COPD patients, supporting the clinical meaningfulness of even shorter six-week protocols as employed in the present investigation [19]. Kaminsky et al. (2017), in a proof-of-concept randomised controlled trial of 43 patients with moderate-to-severe COPD, established that twelve weeks of pranayama significantly improved exercise tolerance and patient-reported respiratory outcomes, recommending yoga breathing as a viable home-based pulmonary rehabilitation adjunct [1].

Conversely, Thomas et al. (2009), in a randomised controlled trial evaluating the effect of breathing retraining in 183 asthma patients reported improvement in patient-reported outcomes without corresponding objective spirometric benefit, highlighting that the quality of structured supervision and protocol fidelity substantially determines the magnitude of spirometric response to respiratory training [20].

Health-related quality of life is assessed via the three validated domains of the St. George's Respiratory Questionnaire (SGRQ), demonstrated substantial and statistically significant improvements in the pranayama group: Symptoms (mean difference = −136.32; $p = 0.0010$), Activity (mean difference = −260.55; $p = 0.0010$), and Impact (mean difference = −374.91; $p = 0.0010$), all substantially exceeding control group reductions. These findings are directly consistent with Katiyar and Bihari (2006), whose randomised controlled study demonstrated statistically significant improvements in SGRQ symptom, activity, impact, and total scores following three months of pranayama in COPD patients, alongside improved six-minute walk distance[5]. Pomidori et al. (2009) similarly reported significant improvements in exercise tolerance and quality-of-life indicators among COPD patients undergoing yoga breathing programmes [21].

Tandon (1978), in one of the earliest controlled investigations of yoga as adjunct therapy for severe chronic airways obstruction, documented meaningful improvements in exercise tolerance and subjective respiratory distress, establishing a foundational evidence base extended by the current findings [22]. Wu et al. (2018), in a systematic review and meta-analysis of sixteen studies involving 1,176 COPD patients, comprehensively confirmed that meditative movement - encompassing yoga, tai chi, and qigong - significantly improved six-minute walk distance (MD = 25.40 m; 95% CI: 16.25–34.54 at three months), FEV_1 (MD = 0.10 L; 95% CI: 0.02–0.18), and health-related quality of life across COPD cohorts, providing high-level meta-analytic validation directly aligned with the present study's multidomain improvements [23].

The haematological findings of the present study merit careful contextualisation. Total leucocyte count reduced significantly from 12,478 to 12,018 cells/mm^3 (mean difference = −460.00; $p = 0.0010$) in the pranayama group, with concomitant reductions in neutrophil percentage (72 to 58.7%; mean difference = −13.30%; $p = 0.0010$) and eosinophil percentage (8.2 to 6.8%; mean difference = −1.42%; $p = 0.0010$), alongside a favourable increase in lymphocyte percentage (26 to 28.3%; mean difference = +2.3%; $p = 0.0010$). Mishra et al. (2024), in a systematic review and meta-analysis of 26 randomised controlled trials evaluating yoga's effects on inflammatory markers including CRP, IL-6, and TNF-α found that 24 of 26 studies reported a favourable reduction in pro-inflammatory cytokines irrespective of yoga type, condition studied, or intervention duration, providing robust meta-analytic validation for the anti-inflammatory trajectory observed in the present cohort [24].

Hyeon-Kyoung Koo et al. (2017) established that white blood cell count is a powerful COPD biomarker correlating inversely with pulmonary function and quality of life, providing biological plausibility for the concurrent leucocyte and spirometric

improvements documented herein [25]. Regarding serum C-reactive protein, the significant reduction from 9.53 mg/L to 7.85 mg/L (mean difference = −1.68 mg/L; p = 0.0010) in the pranayama cohort corroborates Gan et al. (2004), who demonstrated in a systematic review and meta-analysis of 14 studies that COPD is consistently associated with elevated serum CRP (standardised mean difference = 1.21; 95% CI: 0.92–1.50; p < 0.001), validating pranayama's anti-inflammatory mechanistic pathway [26].

The paradoxical, statistically significant increase in serum creatine kinase in the control group (141.64 to 146.37 μ/L; mean difference = +4.73 μ/L; p = 0.0020), contrasted against the significant reduction in the pranayama group (145.01 to 140.57 μ/L; mean difference = −4.44 μ/L; p = 0.0010), is mechanistically explained by Barreiro et al. (2005), who demonstrated by using two-dimensional electrophoresis, immunoblotting and mass spectrometry that creatine kinase is strongly carbonylated in the quadriceps femoris of COPD patients, with total CK activity and expression significantly greater than in controls, reflecting augmented respiratory muscle oxidative stress [27]. Gea et al. (2015), in a comprehensive review of muscle dysfunction in COPD, established that the mechanical loads imposed on respiratory muscles by elevated airway resistance directly increase local oxidative stress, impairing CK activity, a burden attenuated in the present pranayama group through improved bronchodilatation and airway resistance reduction [28].

Holger Cramer et al. (2019), in a systematic review and meta-analysis of eleven randomised controlled trials involving 586 COPD patients, reported robust positive effects of yoga on quality of life (COPD Assessment Test: MD = 3.81; 95% CI: 0.97–6.65; p = 0.009), explicitly recommending yoga breathing as a safe, evidence-based adjunct intervention [2]. Sengupta (2012), in a state-of-the-art review, established that pranayama exerts favourable systemic physiological effects across respiratory, cardiovascular, and immune domains, providing a unifying mechanistic framework that contextualises the multidomain benefits observed across all six outcome domains in the present investigation [29].

The present study demonstrates several notable methodological strengths. The prospective analytical cohort design with two well-matched groups of 50 participants each ensured adequate statistical power, with sample size determined using Cohen's formula (effect size = 0.78; α = 0.05; power = 0.90). The multimodal outcome assessment battery encompassing four spirometric indices, peripheral oxygen saturation, dyspnea grading, three SGRQ quality-of-life domains, total and differential leucocyte counts, serum CRP, and serum creatine kinase provided a holistic biopsychosocial evaluation of pranayama's adjunctive benefits. Standardised spirometric protocols using a validated Easy On-PC Spirometer, a structured 30-minute pranayama regimen comprising five established techniques, and confirmed baseline therapeutic equipoise collectively strengthen the internal validity and scholarly rigour of this investigation.

Several limitations warrant acknowledgement. The six-week intervention duration precludes assessment of the long-term sustainability of observed improvements. The unblinded cohort design introduces performance and detection bias, and pranayama practice outside structured hospital sessions could not be continuously monitored, potentially introducing adherence variability. Exclusion of paediatric populations, despite recognised COPD prevalence across age groups, limits generalisability. The absence of formal randomisation restricts causal inference. Single-centre recruitment from a rural tertiary care institution in Tiruchirappalli may limit external validity to broader, more heterogeneous COPD populations and diverse clinical practice contexts.

Future investigations should employ randomised controlled designs with extended follow-up of six to twelve months. Multi-centre studies incorporating diverse COPD severity profiles and paediatric populations are warranted. Standardised, supervised practice protocols with objective adherence monitoring should be integrated. Investigating optimal pranayama dosage, technique-specific effects, and long-term pharmacological interaction potential constitutes a priority research agenda.

4. CONCLUSION

The present study provides robust empirical evidence that six weeks of structured pranayama and yogic practice comprising Kapalabhati, Anuloma-viloma, Bhastrika,Sasangasana and Bhramari techniques administered as an adjunct to standard pharmacotherapy confers statistically significant and clinically meaningful improvements across all measured outcome domains in adults with GOLD Stage II and III COPD. Spirometric parameters including FEV_1, FVC, FEV_1/FVC ratio, and PEFR that improved substantially in the intervention group, accompanied by significant gains in peripheral oxygen saturation, marked reduction in dyspnea severity, and multidimensional improvement across all three SGRQ quality-of-life domains. Concurrently, favourable modulation of systemic inflammatory and myocellular biomarkers like serum CRP, total and

differential leucocyte counts and serum creatine kinase that demonstrated the mechanistic plausibility of pranayama's anti-inflammatory and cytoprotective effects. Pranayama is a safe, cost-effective, evidence-based adjunct rehabilitation strategy that merits formal integration into comprehensive COPD management protocols, particularly within resource-constrained South Asian healthcare settings where access to formal pulmonary rehabilitation programmes remains limited.

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Author Contribution Statements

Sureshbalaji RA: Conception, methods, and data collection, initial draft of the manuscript

Venkatesh K: Data curing, clinical data analysis and final draft

Maria Diana Gladish L: Literature review, methods, and data collection

Nachal Annamalai: Supervision, reviewed and edited the manuscript

Lavanya R: Review collection, method description, primary data analysis

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