Acta Scientiae
Revista de Ensino de Ciências e Matemática
ONLINE ISSN 2178-7727
ULBRA

IMPACT OF YOGIC PRACTICES ON PULMONARY FUNCTIONS IN STUDENTS RESIDING IN AIR QUALITY SENSITIVE AREAS OF KANPUR CITY

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Received: 10th July, 2025
Revised &Accepted: 15th November, 2025
Published: 25th December, 2025
DOI: https://doie.org/10.65985/AS.2026919631

Abstract
Context: Health risks linked to pollution are more common among persons, particularly students living in urban areas with a low Air Quality Index. Under these circumstances, air pollution aggravates allergic responses, causes inflammation, and compromises lung capacity.
Purpose: This study aimed to assess the effects of a yoga intervention on pulmonary function indicators in students living in areas of Kanpur City with poor air quality.
Design and Methods: Fifty male students living in AQI-sensitive areas of Kanpur City and its surroundings were meticulously selected and randomly allocated to the treatment and control groups. Each group has 25 study participants. Pulmonary function measures were examined at baseline and after the 12-week yoga session. The study data were examined using descriptive techniques and covariance analysis.
Results: The findings of the study demonstrate notable enhancements in various respiratory parameters. The results indicated significant improvements in Forced Vital Capacity ($F=8.567$, $p=.005$), Forced Expired Volume in one second ($F=6.647$, $p=.013$), the FEV1/FVC ratio ($F=4.929$, $p=.031$), Mid-Forced Expiratory Flow ($F=8.991$, $p=.004$), Peak Expiratory Flow Rate ($F=13.217$, $p=.001$), and Breath Holding Time ($F=55.536$, $p=.001$).
Conclusion: Students in Kanpur City are coping with severe air pollution by using yoga practices that enhance lung function. This promising study emphasizes the need to include yoga-based treatments in public health initiatives to enhance respiratory health comprehensively.
Key words: Pulmonary function, air quality index, air pollution, yoga

INTRODUCTION

High concentrations of particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and other pollutants are causing a severe air quality crisis in Kanpur, a major industrial city in northern India (Patel et al., 2024). The city's air pollution has steadily decreased over the last few decades due to its fast industrialization and urbanization (Kaur & Pandey, 2021; Singh et al., 2007)

ISSN:1517-4492 | **E-ISSN**:2178-7727

According to Tripathi et al. (2024), the leading causes of air pollution in Kanpur are vehicles, industrial effluents, construction activities, and domestic biomass burning. Kanpur, a city in the northern India, is one of the most polluted cities in India, according to the 2014-2015 report of the Central Pollution Control Board (CPCB). During the winter season, PM10 levels exceed 300 µg/m3, and this is five times higher than the WHO-recommended limit value (50 µg/m3) (Sharma et al., 2024; Yadav et al., 2020). It has been found from research studies that Pollution levels in Indian metro cities are highly affected by seasonal changes for example, temperature inversions, which trap pollutants near the ground, are at their highest levels in winter season (Gupta, 2008; Zhou et al., 2024).

Deterioration of air quality has a significant and worrying impact on the respiratory health of Kanpur residents, especially those living in already sensitive areas. According to studies conducted by Liu et al. (2013) and Tran et al. (2013), air pollution is significantly associated with an increased incidence of lung diseases, including asthma, COPD, and lung cancer Particulate matter in the air can enter the lungs, which may cause inflammation and exacerbate preexisting respiratory conditions (Kim et al., 2015). Cross-sectional research in Kanpur revealed that persons exposed to high pollution levels had a significantly greater prevalence of respiratory symptoms, such as chronic cough and wheezing, than those in regions with better air quality (Kashyap et al., 2020). Air pollution adversely affects the health of people with vulnerable immune systems, including children and the elderly. Asthma and other respiratory diseases are more common in children exposed to high levels of air pollution over long periods of time, which can have serious consequences for their health and development (Manisalidis et al., 2020). Air pollution especially increases health problems in the elderly, making them more likely to suffer from respiratory diseases and even death (Ding et al., 2020).

Economists have shown that respiratory disorders due to air pollution are more expensive to treat in any country's economy, which puts a burden on the health care system (Khan and Hassan, 2020; Yadav and Ganguly, 2024). India is one of the countries most affected by external environment air pollution, and the World Health Organization estimates that more than 4.2 million people die from it worldwide (WHO, 2021). This fact highlights the importance of implementing effective air quality management laws for policy makers to reduce pollution and protect public health. Serious concerns related to air quality in Kanpur have significantly affected the health of the respiratory system. Important measures to protect the people of Kanpur from air pollution and prevent environmental disasters include greater regulation of emissions, more funding for renewable energy, and awareness campaigns. Research on the effects of air pollution has shown that public health initiatives should be prioritized to improve air quality (Ganguly et al., 2020).

The efficiency and efficacy of the lungs and respiratory system are central to the pulmonary function. It includes various physiological metrics, including lung volume, airflow rate, and gas exchange efficiency, which are important for assessing overall respiratory health. Essential pulmonary function tests (PFTs) include spirometry, which measures the volume and velocity of inhaled and exhaled air, and diffusion capacity testing, which evaluates the lungs' ability to transfer oxygen into the circulation. Assessing these characteristics is important for diagnosing respiratory disorders such as asthma, chronic obstructive pulmonary disease (COPD), and restrictive lung diseases (Stanojevic et al., 2021; Fu et al., 2023). The importance of pulmonary function is not just related to respiratory health; it is also important for general health and quality of life. Adequate blood oxygenation is essential for the maintenance of metabolic processes in all systems of the body, and healthy pulmonary function guarantees this

ISSN:1517-4492 | **E-ISSN**:2178-7727
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(Benner et al., 2023; Mortola, 2019). Fatigue, cognitive decline and impaired physical performance are some of the systemic consequences that can result from low blood oxygen levels due to impaired lung function (Arreaza-Feguevares et al., 2010). Del Buono et al. (2019) found that exercise intolerance is highly associated with poor pulmonary function. This, in turn, increases sedentary behavior and the risk of chronic diseases, including obesity and cardiovascular diseases.

When we talk about lung health, environmental factors, especially air quality, play an important role. Research suggests that respiratory problems are more common among people living in places with poor air quality (Kurt et al., 2016). In Indian cities, especially Kanpur, air pollution due to human activities such as vehicle emissions and industrial processes is becoming a matter of concern for the health of residents (Nasir et al., 2016). According to research studies conducted in this subject area (Lee et al., 2021), long-term exposure to air pollutants such as particulate matter (PM2.5), sulfur dioxide (SO2) and nitrogen dioxide (NO2) increases the risk of chronic airway inflammation, reduced lung function and respiratory disorders. In places with high air pollution, adverse effects on all classes of people, especially children and the elderly, can harm their health, cognitive ability, and personal development (Wolfe et al., 2021). Given these issues, yogic interventions that promote lung health are extremely important. Yoga practices such as asanas (postures), pranayama (breath control) and meditation have been found to be useful in enhancing respiratory function and improving lung capacity (Prasad et al., 2022; Benavides-Pinzon and Torres, 2017). Research shows that regular practice of yoga can increase lung capacity, improve airflow rate and enhance overall respiratory efficiency (Vedala et al., 2014; Beutler et al., 2016). Additionally, these practices can alleviate the impacts of environmental stressors by promoting relaxation, reducing anxiety, and enhancing mental health—factors that directly influence one's ability to manage respiratory issues (Büssing et al., 2012). In light of the declining air quality in Kanpur and its possible negative effects on the pulmonary function of students (Liu et al., 2013; Kumar et al., 2004), In light of the adverse effects of air pollution on human health, examining the effects of yogic practices on respiratory health is timely and important. Understanding how these yoga techniques might enhance respiratory function—especially lung function—from ancient literature and modern research will help us better equip students living in air quality-sensitive areas to manage the negative impacts of pollution and support good living. This study helps create evidence-based treatments to improve respiratory health and well-being in vulnerable populations.

Yoga can benefit individuals with strained respiratory systems caused by factors such as air pollution, according to (Rajbhoj et al., 2023; Sangeethalaxmi et al., 2023) state that yoga's holistic approach, which includes physical postures (asanas), breathing techniques (pranayama), and meditation, provides multiple benefits to the respiratory system. Asanas, which comprise a range of physical poses, can help to enhance breathing, claims (Yamamoto-Morimoto et al.,2019). Pranayama, sometimes known as yogic breathing, uses several techniques to control and modulate respiratory function (Mondal, 2024). Among the other advantages people can get are better lung capacity, more oxygenation, and more general well-being.As part of their practice, yogis meditate and relax to alleviate tension, anxiety, and pollutants in the air that might harm respiratory health (Streeter et al., 2010; Brown et al., 2005; Büssing et al., 2012; Saoji et al., 2019; Djalilova et al., 2019) are just a few researchers who have explored the impact of yoga on respiratory health. The Indian city of Kanpur has poor air quality due to factory and vehicle air pollution. Because of their young age and high levels of

ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)

physical activity, students are particularly vulnerable to respiratory problems associated with air pollution exposure. Indicators of the harmful effects of air pollution on lung function among students in Kanpur include increased respiratory symptoms, reduced lung capacity, and a higher risk of chronic diseases (Guttikunda et al., 2014; Kaur & Pandey, 2021). In communities affected by air pollution, practicing yoga can effectively improve respiratory health. Individuals who incorporate these practices into their daily routines may experience better lung function, increased oxygenation, and enhanced overall well-being.

The main aim of this study was to assess the effects of the intervention on pulmonary function parameters in students residing in areas of Kanpur City with poor air quality. Additionally, the study aimed to compare these findings with those of students who do not practice yoga, all while maintaining the same temporal and environmental conditions.

Objectives of the study

1. To evaluate the effect of yoga practices on pulmonary function metrics in students residing in low Air Quality Index areas of Kanpur city.
2. To compare the pulmonary function outcomes of students practising yoga under similar environmental conditions during the study period with those of non-yoga practitioners.

METHODS

Participants

The study participants were chosen from two colleges (D.A.V. Training College and Prof. H.N. Mishra College of Education) in Kanpur, affiliated with C.S.J.M. University, Kanpur. A cohort of 50 male students from air quality-sensitive areas of Kanpur City was selected for this study. We focused on healthy males aged 18 to 26 who underwent a comprehensive medical evaluation by a physician and expressed their willingness to participate. To maintain study integrity, we excluded individuals who engaged in regular exercise—such as gym workouts, swimming, or sports—as well as those with addictions or significant medical issues, including cardiovascular problems and diabetes. Each volunteer received detailed written information about the research. Before the trial began, informed consent was obtained, ensuring clarity and respecting ethical standards

The researcher used independent and dependent variables to classify the variables in this study. The independent variable was an intervention involving 12-week yoga sessions to evaluate its possible effects on respiratory health. At the same time, the pulmonary function test results and other lung function metrics made up the dependent variables. The metrics included in the analysis of this study were forced vital capacity (FVC), forced expiratory volume in one second (FEV1), mid-forced expiratory flow (FEF25-75), peak expiratory flow rate (PEFR), and FEV to FVC ratio. This study aimed to investigate the effects of yoga intervention on participants' lung function and total respiratory efficiency by examining these dependent variables.

Study Design

This research randomly assigns all subjects to one of two groups, utilizing a genuine experimental random group design. The participants are assigned to two groups utilizing a computer-generated random number table from www.randomizer.org. The yogic practice was performed over 12 weeks. The diagram in [**Figure 1]** illustrates the study design used for this project. The experimental group participated in a 16-week yoga intervention **[Table 1]**, occurring six times weekly for one hour each evening. The control group was placed on a waitlist for the specified duration. The experimental group received yoga intervention from a seasoned senior yoga instructor.

Group	Randomized	Dependent Variables (Pre-test)	Independent Variable	Dependent Variable (Post-test)
Experimental	R	O_1, O_2	X	O_1, O_2
Control	R	O_1, O_2,		O_1, O_2,

Figure-1: Study design

Table-1: Yoga Protocol used in this Study

S.No.	Yogic practices	Duration
1.	**Prayer (Shanti Path)**	**2 Minutes**
2.	**Chalana Kriyas (Loosening Practices)**	
	a) Forward and backward bending b) Sideward bending c) Neck twisting d) Trunk twisting (trunk and knee movements)	*2 Minutes* *2 Minutes* *2 Minutes* *4 Minutes*
3.	**Yogäsanas (Physical Postures)**	
3.1	**Standing Postures** a) *Tadasna* (Palm tree pose) *b) Trikonasana* (The Triangle pose) **c)** *Padhastanasana (The Hand to foot forward bend pose)*	 *2 Minutes* *2 Minutes* *2 Minutes*
3.2	**Sitting Postures** *a) Shashankasana* (Hare pose), b) *Ushstrasana* (Camel pose), c) *Paschimottasana* (Seated forward bend pose)	 *2 Minutes* *2 Minutes* *2 Minutes*
3.3	**Prone Lying Postures** a) *Bhujaìgäsana* (Serpent pose) **b)** *Śalabhāsana* (Locust pose)	 *2 Minutes* *2 Minutes*
3.4	**Supine Lying Postures** **a)** *Setubhandhasana (bridge pose)* **b)** Sarvangasana (Shoulder stand pose)	 *2 Minutes* *2 Minutes*
4.	**Pranayama (Breathing techniques)**	
	a) Bhastrika (Bellows Breath)	*4 Minutes* *4 Minutes*

ISSN:1517-4492 | **E-ISSN**:2178-7727

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	b) Nadi Shodhan (Alternate nostril breathing) c) Bhramari (Bee Breath)	*4 Minutes*
5.	**Kriya (purification technique)**	
	a) Kapalbhati (Skull shining breathing)	*4 Minutes*
6.	**Dhyana (Meditation)**	
	a) Omkar Meditation	*5 Minutes*
7.	**Relaxation poses**	
	a) Shavasana (Corpse pose) b) Makrasna (Crocodile pose)	*2 Minutes 30 seconds* *2 Minutes 30 seconds*
8.	**Sankalpa (A Solemn vow)**	*1 Minute*
9.	**Prayer (Shanti Path)**	*1 Minute*

Assessments of Primary Variables: The Pulmonary Function Test

Both groups will be evaluated at the start and end of the 12-week yoga intervention. Spirometry provides an objective evaluation of airflow limitation by measuring pulmonary mechanics. The pulmonary function tests (PFT) were assessed using the spirolab [spirolab manual, 2022] spirometer equipment (Ver. 4.8, Medical International Research, USA, Inc.) before and after the yoga training. Each individual underwent testing using the same equipment. Participants' age was ascertained using their ID cards. The height and weight of all participants were taken at the time of the test. Each participant was provided with a fresh, one-time-use mouthpiece for blowing air into the handheld spirometer to perform PFT. Participants were instructed about the steps and procedures and were also shown the demonstration of all the tests before conducting the actual test on them.

Statistical Analysis

The effects of yoga on pulmonary functions were evaluated using mean and standard deviation. The statistical technique, Analysis of Covariance (ANCOVA), was used to ascertain the influence that yoga intervention had on the pulmonary function of college students. Every test will have a statistical significance criterion of $P < 0.05$, which was established.

RESULTS

The descriptive statistics of the means for the variables were calculated for the actual post-test situation. These were presented together with the adjusted post-test mean by ANCOVA, one for each variable, for comparison. Table 2 depicts the original means, standard deviation, adjusted means, and standard error of experimental groups and the control group for FVC, FEV_1, FEV_1/FVC, FEF $_{25\text{-}75\%}$ and PEFR respectively. **Fig. 1** is a bar graph which shows the comparison between the means of FEV_1, FEV_1/FVC, FEF $_{25\text{-}75\%}$ and PEFR between the experiment and control groups.

Table 2. Descriptive statistics of post-test and adjusted post-test means of pulmonary function parameters of experimental and control group

Variable	Group	Post-test mean	SD	Adjusted post-test mean	SE	N
FVC (L)	Experiment	4.24	4.28	3.68[a]	.084	25

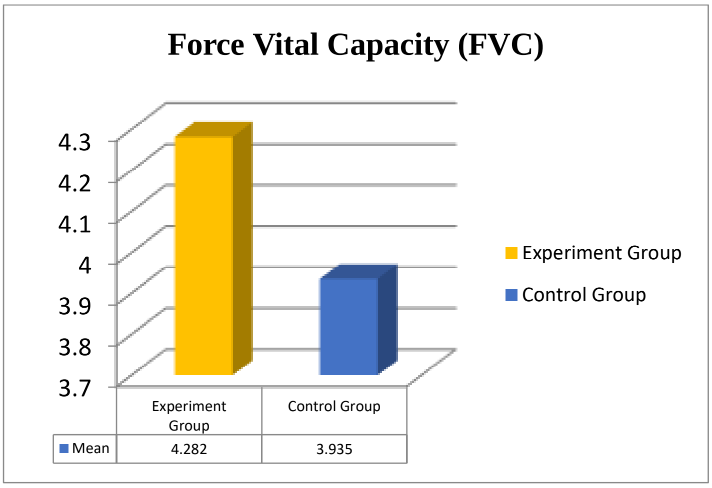
ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)

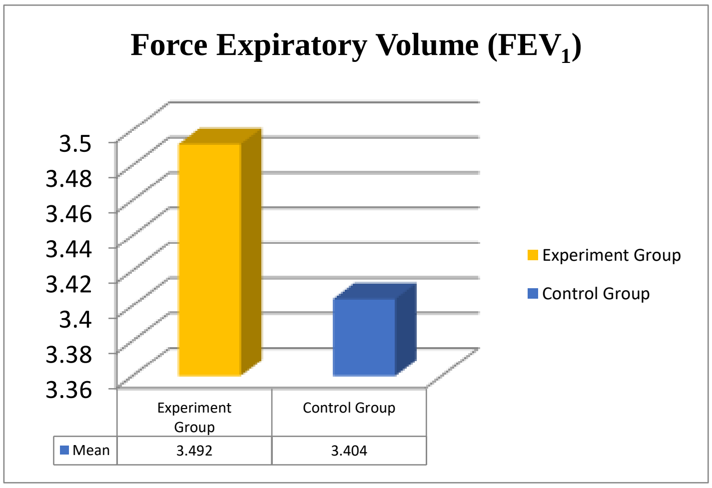
ACTA SCIENTIAE
Revista de Ensino de Ciências e Matemática
PROGRAMA DE PÓS-GRADUAÇÃO EM ENSINO DE CIÊNCIAS E MATEMÁTICA
ONLINE ISSN 2178-7727
ULBRA

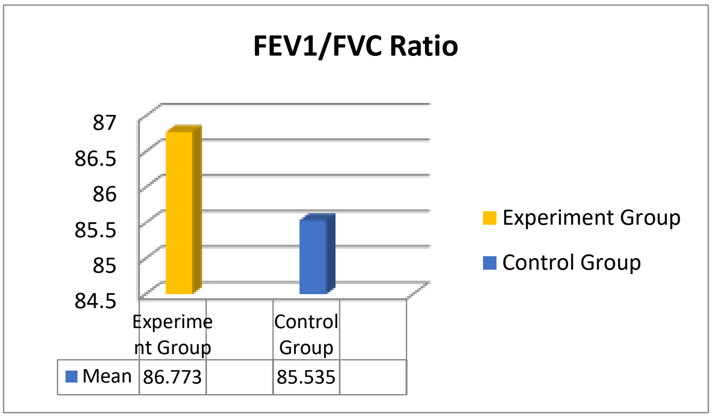
	Control	3.98	3.93	3.15[a]	.085	25
FEV1(L)	Experiment	3.48	0.44	3.49[a]	.024	25
	Control	3.40	0.50	3.40[a]	.025	25
FEV1/FVC %	Experiment	87.24	4.04	86.77[a]	.393	25
	Control	85.06	6.74	85.53[a]	.394	25
FEF 25-75% (L/s)	Experiment	4.36	1.07	4.34[a]	.114	25
	Control	3.85	.823	3.86[a]	.115	25
PEFR (L/min.)	Experiment	524.92	82.95	547.05[a]	11.89	25
	Control	506.16	85.06	484.02[a]	11.91	25

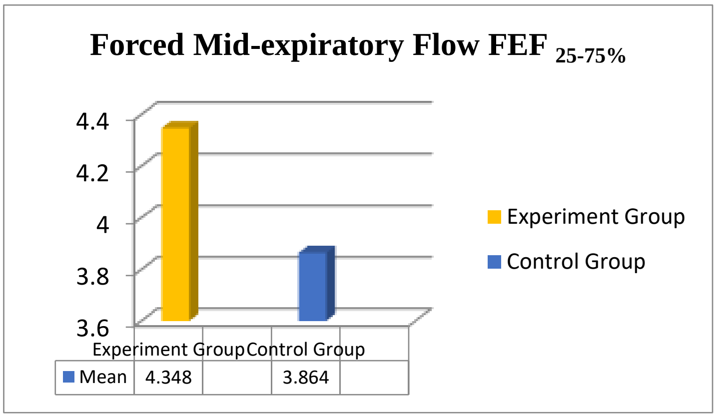
N=50; SD, Standard deviation; SE, Standard error

a) The following values are used to assess covariates in the model: pre-testing score of FVC=3.882; FEV_1=3.338; FEV_1/FVC% = 85.876; FEF $_{25\text{-}75\%}$ = 3.85; PEFR = 453.24









ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)

ACTA SCIENTIAE Revista de Ensino de Ciências e Matemática ONLINE ISSN 2178-7727 ULBRA

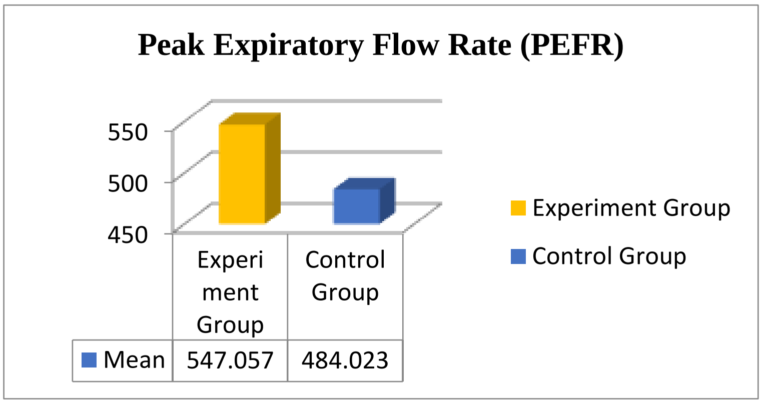


Figure 1. Mean comparison of pulmonary function parameters between treatment and control group.

Table 3. Analysis of Covariance for between subject effect of experimental and control group on all pulmonary function parameters.

Variable	Source	Type III Sum of Squares	df	Mean Square	F	Sig. (p-value)	Partial Eta Squared (η^2)
FVC (L)	Group	1.498	1	1.498	8.567*	.005	0.15
	Error	8.218	47	0.175			
	Corrected Total	20.436	49				
FEV_1(L)	Group	0.096	1	.096	6.647*	.013	0.12
	Error	0.679	47	.014			
	Corrected Total	10.865	49				
FEV_1/FVC %	Group	18.980	1	18.980	4.929*	.031	0.09
	Error	180.982	47	3.851			
	Corrected Total	1544.504	49				
$FEF_{25\text{-}75\%}$ (L/s)	Group	2.923	1	2.923	8.991*	.004	0.16
	Error	15.281	47	0.325			
	Corrected Total	46.880	49				
PEFR (L/min.)	Group	43802.387	1	43802.387	13.217*	.001	0.21
	Error	155757.091	47	3313.981			
	Corrected Total	343200.420	49				

ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)

*Significant at 0.05 level $F_{0.05}$ (1,47)

Table 4. Pair wise comparison of mean of all pulmonary function parameters with least significant difference between experimental and control group

Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
FVC (L)	Experimental Group	Control Group	.537*	.119	.005	.109	.587
FEV_1 (L)	Experimental Group	Control Group	.088*	.034	.013	.019	.157
FEV1/FVC %	Experimental Group	Control Group	1.237*	.557	.031	.116	2.359
FEF $_{25\text{-}75\%}$, (L/s)	Experimental Group	Control Group	.484*	.161	.004	.159	.808
PEFR (L/min.)	Experimental Group	Control Group	63.034*	17.338	.001	28.154	97.913

**The mean difference is significant at the 0.05 level; SE: Standard error*

A one way ANCOVA was conducted to compare the effectiveness of yogic intervention for 12 week duration whilst controlling for pre-test scores between experimental and control group **[Table 3],** revealed a significant effect of the experimental condition on post-test performance on FVC, [$F(1,47) = 8.567$, $p = .005$, $\eta_p^2 = .15$]; FEV_1, [$F(1,47) = 6.647$, $p = .013$, $\eta_p^2 = .12$]; FEV_1/FVC, [$F(1,47) = 4.921$, $p = .031$, $\eta_p^2 = .09$]; FEF $_{25\text{-}75\%}$, [$F(1,47) = 8.991$, $p = .004$, $\eta_p^2 = .16$] and PEFR, [$F(1,47) = 13.217$, $p = .001$, $\eta_p^2 = .21$]. Levene's test and normality checks were carried out with Shapiro-wilk test and the assumptions met. Post hoc comparisons were conducted using the LSD test **[Table 4].** The difference between experimental and control group for FVC, .537, 95% CI [.109, .587]; FEV_1, .088, 95% CI [.019, .157]; FEV_1/FVC, 1.237, 95% CI [.116, 2.359]; FEF $_{25\text{-}75\%}$, .484, 95% CI [.159, .808] and PEFR, 63.034.484, 95% CI [28.154, 97.913] were statistically significant (p = .005). Comparing the estimated marginal means for all pulmonary function parameters **[Table 2]** showed improvements for experimental group compared to control group FVC, [M=3.68 Litres vs M=3.15 Litres]; FEV_1, [M=3.49 Litres vs M=3.40 Litres]; FEV_1/FVC%, [M=86.77 vs M=85.53]; FEF $_{25\text{-}75\%}$, [M=4.34 L/s vs M=3.86 L/s]; and PEFR, [M=547.05 L/min. vs M=484.02 L/min.] respectively.

ISSN:1517-4492 | **E-ISSN**:2178-7727

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DISCUSSION

All lung function measures showed a considerable improvement following 12 weeks of regular yoga practice, according to the present research findings. Consistent with previous research, indicating similar findings for FVC, FEV_1, and FEV_1/FVC%. The following authors have contributed to the research: (Karunarathne et al., 2023; Sangeethalaxmi et al.,2023; Bhagel et al., 2021; Dietrich et al.,2021; Bargal et al., 2022; and Bhagel et al., 2022). Engaging the muscles of the thoracic cavity through various yoga postures can lead to enhanced physical effort and improvements in Forced Vital Capacity (FVC). Consistent practice activates more muscles, which may result in better lung function. pranayama training encourages longer durations of inhalation and exhalation, according to many studies. (Mitra et al., 2024; Kala et al., 2021; Sangeethalaxmi et al., 2023). The release of surfactants and prostaglandins into the alveolar cavities is critically dependent on the expansion and contraction of the lungs, which in turn increases lung compliance [Xing et al., 2023; Sangeethalaxmi et al., 2023].

When comparing the post-intervention outcomes of the two groups, the experimental group showed improvements in FEV1/FVC, PEFR, and FEF25-75% values. In contrast, the control group from previous research exhibited no significant changes in FVC, FEV1, or PEFR values. The results from the experimental group align with findings from earlier studies (Singh et al., 2024; Karunarathne et al., 2024; Jayswal et al., 2024).

The practice of yoga can improve lung function in terms of factors such as lung and thoracic compliance, airway resistance, and respiratory muscle strength. Yoga breathing, also known as pranayama, i.e., expansion of the breath, involves the practice of holding the breath for long periods of time after each inhalation and exhalation. This technique is considered a breathing method and exercise to expand the chest. Pranayama can provide psychological benefits by relieving the patient of stress and increasing the sense of self-control, thereby helping to reduce autonomic arousal factors. Yoga helps maintain a balanced autonomic system, favoring a state of relaxation and calmness over a stress-induced response. Yoga therapy helps to rebalance the autonomic system, control breathing, and relax the muscles involved in breathing. This leads to a decrease in the sympathetic response (Kent et al., 2014).

The practice of yogic breathing techniques has an important role in balancing and regulating respiratory function. It has the ability to increase the strength of the muscles involved in respiration. During its practice, the lungs and chest expand and contract to their full capacity while the muscles contribute to their maximum potential. The study subjects showed significant improvement in breath-holding duration after yoga instruction. This provides further evidence that yogic breathing techniques help to avoid respiratory muscle fatigue. The ability to draw in and hold more air in the lungs increases the oxygen available to various body systems. This may help to increase breath-holding duration and reduce respiratory rate. (Muller et al., 2011; Chakravarty et al., 1988.

CONCLUSION

The significant enhancements reported in the pulmonary function parameters of students living in parts of Kanpur city susceptible to air quality index support the effectiveness of yoga intervention in improving lung function. The yoga intervention might serve as a preventative approach for managing health, including pulmonary functions, among individuals living in environments with moderate to high levels of air pollution.

Limitation of the study

This research studied male participants. If female participants had been included, gender-specific analysis of data would have been more suitable to better understand the effects

ISSN:1517-4492 | **E-ISSN**:2178-7727
Vol. 8, No. 1 (2025)

of yoga on body and mental fitness. Although this research assessed yoga's impact on pulmonary function, autonomic, biochemical, and endocrinal responses were not measured or analysed. The impacts would have been more legitimate and confirming if included and quantified.

Financial support and sponsorship

C.S.J.M. University, Kanpur, Uttar Pradesh under C.V. Raman Minor Research Project Scheme.

Conflicts of interest

There are no conflicts of interest.

Acknowledgement

The authors are thankful to the C.S.J.M. University, Kapur and all participants for their cooperation.

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