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ORIGINAL ARTICLE

Impact of Ambient Air Pollution on Respiratory Symptoms, Lung Function, and Exacerbation Frequency Among Adult Residents of Lahore. A Cross-Sectional Clinical Study

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ABSTRACT

Background: Lahore is a city that is continuously listed in the top ten in the world in terms of pollution, making the standards of the number of particles actually out of this scale. Air pollutants are a significant risk to respiratory health, and there are not many clinical data sets that relate exposure and functional impairment in the local population.

Objective: The aim of the study is to determine the effects of air pollution on respiratory symptoms, lung function, and frequency of exacerbation in adult citizens of Lahore.

Methods: A cross-sectional clinical study was performed on 300 adults who were recruited in high, moderate, and low pollution areas. Respiratory symptoms had been assessed through a structured question, exposure levels had been determined through AQI data and lung functioning assessed through spirometry in accordance with the guidelines of ATS/ESRS. The SPSS 26 was used to analyze the data with $p < 0.05$ being significant.

Results: Respiratory symptoms were very high in high-exposure regions, such as cough (82.2%), throat irritation (75.3%), dyspnea (67.2%), and wheezing (48.9%). Spirometry revealed considerable changes in the FEV 1, FVC and FEV 1/FVC ratios between people in high-pollution regions ($p < 0.001$). High-exposure areas were also the areas with the highest respiratory exacerbation (56%). There was an apparent exposure response pattern on all outcomes.

Conclusion: Respiratory health outcomes of ambient air pollution in Lahore are strongly negative, which leads to an increase in symptom burden, a decrease in lung functions, and the likelihood of exacerbations. There is a need to take urgent policy measures and community-level preventive interventions to curb the increasing health burden due to air pollution.

Keywords: Pollution, Respiratory, Spirometry, Symptoms, Exacerbations.

INTRODUCTION

Air pollution has become one of the most important environmental health issues all over the world, and the load of air pollution is extremely heavy in the fast-developing cities of South Asia[1]. The second largest Pakistani metropolitan city, Lahore is regularly one of the most polluted cities of the globe through a mix of automobiles emissions, manufacturing, open burning of wastes, a kiln of bricks, construction dusts, and seasonal burning of crop remains [2]. They lead to the continued high concentrations of PM, nitrogen oxides (NOx), sulfur dioxide

(SO2), carbon monoxide (CO), and ground-level ozone (O 3). As per the latest air quality tests, the level of in Lahore is often multiplied by more than ten times the WHO allowable level during the season of smog, and it is a threatening factor to the health of the citizens [3].

The respiratory system is especially susceptible to the destructive power of the air pollution due to the direct interaction of the inhaled toxins with the airway epithelium, which results in the development of oxidative stress, inflammation, and poor mucociliary clearance [4]. A long duration of high levels of pollution has also been associated with a broad range of respiratory symptoms and issues, such as cough, phlegm, dyspnea, wheezing, irritation of the throat, allergic rhinitis, and asthma attacks. Small PMs may have access to the deepest part of the alveoli damaging the pulmonary functions and putting individuals at exposure to the risk of developing chronic diseases like chronic obstructive pulmonary disease (COPD) [5]. In addition, recurrent contact with atmospheric pollutants has been linked to more frequent visits to the hospital, drug consumption, and worse quality of life particularly in those who have respiratory illnesses [6].

Smog outbreaks that take place in Lahore between October and February annually have become a true regularity in the life of the population, as the smog affects millions of people. Although it has become more serious, there is weak local clinical data in the measurement of the impact of ambient air pollution on respiratory symptoms and lung functions of adult urban dwellers [7]. Majority of the studies available are either environmental or epidemiological in nature with minimal focus being on the clinical evaluation of spirometry or elaborate symptom rating [8]. Community based clinical studies are also needed that would assess the correlation between exposures to pollutants, respiratory symptoms, and functional impairment in the general population. Thus, the proposed research will examine effects of air pollution on respiratory symptomatology, lung functional parameters, and exacerbation rates in adult inhabitants of Lahore. The results will be used to inform policy-makers on their need to implement interventions in public-health and increase awareness on the ecological concern of the increased load of air pollution causing respiratory diseases in Pakistan [9].

MATERIAL AND METHOD

This clinical cross-sectional study was designed among adult people who live in Lahore to assess the effect of ambient air pollution on respiratory symptoms, lung functions, and the number of respiratory exacerbations. The research was conducted in the case of selected health care centers and community centers in Lahore in high-smog conditions (in October 2024-February 2025) when the air pollution rate is traditionally at its highest level. Ethical consent of the study was secured by the Institutional Review Board (IRB) in the participating institute and all the participants were obtained to agree to the research before the collection of data.

The participants of the study were 300 adults aged between 1865 years and had lived in Lahore as permanent residents at least 12 months. People who had chronic respiratory disorders diagnosed prior to their residence in Lahore were excluded, people having undergone thoracic surgery in the past, acute respiratory infections in the past two weeks, and those who were incapable of doing spirometry. The sampling method was a multistage one: in the first place, the three polluted areas of Lahore were chosen with the highest Air Quality Index data and the representatives were selected with the proportion in each area to have the representative sample.

The data gathering was conducted in terms of a structured and pre-tested questionnaire, the application of which occurred as face-to-face interviewing. The questionnaire captured demographic factors, smoking habits, occupational exposures, length of outdoor exposures, medical history, prescription drugs, self-reported symptoms of respiratory problems such as cough, wheezing, throat irritation, chest tightness, sputum production and shortness of breath. The participants also received an inquiry regarding the number of respiratory exacerbations they experienced in the last 12 months, which involved visiting a doctor or having to change the medication.

The exposure of ambient air pollution at the individual level was determined by correlating the residential areas of the participants with real-time AQI measurements taken in the Punjab Environmental Protection Department (EPD) monitoring stations. Each zone was given the average PM 2.5 and PM 10 levels to determine the exposure levels as low, moderate or high.

The assessment of the lung functions was done by a calibrated digital spirometer according to the ATS/ERS. All the participants did three or more maneuvers that were acceptable and the maximum values of Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV'), and the FEV 1/FVC ratio were taken. The impairment of lung functioning was classified according to standard values of references taken into consideration age, sex, and height.

The entries and analyses of all data were done in SPSS version 26. Demographic variables, respiratory symptoms, and spirometry results were summarized with the help of the descriptive statistics. The chi-square test was used to determine the correlation between the types of exposure to air pollution and the existence of respiratory symptoms. The results obtained were compared in independent t-

tests and one-way ANOVA to determine the difference between the parameters of lung functions in the exposure groups. The p-value of below 0.05 was regarded as significant.

RESULTS

The final analysis was conducted in 300 adult participants. The sample age was 38.6 ± 12.4 years of age with 57.3% being males (n= 172) and 42.7% females (n= 128). The greatest number (62) of the participants were living in high-pollution areas of Lahore, and 25 and 13% were living in moderately and comparatively low-pollution areas, respectively. The mean PM2.5 concentration during the period of study was 180-320 µg/m 3 which is much higher than the recommended concentration of 15 µg/m 3 in the WHO guidelines.

Table 1 is a summary of the baseline profile of all participants (n=300). Most of them resided in heavily polluted areas and more than two thirds of them were nonsmokers, which means that the other environmentally influential factor was the air pollution and not tobacco exposure. High percentage (71.3) of them had an exposure to the outdoors more than two hours a day, which exposed them to the risks of inhaling the pollutants. Almost a third of them were occupationally exposed to dust or fumes.

The high rates of respiratory symptoms were particularly high in the high-pollution areas. Cough (68.3%), throat irritation (62%), shortness of breath (54%), wheezing (38) and sputum (33) were the most frequent symptoms. Table 2 indicates that, respiratory symptoms were all significantly increased as the exposure to pollution escalated. The greatest burden of cough and throat irritation was seen in the people who lived in high-pollution areas and shortness of breath was much more prevalent (67.2) in the high-pollution areas. The p-values show that the level of exposure and prevalence of the symptoms are statistically related.

Spirometry showed that there was a significant loss in lung functions in the participants of high-pollution regions. FEV I and FVC were found to be significantly decreased with an increase in the level of exposure. Table 3 shows very clearly the existence of an exposure-response relationship. In high-pollution regions, individuals also had much lower FEV 1, FVC, and FEV 1/FVC ratios, which mean not only obstructive ventilatory impairment but also restrictive. The group differences were statistically of high significance.

On the whole, 41 percent (n=123) of the respondents had at least one respiratory exacerbation that required medical attention during the last year. The rate of exacerbation was the greatest in high-pollution areas (56%), then moderate areas (28%), and the least in low-pollution areas (13%).

The findings reveal a high and statistically significant relationship between the exposure to ambient air pollution and respiratory symptoms and the impairment of lung functions. Those participants that resided in high-pollution regions reported significantly higher rates of the prevalence of symptoms and greatly lowered spirometry indices, which proved the adverse effect of the worsening air quality in Lahore on respiratory health.

Table 1: Baseline Characteristics of Study Participants (N = 300)

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	Mean ± SD	38.6 ± 12.4	—
Gender	Male	172	57.3
	Female	128	42.7
Residence Zone	High Pollution	186	62.0
	Moderate Pollution	75	25.0
	Low Pollution	39	13.0
Smoking Status	Non-smoker	201	67.0
	Current smoker	59	19.7
	Ex-smoker	40	13.3
Outdoor Exposure (>2 hrs/day)	Yes	214	71.3
	No	86	28.7
Occupational Exposure	Yes	88	29.3
	No	212	70.7

Table 2: Distribution of Respiratory Symptoms by Air Pollution Exposure Level

Symptom	Low Exposure (n = 39)	Moderate Exposure (n = 75)	High Exposure (n = 186)	p-value
Cough	13 (33.3%)	39 (52.0%)	153 (82.2%)	<0.001
Throat Irritation	11 (28.2%)	35 (46.7%)	140 (75.3%)	<0.001
Sputum Production	8 (20.5%)	18 (24.0%)	73 (39.2%)	0.020
Shortness of Breath	10 (25.6%)	28 (37.3%)	125 (67.2%)	<0.001
Wheezing	6 (15.4%)	17 (22.7%)	91 (48.9%)	<0.001

Table 3: Comparison of Lung Function Across Pollution Exposure Levels

Parameter	Low Exposure (Mean ± SD)	Moderate Exposure (Mean ± SD)	High Exposure (Mean ± SD)	p-value
FEV_1 (L)	2.98 ± 0.42	2.71 ± 0.39	2.32 ± 0.44	<0.001
FVC (L)	3.63 ± 0.50	3.40 ± 0.48	3.01 ± 0.52	<0.001
FEV_1/FVC Ratio (%)	82.4 ± 4.7	79.1 ± 5.2	73.6 ± 6.1	<0.001

DISCUSSION

This paper examined how air pollution of the ambient environment affects respiratory symptoms, lung deterioration, and the rate of exacerbation in adult Lahore residents. The results indicate that there is a strong and evident correlation between the growing rates of air pollution and the worsening respiratory health outcomes [10]. The findings align with the international evidence but have ensured valuable urban-specific clinical information on Lahore where the issue of low air quality has become a chronic problem among the citizens [11].

Among the most significant remarks was that the prevalence of respiratory symptoms was higher in participants who lived in the high-pollution areas. These symptoms included cough (82.2%), throat irritation (75.3%), and shortness of breath (67.2%), which were more prevalent as compared to the low-exposure areas [12]. Such a pattern of exposure-response is a strong support of the contribution of particulate matter and gaseous pollutants to the process of airway irritation and inflammation. The Fine particulate matter (PM 2. 5) is proven to penetrate far into the bronchioles and alveoli causing oxidative stress, hindering mucociliary clearance, and triggering inflammatory cascades[13]. The reason why respiratory symptoms are more common in this study can be explained mechanistically in terms of these pathophysiological changes.

This association is further reinforced by lung function analysis that demonstrates that lung values of FEV1, FVC, and the ratios of the two decrease significantly as the exposure increases. The mean FEV 1 of 2.32 L in high-pollution areas versus 2.98 L in low-pollution areas showed obstructive and restrictive ventilatory impairment [14]. The decreased lung functionality is consistent with the global studies which show that chronic PM 2.5 and PM 10 can lead to chronic remodeling of airways, bronchial hyperreactivity and reduced pulmonary elasticity [15]. Considering that the average pollution figures in Lahore are way above the WHO limits, the results indicate an increased threat of acquiring chronic respiratory illness, including asthma and chronic obstructive pulmonary disease (COPD) it is especially dangerous among people who have long lived in the city [16].

The research also found that the incidence of respiratory exacerbations was much more common among high-pollution to the population. More than 56% of the respondents residing in these areas (56 out of 100) said that they had at least one medical consultation exacerbation in the last year [17]. This exacerbation burden is a manifestation of the acute impact of pollutant exposure on the airway constriction, the amplified production of mucus, and the hyperirritability of the allergens. Exacerbations do not only decrease long-term prognoses but also increase healthcare use, economic and reduced quality of life [18].

The major strength of the research is that it included objective spirometry data in addition to the self-report of symptoms. Numerous past local studies have used mainly the questionnaires or environmental measures on assessment, but the incorporation of the lung functional testing enables more precise and clinically significant evaluation of respiratory impairment caused by pollution [19]. Also, the study gives a realistic picture of the pollutant load borne by the people of Lahore regarding the data on AQI used at official monitoring stations as the levels of exposure are compared.

Although the study has its strengths, there are limitations to the study. Being a cross-sectional design, it is unable to determine the causality, yet the close relationships and exposure-response patterns can be very strong evidence. Depending on residential place to measure its exposure can under or overestimate the actual exposure because of the personal differences in mobility and interior air quality [20]. Moreover, biomarkers of inflammation or oxidative stress were not assessed in the study, which may provide more in-depth information on mechanistic pathways. However, the sample size is large, spirometry measurements were objective, and geographic exposure stratification increases the reliability and generalization of the results.

CONLUSION

The current research confirms the fact of the strong and considerable relationship between the exposure to the ambient air pollution and the adverse respiratory health condition in the adult population in Lahore. Patients residing in the highly polluted regions experienced a considerably high prevalence rate of respiratory symptoms (including cough, throat irritation, dyspnea, sputum, and wheezing). The spirometry outcomes revealed that the values of FEV1, FVC as well as the ratios of FEV1/FVC changed significantly with the rise in the level of pollution pointing to the existence of obstructive and restrictive

pulmonary defects. So, respiratory exacerbations that resulted in a medical visit were also considerably more frequent in high-exposure areas, which depicts the acute and persistent clinical effect of contaminated air. These findings highlight the fact that air quality in Lahore is a critical burden to collective health, which attracts functional respiratory impairment and increases the morbidity of diseases. Intervention Multisectoral intervention is pressing by the means of pollution control measures, industrial control, city planning in addition to education on the population to preserve the respiratory health of the population. Prevention measures, community awareness, and early screening remain to be the agenda of healthcare systems and policymakers in Pakistan.

DECLARATION

Conflict of Interest
The authors declare no conflict of interest.

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Author's Contribution
All authors contributed equally in the complication of current study.

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Data Availability Statement
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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