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Assessment of Lung Function of People, Chronically Exposed to Air Pollution in Delhi/NCR, India

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Abstract

Background: Air pollution in India is a serious issue with the major sources being motor vehicle emissions, thermal power stations, cooling towers, biomass burning, fuel adulteration, factory smoke, and stubble burning. Chronic exposure to ambient air pollution has obtunded effects on the development of lung function in children and detrimental effects on lung function of adults. The adverse effects of pollution on lung function increase the development of lung diseases in the future. **Aims and Objective:** The aim of the study was a comparison of lung function between two groups of population with different occupations, one group with outdoor occupation (high exposure) and second group with indoor occupation (low exposure). **Settings and Design:** It was a cross-sectional study and the sampling approach was Quota sampling. Quota sampling is a type of non-probabilistic sampling. There are certain groups of people who are particularly vulnerable to ambient air pollution because of their sustained high exposure like traffic police personnel deputed at traffic junctions, auto rickshaw driver/Taxi driver, E-Rickshaw driver plying in this area, and road side vendors this group. Low exposure group chosen were employee of offices and showrooms who are working indoor. **Methods and Materials:** This study was a two groups of 245 participants in each. First group with outdoor occupation and second group with indoor occupation having different level of exposure to air pollution due to their nature of occupation. Lung function parameters FEV1, FVC, FEV1/FVC, PEFR, and FEF were compared between two groups. **Statistical Analysis:** SPSS 26 software was used. Independent "T" test for continuous data type for different population, paired "T" test within the group, and Chi-square test for categorical data were applied. **Results:** Among high exposure group, 62.7% and 9.4% were found to have restrictive and normal lung function pattern, respectively. In comparison, among low exposure group, 31% and 59.5% were found to have restrictive and normal lung function pattern, respectively. Among outdoor group, there was a significant decline of lung function parameters such as FEV1, FVC, FEV1/FVC, PEFR, and FEF in comparison to indoor group. **Conclusion:** In this study, the lung function parameters were decreased in population working outdoor and chronically exposed to air pollution, in comparison to indoor subjects.

Keywords: Air pollution, Indoor occupation, Lung function, Outdoor occupation, Restrictive pattern

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Introduction

Air pollution in India is a serious issue with the major sources being thermal power stations, cooling towers, biomass burning, fuel adulteration, factory smoke, stubble burning, vehicle emission, and traffic congestion.[1] The air quality in Delhi, the capital territory of India, according to a WHO survey of 1650 world cities, is the worst of any major city in the world. It also affects the districts around Delhi.[2,3] In autumn and winter months, large scale crop residue burning in agriculture fields – a low cost alternative to mechanical tilling – is a major source of smoke, smog, and particulate pollution.[4-6] India has low per capita emissions of greenhouse gases but the country as a whole is the third largest after China and the United States.[7] A study conducted in 2013 on non-smokers has found that Indians have 30% lower lung function compared to Europeans.[8]

According to a WHO study, 13 of the 20 most-polluted cities in the world are in India; however, the accuracy and methodology of the WHO study were questioned by the Government of India.[9]

Over a million Indians die prematurely every year due to air pollution, according to the non-profit Health Effects Institute. Over 2 million children, half the children in Delhi, have abnormalities in their lung function, according to the Delhi Heart and Lung Institute.[10]

Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV1), PEFR, and forced expiratory flow (FEF) are objectively measurable lung function parameters and these are adversely affected by multiple environmental and genetic factors. Lung function parameters, specifically FVC and FEV1, are important objectively measurable quantitative parameters of respiratory health. The derangement in lung function indicates early respiratory and systemic inflammation leading to cardiorespiratory morbidity and mortality. The detrimental acute effects of air pollution on lung function observed in Western Europe at all ages are well established.[11] To what extent long-term exposure to air pollution results in the lower lung function remains less clear.[12] There is a strong evidence that long-term exposure to air pollution is associated with slowing down lung function growth in children while data on long-term effects of air pollution on lung function of adults are limited and mostly restricted to susceptible populations.[12-14] The cross-sectional studies conducted to see the

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effects of increase in 10 $\mu g \cdot m^{-3}$ of particulate matter of size 10 μm or less (PM10), it was associated with a decrease of about 3% in FEV1.[15-18] SAPALDIA found an increase of 10 $\mu g \cdot m^{-3}$ in annual mean concentration of PM10 was associated with 3.4% lower FVC and 1.6% lower FEV1.[16] There was a negative association of PM10 concentrations with FEV1 and FVC (5.1% and 3.7% respectively, per 7 $\mu g \cdot m^{-3}$ 5-year annual mean rise of PM10) as found in one of the study conducted among female.[18] The very strong indirect evidence for adverse effects on lung function due to long-term air pollution effects on lung function decline in adults emerged from follow-up study proving that improvements in PM10 exposure over a period of 11 years attenuated the age-related decrease in lung function.[19] A recent study found decline in lung functions, that is, FVC and FEV1 of elderly due to cumulative long-term exposure to ambient PM10 and ozone and an increased susceptibility among frail persons.[20]

Lung function test of diesel taxi driver when compared with medicos of similar age group in Bikaner city in India, where the density of taxies on the narrow roads of Bikaner is very high (around 10,000 taxies) in 10 × 10 km^2 area of the city, it was found that there was a restrictive impairment in 87% and mixed pattern in 13% of study group. There was also a significant low value of FVC, FEV1, PEFR, and PEF among diesel taxi driver than control group, it signifies the adverse effects of air pollution on lung function.[21] The pulmonary function test was assessed using computerized spirometer among petrol pump workers and the results showed that there was a significant decline of FVC, FEV1, FEV1/FVC%, FEF_{25-75}%, and PEFR. The results suggest that there is a need to improve control measures and the health status of workers engaged in petrol pump. Because petrol pumps are on road side, therefore, these workers are chronically exposed to air pollution as well as petrol fumes leading to adverse effects on lung function.[22]

The present study included the subjects who are at greater risk of developing adverse effects of air pollution due to their nature of occupation. Further this group is neglected one also. The studies done abroad[23] cannot be extrapolated on India. Very few studies[24] in India have been done considering the difference in exposure to ambient air pollution because of the nature of their occupation. Therefore, this study is aimed to address the above mentioned gap in the existing literature. The Government of Delhi needs to develop an action plan encompassing multiple sources and includes technological, institutional, and behavioral interventions.

Aims and Objective

The aim was to study the impact of chronic exposure to outdoor air pollution on lung function parameters such as FEV1, FVC, FEV1/FVC (%), FEF_{25-75}, and PEFR. The interpretation of measured lung function parameters was: Restrictive, obstructive, mixed, and normal pattern.

Materials and Methods

Study Design

The design of the study was cross sectional. The sampling approach was Quota sampling. Quota sampling is a type of non-probabilistic sampling in which the target population is divided into mutually exclusive subgroups also called strata, based on their peculiar features or traits. The sample size was 245 in each group. The data were entered into a predesigned and pretested questionnaire. A structured Performa consists of demographic profile, smoking history, and spirometry parameters. After taking informed consent for each eligible personnel, a structured interview Performa was filled. Then, these personnel were subjected to spirometry test. Medical international research spirolab was used to perform spirometry. The spirometry was performed as per the American thoracic society/European Respiratory Society guidelines (2005).[25]

Study Population

The study was conducted in Delhi/NCR which covered area of Mohan Nagar Bus stand, old Delhi railway station, Wazir Pur Depot, Rohini Metro station and Shadi Pur depot. The risk population of the particular area to be studied was divided into two groups:

Group (A): Outdoor exposure group: This group was considered as high exposure group. Traffic police personnel deputed at traffic junctions, auto rickshaw driver/taxi driver, E-rickshaw plying in this area, and road side hawkers.

Group (B): Indoor exposure group: This group was considered as low exposure group in this office employees who were included in the study.

Inclusion Criteria

Persons of age group of 19–60 years, both male and female, were included in the study. Male were both smokers as well as non-smokers; however, female were only non-smokers. Those having outdoor air pollution exposure regularly at least 6 h daily with at least 5 days a week and more than 2 years duration were included in study.

Exclusion Criteria

Persons who were unable to perform spirometry test in technically correct manner were exluded from the study. Personnel with history of: Tuberculosis, bronchial asthma, chest trauma, CTVS surgery, pleural effusion/empyema, ICD insertion, and cardiac ailment (CAD, Valvular Heart Diseases, etc.) were excluded from the study. Personnel with the history of neuromuscular disorders, spinal cord deformity, any surgery of chest, abdomen, eye in the past 3 months, myocardial infarction in the past 3 months, use of bronchodilators in the past 6 h, and interstitial lung disease were excluded from the study.

Results

For high exposure and low exposure groups, the distribution of gender, smoking status, occupation, height, weight, age, BMI profile, and education level of the participants is depicted in in Table 1. In Group A:– Subgroup I: Non-smoker male, Subgroup II: Smoker male, and Subgroup III: Female. In Group B: – Subgroup IV: Non-smoker male, Subgroup V: Smoker male, and Subgroup VI: Female.

The Comparison of Spirometry Parameters Between High and Low Exposure Subgroups/Groups [Table 2]

Among non-smoker group, smoker group, and female group and among total participants as a whole the FVC and FEV1 were found to be significantly lower ($P < 0.05$) in high exposure group in comparison to low exposure group.

Among total participants as a whole and among smoker group, the FEV1/FVC was found to be significantly lower ($P < 0.05$) in high exposure group in comparison to low exposure group.

Among non-smoker and among female group for FEV1/FVC, the difference was found to be non-significant between high and low exposure group.

Among smoker group and among female group, the PEF and FEF were found to be significantly lower ($P < 0.05$) in high exposure group in comparison to low exposure group.

Among non-smoker and among total participants as a whole for PEF and FEF, the difference was found to be non-significant between high and low exposure group.

The Comparison of Frequency of Spirometry Patterns Between High and Low Exposure Subgroups/Groups [Table 3]

Among non-smoker male group

Among high exposure group, 77.7% and 10.3% were found to have restrictive and normal lung function pattern, respectively. In comparison, among low exposure group, 18.1% and 75.5% were found to have restrictive and normal lung function pattern, respectively.

Table 1: Distribution of participants according to the level of exposure to air pollution and demographic profile of participants

Demographic Profile	*Group*		*P-value*
	Outdoor group (High Exposure) (Mean±SD)	*Indoor group (Low Exposure) (Mean±SD)*	
Height (cm)	163.107±8.8563	164.397±8.6961	0.105
Weight (kg)	65.53±12.564	67.13±12.480	0.159
Age (Mean±SD)	43.26±13.241	41.22±15.186	0.114
BMI (kg/m^2)	24.434±4.3103	24.871±4.4184	0.269
Male			
Non-smoker	135 (I)	143 (IV)	-
Smoker	57 (II)	53 (V)	-
Female			
All non-smoker	53 (III)	49 (VI)	-

*Group I (n=135) – High exposure non-smoker male. Group II (n=57) – High exposure smoker male. Group III (n=53) – High exposure non-smoker female. Group IV (n=143) – Low exposure non-smoker male. Group V (n=53) – Low exposure smoker male. Group VI (n=49) – Low exposure non-smoker female

Among smoker group

Among high exposure group, 25%, 76.7%, and 0.0% were found to have restrictive, mixed, and normal lung function pattern, respectively. In comparison, among low exposure group, 49.0%, 9.4%, and 30.1% were found to have restrictive, mixed, and normal lung function pattern, respectively.

Among female group

Among high exposure group, 64.1%, 16.9%, and 16.9% were found to have restrictive, mixed, and normal lung function pattern, respectively. In comparison, among low exposure group, 46.9%, 4%, and 46.9% were found to have restrictive, mixed, and normal lung function pattern, respectively.

Comparison of Spirometry Parameter (mean ± SD) of Absolute Observed and Absolute Predicted Values (Liters) within the Each Sub Group [Table 4]

The mean ± SD of absolute observed values (liters) FVC, FEV1, and FEV1/FVC is significantly lower than absolute predicted values within the Subgroups I, II, and III which are the high exposure groups and indicate the effects of high exposure to ambient air pollution on lung function. The mean ± SD of absolute observed values (Liters) FVC and FEV1 is significantly lower than absolute predicted values within the Subgroups IV, V, and VI which are the low exposure groups. The mean ± SD of absolute observed values (liters) of FEV1/FVC is significantly lower than absolute predicted values within the Subgroups IV and V which are the low exposure groups but not in Subgroup VI.

The mean ± SD of absolute observed values (liters) of PEFR is significantly lower than absolute predicted values within the Subgroups I, II, and III which are the high exposure groups. The mean ± SD of absolute observed values (liters) of PEFR is significantly lower than absolute predicted values within the Subgroups IV and V which are the low exposure groups but not in Subgroup VI.

The mean ± SD of absolute observed values (liters) of FEF is significantly lower than absolute predicted values within the Subgroups II and III which are the high exposure groups but not in Subgroup I. The mean ± SD of absolute observed values (Liters) of FEF is significantly lower than absolute predicted values (liters) within the Subgroup V which is the low exposure groups but not in Subgroups I and III.

Table 2: Comparison of spirometry parameters between subgroups, high and low exposure group

Exposure	*Spirometry parameters*				
Subgroup/Group	*FVC*	*FEV1*	*EFV1/FVC*	*PEF*	*FEF*
Subgroup I	2.7±0.5	2.1±0.5	77.8±9.9	234.4 v 171.5	2.2±1.10
Subgroup IV	3.4±0.75	2.7±0.77	80.0±11.82	238.7±19	2.4±1.08
P value	0.00	0.00	0.107	0.846	0.245
Subgroup II	1.7±0.50	1.07±0.36	60.5±13.35	113.4±102.3	0.9±0.56
Subgroup V	2.9±0.68	2.1±0.68	72.7±11.1	210.2±178.5	1.9±0.72
P value	0.000	0.000	0.000	0.001	0.000
Subgroup III	1.7±0.70	1.3±0.60	78.0±14.13	108.8±128.2	1.6±0.8810
Subgroup VI	2.3±0.6	1.8±0.6	80.4±12.1	18.2±52.5	2.2±1.0
P value	0.00	0.00	0.359	0.00	0.00
Outdoor Group (High Exposure) Total	2.3283±0.7791	1.7467±0.7182	73.889±13.8472	179.10428±160.738	2.1411±4.3943
Indoor Group (Low Exposure) Total	3.0980±0.8396	2.4572±0.8182	78.175±13.0319	189.0702±193.531	2.8204±8.0304
P value	0.00	0.00	0.00	0.536	0.246

*Group I – High exposure non-smoker male, Group II – High exposure smoker male, Group III – High exposure non-smoker female, Group IV – Low exposure non-smoker male, Group V – Low exposure smoker male, Group VI – Low exposure non-smoker female.

Table 3: Comparison of spirometry patterns between subgroups, high exposure and low exposure group

Exposure Subgroup/Group	*Spirometry patterns*			
	Restrictive	*Obstructive*	*Mixed*	*Normal*
Subgroup I (135)	105 (77.7%)	5 (3.7%)	11 (8.1%)	14 (10.3%)
Subgroup IV (143)	26 (18.1%)	4 (2.7%)	5 (3.4%)	108 (75.5%)
P value	0.00	0.66	0.09	0.00
Subgroup II (57)	14 (25%)	0 (0%)	43 (76.7%)	0 (0%)
Subgroup V (53)	26 (49.0%)	5 (9.4%)	5 (9.4%)	16 (30.1%)
P value	0.00	0.01	0.000	0.000
Subgroup III (53)	34 (64.1%)	1 (1.8%)	9 (16.9%)	9 (16.9%)
Subgroup VI (49)	23 (46.9%)	2 (4.0%)	2 (4.0%)	23 (46.9%)
P value	0.08	0.50	0.03	0.00
Outdoor Group (High Exposure, Total all participants)	153 (62.7%)	6 (2.4%)	63 (25.8%)	23 (9.4%)
Indoor Group (Low Exposure, Total all participants)	76 (31%)	11 (4.4%)	12 (4.8%)	146 (59.5%)
P value	0.00	0.15	0.00	1.00

*Group I – High exposure non-smoker male, Group II – High exposure smoker male, Group III – High exposure non-smoker female, Group IV – Low exposure non-smoker male, Group V – Low exposure smoker male, Group VI – Low exposure non-smoker female.

Discussion

The present study shows that the FVC and FEV1 (mean ± SD) are significantly lower in high exposure group in comparison to low exposure group ($P < 0.05$,CI 95%) which indicates the adverse effects of ambient air pollution on lung function. The similar findings were reported in the study done by Panis *et al*.[23] which showed negative association between FEV and FEV1 and variation in ambient air pollution but no association with FEV1/FVC ratio. The similar finding reported in the present study which showed no significant difference of FEV1/FVC ration between high exposure and low exposure group among non-smoker group and female group. The similar findings were reported by Rice *et al*.[26] and Baccarelli *et al*.[27] However, in the present study, there was a significant difference of FVC, FEV1, and FEV1/FVC all three spirometry parameters between high exposure and low exposure group among smokers, which indicates additive effects of ambient air pollution on smoking and causing decline in both FVC as well as FEV1. The decline in both FVC as well as FEV1 has been proved in other studies by Son *et al*.[28] which showed decline by 6.1% for FVC and 0.5% for FEV1 and this decline was associated with all types of pollutants. Wong *et al*.[29] found that ambient air pollution was negatively associated with decreased lung function in young males, contrary to females. Similar finding has been found in the present study which showed decline in FEV1/FVC between female non-smoker group III (high exposure) and VI (low exposure) is not significant.

FEF

$FEF_{25-75\%}$—FEF over the middle one half of the FVC; the average flow from the point at which 25% of the FVC has been exhaled to the point at which 75% of the FVC has been exhaled. The earliest change which is associated with airflow obstruction in small airways is thought to be a slowing in the terminal portion of the spirogram, even when the initial part of the spirogram is hardly affected.[30-32] This slowing of expiratory flow is reflected in mean expiratory flow between 25% and 75% of FVC than in FEV_1. However, abnormalities in these mid-range flow measurements during a forced exhalation are not specific for small airway disease in individual patients.[33] As airway disease becomes, more advanced and/or more central airways become involved, timed segments of the spirogram such as the FEV_1 will, in general, be reduced out of proportion to the reduction in VC.

Pellegrino *et al*.[34] summarized in "Interpretative strategies for lung function tests" that although FEF_{25-75} is considered to be reflection of more peripheral airways, the measurement of which is made at the lower end of flow-volume curve but there are many problems with the FEF_{25-75} as a measure of peripheral lung function. FEF_{25-75} always demonstrates a greater percent change than the FEV1. In addition, the predicted value of FEF_{25-75} is much more variable than those of FEV1 and serial measures are highly dependent on an unchanged FVC. In many longitudinal studies, there have been changes in the FVC which makes comparisons of the FEF_{25-75} problematic. Amarloei *et al*.[35] investigated the lung function of general population I Ilam West of Iran where dust storm is the most important natural source of air pollution The results also showed a negative significant relationship between duration of inhabitance in Ilam city and all respiratory capacities including FEF_{25-75}. Laeremans *et al*.[36] studied the effects of air pollution on lung function in relation to outdoor exercise. It was found that short-term lung function increases as a response to physical activity, but this beneficial effect is obtunded during elevated level of air pollution. Negative interaction effects of physical activity during the high level of black carbon exposure were found on lung function including FEF_{25-75}. In the present study, there was no significant difference of FEF (mean ± SD) between Subgroups I and II. There was a significant difference of FEF (mean ± SD, $P < 0.05$, 95% CI) between Subgroups II and V and III and VI.

PEFR

Al-Qerem *et al*.[37] studied the lung function of children 7–12 years old between rural and urban habitants. Their lung function was measured 5 times over the period of 2 years. Significant difference was found in the changes between two locations, the children from urban area showed smaller increase in lung function including PEFR. Amarloei *et al*.[38] also showed decline in PEFR among people of Ilam city (Iran) due to chronic exposure to dust storm. In the present study, there was no significant difference of PEFR (mean ± SD, $P < 0.05$, 95% CI) between Subgroups I and II and II and IV (all four non-smokers group). There was a significant difference of PEFR (mean ± SD, $P < 0.05$, 95% CI) between Subgroup II (smokers) and V (smokers), which indicates the additive effects of ambient air pollution on smoking, and probably ambient air pollution made the lungs more sensitive to adverse effects of smoking.

In the present study, there was a significant difference of PEFR (mean ± SD, $P < 0.05$, 95% CI) between Subgroups III

Table 4: Spirometry parameters absolute values (liters) Mean±SD of high exposure and low exposure group within the group

Spirometry parameters absolute values (liters) (Mean±SD)	*Sub-groups*					
	I	*II*	*III*	*IV*	*V*	*VI*
FVC (Observed): L/S	2.7872±0.57578	1.7872±0.50049	1.7413±0.70870	3.4354±0.75781	2.9137±0.68663	2.3248±0.61431
FVC (Predicted): L/S	3.9491±0.65502	3.7356±0.58280	2.8521±0.54618	3.8624±0.64184	3.7854±0.62755	2.9668±0.68634
P-value	0.000	0.000	0.000	0.000	0.000	0.000
FEV1 (Observed):L/S	2.1779±0.55393	1.0760±0.36947	1.3696±0.60136	2.7686±0.77926	2.1513±0.68062	1.8846±0.61199
FEV1 (Predicted):L/S	3.2369±0.60950	2.9872±0.54773	2.3651±0.58781	3.1698±0.63557	3.1040±0.59334	2.4480±0.63907
P-value	0.000	0.000	0.000	0.000	0.000	0.000
FEV1/FVC (Observed) %	77.874±9.9457	60.585±13.3546	78.050±14.1375	80.001±11.8272	72.739±11.1142	80.451±12.1746
FEV1/FVC (Predicted) %	81.690±3.7207	79.742±5.4006	82.027±6.886	81.903±7.2154	81.720±4.4594	82.117±6.8453
P-value	0.000	0.000	0.000	0.086	0.000	0.345
PEFR (Observed): L/S	34.42473±171.5177	113.4328±102.33978	108.8215±128.21626	238.7425±197.78405	210.2823±178.58851	5.0222±1.73335
PEFR (Predicted): L/S	360.0410±219.3159	322.9893±220.87979	161.4549±173.02335	302.94522±226.4010	318.6502±223.27058	5.3504±1.66739
P-value	0.000	0.000	0.000	0.000	0.000	0.164
FEF (Observed): L/S	2.8610±5.7847	0.9232±0.56990	1.6174±0.88095	3.3199±10.47124	1.9563±0.72702	2.2906±1.00585
FEF (Predicted): L/S	3.4467±1.0712	2.9660±1.17981	2.7985±2.75113	3.5457±0.89970	3.1671±1.10232	2.5572±1.19529
P-value	0.247	0.000	0.005	0.797	0.000	0.090

*Group I – High exposure non-smoker male, Group II – High exposure smoker male, Group III – High exposure non-smoker female, Group IV – Low exposure non-smoker male, Group V – Low exposure smoker male, Group VI – Low exposure non-smoker female.

(non-smokers high exposure female) and VI (non-smokers low exposure female). Although non-smokers group, it indicates the adverse effects of ambient air pollution on small airways among female leading to decline in small airways parameters (PEFR and FEF), it signifies that the small airways may be more sensitive to adverse effects of ambient air pollution among female population.

FEV1, FVC, and FEV1/FVC

Long-term exposure to air pollution has also been previously shown in majority, but not all, studies to adversely affect lung function. In the present study, subjects from our cohort of high exposure non-smoker (Group I), high exposure smoker (Group II), high exposure female (Group III), and low exposure smoker (Group-IV) demonstrated a mixed pattern of lung function decline with decline in FVC and FEV1 as well as FEV1/FVC. Liu *et al*.[39] conducted a cross-sectional study in Southern Chinas in which seven clusters were randomly selected from four cities across Guangdong province and found decline in FVC, FEV1, and FEV1/FVC due to chronic exposure to PM10 and PM2.5. Guo *et al*.[40] conducted a study and found that every 5 $\mu g/m^3$ increment in PM2·5 was associated with a decrease of 1·18% for FVC, 1·46% for FEV1, 1·65% for maximum mid-expiratory flow (MMEF), and 0·21% for FEV1:FVC ratio. The decrease accelerated over time. Additional annual declines were observed for FVC (0·14%), FEV1 (0·24%), MMEF (0·44%), and FEV1:FVC ratio (0·09%). Doiron *et al*.,[41] Lin *et al*.,[42] Adam *et al*.,[11] and Ackermann-Liebrich *et al*.[16] similarly described decline in FVC, FEV1, and FEV1/FVC due to chronic exposure to ambient air pollution. In contrast to the present study and other studies mentioned above, Elbarbary *et al*.[43] found decline in FEV1 and FEV1/FVC but not in FVC due to chronic exposure to ambient air pollution.

Conclusion

There is an objective evidence of adverse effects of ambient air pollution on lung function leading to decrease in lung function in high exposure participants in comparison to low exposure group with high prevalence of restrictive defects and mixed defects in spirometry.

Among non-smoker groups: There was a significant ($P < 0.05$, 95% CI) high absolute value (mean ± SD) of FVC and FEV1 in high exposure group in comparison to low exposure group but not significant difference of FEV1/FVC, PEF, and FEF between high and low exposure group. There was a significant ($P < 0.05$, 95% CI) higher prevalence of restrictive pattern in high exposure group normal pattern in low exposure group.

Among smokers groups: There was a significant ($P < 0.05$, 95% CI) high absolute value (mean ± SD) of FVC, FEV1, FEV1/FVC, PEF, and FEF in high exposure group in comparison to low exposure group. There was a significant ($P < 0.05$, 95% CI) higher prevalence of mixed pattern in high exposure group normal pattern in low exposure group.

Among female groups: There was a significant ($P < 0.05$, 95% CI) high absolute value (mean ± SD) of FVC, FEV1, PEF, and FEF but not FEV1/FVC in high exposure group in comparison to low exposure group. There was a significant ($P < 0.05$, 95% CI) higher prevalence of mixed pattern in high exposure group and normal pattern in low exposure group.

Limitations and Strength of the Study

This study has some limitations. First, analyses are limited by the cross-sectional study design and longitudinal effects of ambient air pollution are not evaluated. Second, differential physical activity patterns, changes in participant residence environment, and indoor housing structure having different level of indoor pollution may have contribution to the air pollution exposure level. These limitations are offset by some important strength. The results of the present study are based on representative populations of adults from Delhi and NCR having high level of AQI where the level of pollution is in the moderate-to-severe category almost through the years. Whereas the most previously published work has been focused on the general population not specific any particular vulnerable population, but this study has taken into consideration the most vulnerable population due to nature of their occupation. In addition, we were able to adjust for many important confounders.

Ethical Clearance

Ethical clearance taken from the Institutional Ethical Committee.

References

1. Urban Air Pollution, Catching Gasoline and Diesel Adulteration. United States: The World Bank. 2002.
2. Ambient (Outdoor) Air Pollution in Cities Database; 2014. Available from: https://www.who.int/phe/health_topics/outdoor air/databases/cities/en. [Last accessed on 2020 May 31].
3. Harris G. Delhi Wakes Up to an Air Pollution Problem It Cannot Ignore. The New York Times. Available from: https://www.nytimes.com/2015/02/15/world/asia/delhi-wakes-up-to-an-air-pollution-problem-it-cannot-ignore.html [Last accessed on 2020 May 30].
4. Badarinath KV, Kharol SK, Sharma AR. Long-range transport of aerosols from agriculture crop residue burning in Indo-Gangetic plains-a study using LIDAR, ground measurements and satellite data. J Atmospheric Solar Terrestrial Phys 2009;71:112-20.
5. Agricultural Fires in India NASA. United States: NASA; 2012.
6. Weinhold B. Fields and Forests in Flames: Vegetation Smoke and Human Health. United States: National Institutes of Health; 2021.
7. Co_2 Emissions from Fuel Combustion Highlights. France: International Energy Agency; 2011.
8. Indians have 30% Weaker Lungs than Europeans. India: Times of India; 2013.
9. Burke J. India's Doctors Blame Air Pollution for Sharp Rise in Respiratory Diseases. India: The Guardian; 2015.
10. Madhok M. Here is Why India has no Clue how Bad its Air Pollution Problem is. India: Quartz India; 2015.
11. Adam M, Schikowski T, Carsin AE, Cai Y, Jacquemin B, Sanchez M, *et al.* Adult lung function and long-term air pollution exposure. ESCAPE: A multicentre cohort study and meta-analysis. Eur Respir J 2015;45:38-50.
12. Sunyer J. Lung function effects of chronic exposure to air pollution. Thorax 2009;64:645-6.
13. Anderson JO, Thundiyil JG, Stolbach A. Clearing the air: A review of the effects of particulate matter air pollution on human health. J Med Toxicol 2012;8:166-75.
14. Gehring U, Gruzieva O, Agius RM, Beelen R, Custovic A, Cyrys J, *et al.* Air pollution exposure and lung function in children: The ESCAPE project. Environ Health Perspect 2013;121:1357-64.
15. Forbes LJ, Kapetanakis V, Rudnicka AR, Cook DG, Bush T, Stedman JR, *et al.* Chronic exposure to outdoor air pollution and lung function in adults. Thorax 2009;64:657-63.
16. Ackermann-Liebrich U, Leuenberger P, Schwartz J, Schindler C, Monn C, Bolognini G, *et al.* Lung function and long term exposure to air pollutants in Switzerland. Study on air pollution and lung diseases in adults (SAPALDIA) team. Am J Respir Crit Care Med 1997;155:122-9.
17. Götschi T, Heinrich J, Sunyer J, Künzli N. Long-term effects of ambient air pollution on lung function: A review. Epidemiology 2008;19:690-701.
18. Schikowski T, Sugiri D, Ranft U, Gehring U, Heinrich J, Wichmann HE, *et al.* Long-term air pollution exposure and living close to busy roads are associated with COPD in women. Respir Res 2005;6:152.
19. Downs SH, Schindler C, Liu LJ, Keidel D, Bayer-Oglesby L, Brutsche MH, *et al.* Reduced exposure to PM10 and attenuated age-related decline in lung function. N Engl J Med 2007;357:2338-47.
20. Eckel SP, Louis TA, Chaves PH, Fried LP, Margolis AH. Modification of the association between ambient air pollution and lung function by frailty status among older adults in the Cardiovascular Health Study. Am J Epidemiol 2012;176:214-23.
21. Binawara BK, Gahlot S, Kamlesh C, Mathur A, Kakwar R. Pulmonary function tests in three wheeler diesel taxi drivers in Bikaner city. Pak J Physiol 2010;6.
22. Madhuri BA. A study on pulmonary function test in petrolpump workers in kanchepuram population. Int J Biol Med Res 2012;3:1712-4.
23. Int Panis L, Provost EB, Cox B, Louwies T, Laeremans M, Standaert A, *et al.* Short-term air pollution exposure decreases lung function: A repeated measures study in healthy adults. Environ Health 2017;16:60.
24. Nautiyal J 3rd, Garg ML, Kumar MS, Khan AA, Thakur JS, Kumar R. Air pollution and cardiovascular health in Mandi-Gobindgarh, Punjab, India-a pilot study. Int J Environ Res Public Health 2007;4:268-82.
25. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, *et al.* Series "ATS/ERS task force: Standardisation of lung function testing. Eur Respir J 2005;26:319-38.
26. Rice MB, Ljungman PL, Wilker EH, Dorans KS, Gold DR, Schwartz J, *et al.* Long-term exposure to traffic emissions and fine particulate matter and lung function decline in the Framingham heart study. Am J Respir Crit Care Med 2015;191:656-64.
27. Baccarelli AA, Zheng Y, Zhang X, Chang D, Liu L, Wolf KR, *et al.* Air pollution exposure and lung function in highly exposed subjects in Beijing, China: A repeated-measure study. Part Fibre Toxicol 2014;11:51.
28. Son JY, Bell ML, Lee JT. Individual exposure to air pollution and lung function in Korea: Spatial analysis using multiple exposure approaches. Environ Res 2010;110:739-49.
29. Wong SL, Coates AL, To T. Exposure to industrial air pollutant emissions and lung function in children: Canadian Health Measures Survey, 2007 to 2011. Health Rep 2016;27:3-9.
30. Bates DV. Respiratory Function in Disease. 3rd ed. Philadelphia, PA: WB Saunders; 1989.
31. Wilson AF. Pulmonary Function Testing, Indications and Interpretations. Orlando: Grune & Stratton; 1985.
32. Pride NB, Macklem PT. Lung mechanics in disease. In: Macklem PT, Mead J, editors. Handbook of Physiology. The Respiratory System. Mechanics of Breathing. Section 3, Vol. 3, Part 2. Bethesda: American Physiological Society; 1986. p. 659-92.
33. Flenley DC. Chronic obstructive pulmonary disease. Dis Mon 1988;34:537-99.
34. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, *et al.* Interpretative strategies for lung function tests. Eur Respir J 2005;26:948-68.
35. Amarloei A, Jonidi Jafari A, Mahabadi HA, Asadollahi K, Nourmoradi H. Investigation on the lung function of general population in Ilam, west of Iran, as a city exposed to dust storm. Glob J Health Sci 2015;7:298-308.
36. Laeremans M, Dons E, Avila-Palencia I, Carrasco-Turigas G, Orjuela-Mendoza JP, Anaya-Boig E, *et al.* Lack carbon reduces the beneficial effects of physical activity on lung function. Med Sci Sports Exerc 2018;50:1875-81.

37. Al-Qerem W, Ling J. Pulmonary function tests in Egyptian schoolchildren in rural and urban areas. East Mediterr Health J 2018;24:325-32.
38. Amarloei A, Jafari AJ, Mahabadi HA, Asadollahi K, Nourmoradi H. Investigation on the lung function of general population in Ilam, west of Iran, as a city exposed to dust storm. Glob J Health Sci 2015;7:298-308.
39. Liu S, Zhou Y, Liu S, Chen X, Zou W, Zhao D, *et al.* Association between exposure to ambient particulate matter and chronic obstructive pulmonary disease: Results from a cross-sectionalstudy in China. Thorax 2017;72:788-95.
40. Guo C, Zhang Z, Lau AKH, Lin CQ, Chuang YC, Chan J, *et al.* Effect of long-term exposure to fine particulate matter on lung function decline and risk of chronic obstructive pulmonary disease in Taiwan: A longitudinal, cohort study. Lancet Planet Health 2018;2:e114-25.
41. Doiron D, de Hoogh K, Probst-Hensch N, Fortier I, Cai Y, De Matteis S, *et al*. Air pollution, lung function and COPD: Results from the population-based UK Biobank study. Eur Respir J 2019;54:1802140.
42. Lin H, Guo Y, Di Q, Zheng Y, Xian H, Li X, *et al.* Consumption of fruit and vegetables might mitigate the adverse effects of ambient $PM_{2.5}$ on lung function among adults. Environ Res 2018;160:77-82.
43. Elbarbary M, Oganesyan A, Honda T, Kelly P, Zhang Y, Guo Y, *et al.* Ambient air pollution, lung function and COPD: Cross-sectional analysis from the WHO Study of AGEing and adult health wave 1. BMJ Open Respir Res 2020;7:e000684.