Original Article

A Comparative Study of the Effect of Ambient Air Pollution on Ventilatory Function Tests in Urban and Rural Population

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Abstract

Background and Aim: The particulate matter (PM10) is considered as the criteria parameter for assessing the quality of air that we respire as it is known to produce a significant impairment in ventilatory functions leading to respiratory diseases including bronchial asthma and chronic obstructive pulmonary disease. The aim of this study was to compare the lung function status in an urban population residing in an area with high ambient air pollutant with rural population with minimal concentration of air pollutant in their working environment. **Methods:** A cross sectional study was conducted with 144 exposed subjects and 148 control subjects. A computerised spirometer was used to assess the ventilatory function parameters. Ventilatory parameters like FVC, FEV1, FEV1/FVC, PEFR, FEF25, FEF50, FEF75, MVV was taken into consideration for the preset study which was also analysed with respect to the control and study group as well as with respect to the age group of the study subjects. Monitoring the concentration of the ambient air pollutants was done by the air monitoring stations of the Karnataka state pollution control board. Statistical analysis was done using SPSS package. **Results:** There was no significant differences in the anthropometric parameters of both study and control group. The results showed that the ventilatory function test of the urban study group was markedly declined when compared with the control group which was statistically significant. It was also found that the mean values of parameters like FVC, FEV1, PFF, FEV1/FVC%, FEF25-75%, V max 25%, 50%, 75% was statistically different in <30 years and >30 years among study and control group.**Conclusion:** Considering the fact that all the subjects participated in the study are from the same ethnic origin, residing at same altitude and non smokers, the significant reduction in the lung function parameters in the exposed group could be only due to the their exposure to the air pollutants.

Keywords: Bronchial asthma, chronic obstructive pulmonary disease, particulate matter, ventilatory functions

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Introduction

Air pollution is a major environmental health problem affecting the developing and developed countries alike. Exposure to air pollutants is known to be harmful to health in general and to lung in particular. In urban areas, road traffic produces volatile organic compounds, suspended particulate matter (SPM), oxides of sulfur, oxides of nitrogen (NOx), and carbon monoxide, which makes adverse health effects on the exposed population. The particles emitted from the vehicular exhaust of >10 μ size are held in upper respiratory tract, and particles <10 μ size (PM10) accumulate in the lung and produce respiratory abnormalities. Hence, PM10 are of great concern in air pollution studies.[1]

A large body of epidemiological evidence has shown adverse effects of ambient air pollution on human health which include headache, nausea, and lung function changes.[2-5] The long-term effects of ambient air pollution on lung function have been investigated in many cross-sectional and some cohort studies which are found to be detrimental in terms of lung function.[6,7]

Bengaluru is one of the rapidly growing cities of India which was ranked 63rd among 168 cities for PM 2.5 levels in 2015–2016 by a report – titled "Airpocalypse" – on air quality. Karnataka State Pollution Control Board (KSPCB) during 2015–2016 shows that PM10 levels in Bengaluru were higher than the average of 60 μg/m^3 prescribed under the National Ambient Air Quality Standards.

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Effect of air pollution on the pulmonary function parameters has been well documented both nationally and internationally. However, this study examined the differences in the levels of pulmonary function parameters with respect to age-wise comparison of mean values of height, weight, and ventilatory parameters of adults from two regions of Bengaluru with differing degrees of air pollution declared by KSPCB.

Materials and Methods

This study was conducted at the Department of Physiology, Bangalore Medical College. The individuals who participated in this study gave an informed consent after a detailed procedure of this noninvasive investigation was explained to them. The participants included are normal, healthy nonsmoking hardworking male laborers. They are divided into two groups. Study group and control group on the basis of their exposure to the concentrations of ambient air pollutants in their respective working environments.

The study group includes coolies and shopworkers from KR market area in Bengaluru city. They are exposed to high concentrations of ambient air pollutants in their working environment and they give a history of working in that environment for 8–10 h a day for a period of not <10 years. The control group includes mostly farmers from rural areas of Bengaluru who are exposed to concentrations of ambient air pollutants in their working environment for 8–10 h a day for a period of not <10 years. A total number of 144 study participants and 148 controls participated in this study.

Inclusion criteria

- Healthy male individual of South Indian origin
- Age group of 20–60 years
- Nonsmoker
- Free from any respiratory tract infections for at least 3 months.

Exclusion criteria

- Past or present history of any respiratory diseases such as tuberculosis or chronic obstructive pulmonary disease (COPD)
- Smoker
- Any forms of thoracic cage deformities, spinal cord deformities.

After filling up the questionnaire which included their sociodemographic details, the participants were medically examined. Ventilatory function tests were done on empty stomach, preferably in the morning to get the optimal results. Each participant is given a detailed instruction and demonstration of the method of performing forced vital capacity (FVC) maneuver. The computerized spirometer named Kit Micro Spirometer manufactured by COSMED S.R.I Rome, Italy, was used for the test. A minimum of three to five repetitions are allowed, and the tests with the maximum values are selected as the best tests.

Monitoring the concentration of the ambient air pollutants present in the study and control area is done by the air monitoring station of the KSPCB using APM451 respirable dust sampler from Envirotechs and APM 411 - gaseous sampling attachment developed at NEERI Nagpur, CSIR laboratory. Monitoring of the various pollutants is done every 24 h with 8 h sampling. Modified Jacob and Hochheiser method was used to measure nitrogen dioxides; West and Gaeke method was used to measure sulfur dioxide.

Statistical analysis

Mean and standard deviation (SD) values of the ventilator function test in the study and control group were calculated separately. Mean difference was tested using *t*-test. The Chi-square test was applied to find out the significant correlation of a particular parameter between the study and control group. Data were analyzed using statistical package for social sciences (SPSS) version 17, USA.

Results

Age distribution

The age of the study group ranged from a minimum of 20 years to a maximum of 55 years with a mean age of 31.03 years. The age of the control group ranged from a minimum of 20 years to a maximum of 57 years with a mean age of 29.96 years. There was no statistical difference between the study group and the control group with regard to age [$P > 0.05$, Table 1].

Anthropometric data

The height of the study group varied from a minimum of 148 to 179 cm with a mean of 168.42 and of the control group varied from a minimum of 155 cm to a maximum of 187 cm with a mean of 167.64 cm. The mean weight of the study group was 58.52 kg and that of the control group was 57.16 kg. There were no statistical difference between the study and control group with respect to the weight [$P > 0.05$, Table 1].

Ventilatory parameters

The mean and SD of all the ventilator parameters (FVC, forced expiratory volume in 1 s [FEV1], peak expiratory

Table 1: Comparison of the mean values of age, height, and weight between study and control group

Group	Mean	SD	*t*	*P*
Age (years)				
Study 144	31.03	8.28	−1.17	>0.05
Control 148	29.96	7.9		
Height (cm)				
Study 144	168.4	5.98	−1.05	>0.05
Control 148	167.6	6.91		
Weight (kg)				
Study 144	58.52	6.51	−1.71	>0.05
Control 148	57.16	7.06		

$P < 0.05$ was considered significant. SD: Standard deviation flow [PEF], FEV1/FVC%, forced expiratory flow (FEF 25%–75%), Vmax 25%, 50%, 75%) are shown in Table 2. It was seen that all the ventilator parameters showed significant difference between the study and control group [$P < 0.001$, Table 2].

The mean and SD values of the ventilator parameters in different age groups among study and control group are shown in Table 2. The age group division among the study and control group was done with 5 years difference starting with 25 years and ending with above 46 years. Even though we could find significant difference in some ventilator parameters, parameters such as FEV1, FEV1%/FVC, FEF 25%–75%, Vmax 25%, Vmax 50%, and Vmax 75% showed significant difference between the study and control group in all the age groups [$P < 0.05$, Table 3].

The monthly maximum and the monthly average of various pollutants that taint the ambient air of the study area for a period of 6 months are given in Table 4, while only the monthly average of the corresponding pollutants present in the ambient air of the control area for the same period of 6 months are shown in Table 4. The permissible limits for SO2, NOx, SPM, and RPM were 30, 30, 100, and 75 μg/m^3, respectively. It is very evident that the concentration of these air pollutants was much higher than the permissible limits in the study area [Table 4] and the concentration was less when compared with the permissible limits in the control area [Table 5].

Discussion

Rising levels of ambient air pollutants in cities have been attributed to increased rates of mortality and morbidity in the developed and developing countries.

Numerous studies undertaken by many workers have related the increase in health morbidity in urban populations to the prevailing ambient air pollutant levels, while their rural counterparts who breathe air devoid of pollutants enjoyed a far better health status. The ventilatory function tests were significantly lowered in the urban populations when compared to those of their rural counterparts.

The earliest work was done by Ferris *et al*.[8] in the USA. He demonstrated that a long-term exposure to SO_2 present in the urban ambient air beyond 35 μg/day contributed to a significant decrement in the results of the ventilatory function tests of the urban populations when compared to those of their rural counterparts. However, morbidity status remained the same in both urban and rural populations except for the smokers.

Among the Indian studies, Kamat *et al*.[9] have found that the prevalence of health morbidity was higher in the urban participants of Bombay, when compared to their rural counterparts. Respiratory morbidity was higher in those areas where SO_2 and SPM levels in the ambient air were high and cardiac morbidity was higher in those areas where NOx and SPM levels in the ambient air were high. Results of the ventilator function tests such as PEF and maximum expiratory flow rate were higher in the rural participants when compared with the urban counterparts.

Independent studies like those of Vijayan *et al*.[10] on normal healthy nonsmoking individuals from the city of Madras, have a higher values for small airways ventilator parameters when compared to those of their counterparts from the Bombay city as recorded by Udwadia *et al*.[11] This decrement in values of small airways ventilator parameters was attributed to the effects of ambient air pollutants which are higher in Bombay city when compared to the Madras City.

Gupta *et al*.[12] in their study found a significant decrement in the results of the ventilator functions tests such as FEV1

Table 2: Comparison of the mean values of ventilatory parameters between study and control group

Parameters	Group	Mean	SD	Range (maximum-minimum)	*t*	*P*
FVC	Study	3.62	0.59	6.19-2.39	4.01	<0.001
	Control	3.88	0.51	5.49-2.58		
FEV1	Study	2.78	0.44	3.81-1.78	10.11	<0.001
	Control	3.3	0.43	4.64-2.38		
PEF	Study	7.56	1.55	10.89-3.48	9.4	<0.001
	Control	9.11	1.26	12.74-6.16		
FEV1/FVC × 100	Study	77.26	7.1	94.8-56.4	11.55	<0.001
	Control	85.23	4.33	95.5-73.7		
FEF 25%-75%	Study	2.49	0.67	3.94-0.97	19.5	<0.001
	Control	4.28	0.88	6.33-2.30		
Vmax 25%	Study	5.49	1.44	8.82-2.63	13.93	<0.001
	Control	7.63	1.17	10.47-4.46		
Vmax 50%	Study	2.97	0.8	4.82-1.33	18.06	<0.001
	Control	4.83	0.96	7.30-2.67		
Vmax 75%	Study	1.1	0.39	2.31-0.34	16.84	<0.001
	Control	2.07	0.57	3.90-0.96		

PEF: Peak expiratory flow, FVC: Forced vital capacity, FEV1: Forced expiratory volume in 1 s, FEF: Forced expiratory flow, SD: Standard deviation. $P < 0.05$ was considered significant

Table 3: Ventilatory parameters under various age groups

Age	Group	Height	Weight	FVC	FEV1	PEF	FEV1/FVC × 100	FEF 25%-75%	Vmax		
									25%	50%	75%
20-25	Study										
	Mean	167.02	55.80	3.80	2.99	7.63	79.36	2.82	5.80	3.27	1.13
	SD	6.65	6.75	0.68	0.41	1.68	6.57	0.59	1.55	0.72	0.33
	Control										
	Mean	166.12	54.18	4.01	3.50	9.32	87.61	4.56	7.94	5.06	2.32
	SD	7.92	5.15	0.60	0.46	1.34	3.95	0.65	1.17	0.71	0.39
	t	−0.589	−1.254	1.546	5.646	5.153	7	13.38	7.281	11.84	13.3
	P	>0.05	>0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
26-30	Study										
	Mean	168.94	58.78	3.69	2.84	7.43	77.24	2.56	5.48	3.30	1.14
	SD	5.95	5.95	0.55	0.44	1.71	6.85	0.67	1.41	0.78	0.42
	Control										
	Mean	168.14	56.86	3.97	3.38	9.26	85.18	4.51	7.81	5.08	2.24
	SD	6.09	6.60	0.41	0.34	1.17	3.87	0.93	1.09	1.02	0.61
	t	−0.688	−1.545	2.964	6.938	12.123	7.327	12.123	9.437	11.37	10.687
	P	>0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
31-35	Study										
	Mean	170.38	59.38	3.45	2.65	7.64	77.02	2.17	5.13	2.61	0.88
	SD	5.46	6.70	0.44	0.39	1.20	6.31	0.56	1.24	0.76	0.24
	Control										
	Mean	167.35	60.47	3,82	3.21	9.08	84.83	4.16	7.44	4.65	1.87
	SD	7.42	8.64	0.38	0.28	1.26	3.99	0.66	0.97	0.68	0.48
	t	−1.338	0.408	2.539	4.684	3.895	9.347	3.36	5.953	8.152	7.556
	P	>0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
36-40	Study										
	Mean	166.91	58.55	3.37	2.48	7.58	73.81	2.05	5.17	2.44	0.90
	SD	5.11	7.75	0.58	0.42	1.12	5.15	0.65	1.37	0.67	0.37
	Control										
	Mean	168.927	60.58	3.58	2.97	8.18	83.27	3.92	6.71	4.66	1.66
	SD	7.45	8.18	0.43	0.30	0.76	5.28	1.11	1.14	1.42	0.34
	t	0.759	0.613	0.991	3.164	1.469	4.35	4.981	2.924	4.869	5.057
	P	>0.05	>0.05	>0.05	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05
41-45	Study										
	Mean	168.70	63.00	3.34	2.62	7.97	77.03	2.36	5.78	3.06	1.02
	SD	5.62	3.53	0.56	0.39	1.48	6.17	0.51	1.04	0.78	0.30
	Control										
	Mean	170.924	59.69	3.60	2.93	9.22	81.45	3.18	7.25	3.80	1.38
	SD	4.27	6.94	4.5	0.35	1.33	2025	0.52	1.30	0.66	0.40
	t	1.509	−1.486	0.755	1.927	2.095	2.159	3.784	2.571	2.422	2.471
	P	>0.05	>0.05	>0.05	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05
46+	Study										
	Mean	170.00	61.31	2.45	2.45	7.40	74.19	2.07	5.08	2.58	0.85
	SD	5.02	5.84	0.29	0.29	1.35	10.84	0.62	1.54	0.95	0.32
	Control										
	Mean	167.29	62.00	2.80	2.80	8.09	81.42	3.54	6.88	4.11	1.48
	SD	5.32	8.29	0.24	0.24	0.92	2.00	0.42	0.86	0.44	0.24
	t	−1.106	0.196	2.855	2.855	1.338	2.334	6.313	3.354	4.907	4.897
	P	>0.05	>0.05	>0.055	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05	<0.05

PEF: Peak expiratory flow, FVC: Forced vital capacity, FEV1: Forced expiratory volume in 1 s, FEF: Forced expiratory flow, SD: Standard deviation

and FEF 25%–75% of the traffic policemen exposed to high concentration of ambient air pollutants when compared to their controls. Decrement in the results of FEF 25%–75% is an indication of the early onset of small airway obstruction.

In this present cross-sectional study, the extent of damage ambient air pollution has done to the airways is estimated by comparing the results of the ventilator functions tests of the urban populations with those of the rural populations.

Table 4: Ambient air pollutant concentration at study area

Month	SO_2		Nox		SPM		RPM	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
November	34.8	31.6	58	54.2	571	360	336	188
December	40.3	37.2	46.2	44.2	651	361	194	123
January	56.1	51.3	55.7	51.6	421	304	203	103
February	41.2	37.5	40.8	40.4	426	262	260	98
March	55.2	53.5	31	29.2	272	217	173	83
April	38	31	53	51	172	172	44	44

SPM: Suspended particulate matter, RPM: Respirable particulate matter, Nox: Oxides of nitrogen

Table 5: Ambient air pollutant concentration at control area

Month	SO_2		Nox		SPM		RPM	
	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
November	microgm/m3	5	-	5	-	80	-	60
December	-	4	-	4	-	50	-	40
January	-	5	-	5	-	60	-	50
February	-	3	-	3	-	60	-	60
March	-	3	-	3	-	50	-	40
April	-	2	-	2	-	50	-	30

SPM: Suspended particulate matter, RPM: Respirable particulate matter, Nox: Oxides of nitrogen

By comparing the results of the ventilatory functions tests between the study group and the control group, a statistically significant difference is seen in all the ventilator parameters. There is a considerable decline in the results of the ventilator function tests of the study group when compared to those of the control group. This decline could be attributed to the damaging effects of ambient air pollutants present in a high concentration in the study area often exceeding the normal permissible limits.

According to Woolcock *et al*.,[13] the factors that affect the normal values for ventilator lung functions are ethnic variation, physical activity, altitude of dwelling, environmental conditions, and tobacco smoking. In our study, both the groups included participants from the same ethnic South Indian origin, undergoing strenuous physical activity, residing at the same altitude besides being nonsmokers but differing only in the environmental exposure to varying concentration of ambient air pollutants. This difference in exposure to varying concentration of ambient air pollutants is the only factor, which may be responsible for the decline in the results of ventilator functions tests of the study group.

Among the ambient air pollutants, the reparable fraction of the particulate matter (PM10) and sulfur dioxide are the most dangerous to the respiratory system. Both of them derived from common sources. These are very dangerous to the respiratory tract, as being very small and in the reparable range; they can reach deep inside the tracheobronchial tree on respiration leads to the bronchoconstrictor response of the small airways. Bronchoconstriction in small airways is reflected by a sharp decline in the results of the ventilatory functions tests such as FEF 25%–75% and Vmax 75% of the study group on comparison with those from the control group. This establishes an early onset of small airways dysfunction.

On analyzing the results of the ventilator parameters age wise, by dividing them into groups of 5 years each, in an ascending order, it was seen that the values are higher in the younger age groups and decline progressively with increasing age in the control group. This is in conformity with other studies such as Udwadia *et al*., Singh, and OmPrakash.[11,14-16] However, in the study group, such a decline is rapid and often inconsistent which can be attributed to the damaging effects of high concentrations of ambient air pollutants resulting in premature aging of lungs in individuals from the study area.

After 30 years, ventilator parameters decline significantly with increasing age even in normal healthy nonsmoking individuals as shown by the works of Udwadia *et al*. and Singh.[11,15,16] This is attributed to the loss of elastic recoil tendency of the lungs with increasing age. Taking 30 years as the cutoff point, for comparing the ventilator parameters in both the study group and the control group participants above 30 years of age, it is seen that there is a considerable decline in the results of FEV1/FVC% than FEF 25%–75% in the study group when compared to those from the control group thereby confirming that FEV1/FVC% is indeed a more sensitive indicator than FEF 25%–75% in the detection of early onset of small airway dysfunction.

In children, PEF values are more sensitive to changes in particulate concentration in the ambient air when compared to adults. Studies in children have shown that a 10 µg per cubic millimeter increase in PM was associated with a 2.7% increase in the prevalence of PEF decrements > 10% which is attributed to the onset of COPD. Venn *et al*.[17]

in their study have found that among the children, most affected are those who live within 150 meters of a main road because this is the distance within which the concentrations of primary vehicle traffic pollutants are raised above the ambient background levels. Primary school children are more affected than secondary school children who were shown in this study.

Limitations of the study

Urbanization appears to play a role in the prevalence of asthma. Lin *et al*.[18] in their study from Taiwan report that adolescent asthma is most prevalent in urbanized areas. In Bengaluru city, incidence of asthma is on an increase following rapid urbanization. According to Parmesh and Cherian,[19] it was only 9% of the child population in the 80s and raised to 30% in the next 20 years which shows that every year, there is an increase of 1%–2% in the incidence of asthma in Bengaluru city.

Conclusion

With rapid industrialization and urbanization of the developing countries, ambient air pollution is on an increase especially in the metropolitan cities. This is responsible for an increase in the prevalence of the mortality and morbidity status in the urban populations. Ambient air pollution episodes affect children and elderly individuals to a great extent thereby endangering the public health of exposed populations. This calls for an enactment of new legislations similar to the "Clean Air Act" which was brought about a tremendous change in the health status of the London population, besides proper enforcement of the existing laws. In addition, people should be made aware of the dangerous consequences of ambient air pollution and should be motivated to prevent its occurrence in all stages.

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Conflicts of interest

There are no conflicts of interest.

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