

Original Research Article

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Air pollution and its association with respiratory dysfunction among healthy adolescents: a cross sectional study from South Western Punjab, India

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ABSTRACT

Background: This study has been performed to compare the pulmonary functions of healthy adolescents studying in schools situated in highly polluted areas with those studying in schools of low polluted areas of south western Punjab.

Methods: This study was conducted in various schools located at Faridkot and Bathinda city. These places had been identified by the Punjab Pollution Control Board (PPCB) as having low and high air pollution levels respectively. Study Population divided into two groups that is Group A: 300 children from schools situated in Bathinda city. Group B: 301 children from schools situated in Faridkot city. Spiro Excel spirometer was used, and following parameters were obtained: FVC, FEV₁, FEV₁% (relation of FEV₁ to FVC), PEFR, FEF_{25-75%}.

Results: FVC was low in males and females in the high polluted group as compared in the low polluted group ($p = 0.042$; significant; males) ($p = 0.039$; significant; females). FEV₁ was low in males and females in high polluted group as compared in low polluted group ($p = 0.003$; significant; males) ($p = 0.026$; significant; females). In this study only, males showed a significant fall in mean percentage of FEF_{25-75%}. PEFR was low in males in high polluted group as compared to that in low polluted group ($p = 0.007$; significant) while in females it was insignificant.

Conclusions: It is concluded that in South Western Punjab, air pollution has detrimental effect on pulmonary functions (FVC, FEV₁, FEV₁%, FEF_{25-75%} and PEFR) in healthy adolescents.

Keywords: FVC, FEV₁, FEV₁%, FEF_{25-75%}, PEFR, Pulmonary function

INTRODUCTION

The modern era of industrialization and heavy vehicular traffic has left a legacy of widespread, often poorly controlled pollution which has adverse implications on health. The respiratory system is a direct target for the adverse effects of air pollution. Children seem to be affected more than the adults as lungs are in growing stage, lung clearing mechanisms are not well developed and immune mechanisms are not well established. This fact assumes significance as it may hinder attainment of

mature lung functions which may be associated with serious repercussions in adult life. Repeated and chronic exposure to air pollutants may lead to long term cumulative lung damage.¹ Scientific understanding of the spectrum of health effects of air pollution is constantly increasing and there are numerous reports of adverse health effects from air pollution at levels previously considered safe.

Recent studies have found links between air pollution and preterm births, infant mortality, deficits in lung growth

and possibly, development of asthma.² Children and infants are among the most susceptible. Children living in communities with higher levels of ambient air pollution tend to have lower average lung function.³ Although these deficits are small, yet even small deficits in lung function growth over childhood can accumulate into substantial deficits in maximum attained lung function at maturity in the 20's, thus reducing pulmonary reserve capacity and placing individuals at elevated risk of clinical respiratory impairment later in adult life. Air pollution acting on pregnant women could affect fetal development contributing to a variety of undesirable reproductive outcomes such as preterm delivery, birth defects or low birth weight.^{4,5}

Air pollutants can damage blood vessels and increase risks of cardiovascular complications. Recent studies have indicated that exposure to ultrafine particles in school children alters micro RNA-222 expression in the extracellular fraction of saliva and these micro RNAs have been linked with initiation and progression of atherosclerosis via endothelial dysfunction and inflammation. Air pollution is ubiquitous and ultrafine particles (<100 nm) translocate from lung into the system and may contribute to adverse cardiovascular effects.⁶

There are some studies in India on this topic but data from pollution monitoring centers has not been taken for such analysis.⁷ Very few studies have been done in the pediatric age group. Hence, this study has been performed to compare the pulmonary functions of healthy adolescents studying in schools situated in highly polluted areas with those studying in schools of low polluted areas of south western Punjab.

METHODS

The present analytical cross-sectional study was conducted in various schools located at Faridkot and Bathinda city. These places had been identified by the Punjab Pollution Control Board (PPCB) as having low and high air pollution levels respectively

Study population

The study population was divided into two groups:

- Group A: 300 children from schools situated in Bathinda city were finally recruited as this is a highly polluted area as identified by PPCB, with heavy vehicular traffic and industrialization.
- Group B: Another 301 children from schools situated in Faridkot city were finally recruited as this is a low polluted area as identified by PPCB, having less vehicular traffic and devoid of industries.

The children in the two groups were age, sex, weight and height matched. As our aim was to study the long-term effects of air pollution on pulmonary functions, only those children who had been studying in the school for

more than three years were included in the study.⁸ A formal permission was sought from the requisite school/competent authorities before the initiation of the study. Before the child was enrolled for the study, a pre-designed, pre-tested questionnaire was administered to the parents/guardians so as to rule out any respiratory morbidity likely to influence the pulmonary functions. A formal informed consent was taken from the parents/guardians and they were provided with a brief description of pulmonary function testing by spirometry in English/local language.

Inclusion criteria

- Age: 10-18 years.
- Sex: either sex.
- Children studying in the school for more than three years.

Exclusion criteria

- History of acute or persistent respiratory symptoms in the child.
- Past history of any illness likely to give rise to alteration in pulmonary functions e.g. empyema, pleural effusion, pulmonary tuberculosis, foreign body removal, lower motor neuron paralysis e.g. Gullian-Barre Syndrome etc.
- History of atopy in the child viz. asthma, allergic rhinitis or atopic dermatitis
- Underlying congenital anomaly or acquired lesion which could account for recurrent respiratory problems, e.g. scoliosis, Potts spine, Fracture rib, heart defect.
- Children exposed to domestic fuels (biomass or kerosene) at home.
- Children exposed to passive smoke and furry pets at home.
- Child with cleft lip or palate, facial paralysis or any other alteration that could prevent spirometry from being performed.

Equipment

Spiro Excel spirometer was used. It is a new generation spirometer which facilitates the total valuation of lung function. It also meets the quality criteria established by both European Respiratory Society (ERS) and the American Thoracic Society (ATS). The instrument calculates the spirometric parameters and compares them with predicted (Reference) values which have been derived from large population studies. This instrument has five such sets available given by different authors and while calculating the spirometric values in children, KNUDSON values were used in the present study.⁹

Data collection

The data was collected by the doctor himself along with a trained technician well versed with the spirometer. Each

student was given thorough instructions on the use of the instrument and given several test trials before recording the data. The student underwent a forced spirometry. He/ She was asked to sit comfortably for 5 minutes and was made to relax. The procedure was explained through self-demonstrations. Then he/she was asked to take a deep inspiration up to his/her maximum capacity and then expire in to the mouth piece of spirometer forcefully and for as long as possible. A nose clip was used where needed to direct all expired air into the spirometer. Subsequently he/she was asked to take deep inspiration in continuation of his/her expiratory effort to obtain the flow volume loop.

The following parameters were obtained:

- FVC (forced vital capacity).
- FEV₁ (forced expiratory volume in the first second).
- FEV₁% (relation of FEV₁ to FVC).
- PEFR (peak expiratory flow rate).
- FEF_{25-75%} (forced expiratory flow 25-75%).

For the purpose of data collection three trials were recorded (As recommended by American Thoracic Society and European Respiratory Society). The best of the three trials was taken as the final reading, provided it was reproducible. The readings were taken in sitting posture for all children so as to standardize the procedure. Sufficient time was given between each test so that the subject was comfortable and had no feeling of dizziness.

Air Pollution Data

The data regarding levels of various air pollutants in study areas was provided by Punjab Pollution Control Board (PPCB).

The PPCB has established air pollution monitoring stations in different areas of Punjab and fourteen stations are continuously monitoring the levels of air pollution in accordance with National Ambient Air Quality Monitoring Programmed. One of these stations is located at Bathinda in South western Punjab.

The concentration of Suspended Particulate Matter (SPM), sulphur dioxide (SO₂) and nitrogen dioxide (NO₂) are monitored at these centers. Faridkot being a low polluted zone does not have an air pollution monitoring station.

Thrice weekly readings are taken by PPCB in these areas and single 24-hour average values of different pollutants (SO₂, NO₂ and PM₁₀) were recorded in the study area. The students of the study group A were subjected to spirometry within 24 hours of such data acquisition.

Statistical methods

Data analysis was done by using IBM SPSS windows version 20.0.0. Pearson Chi-square test was used to find out the association between the outcome of lung function tests and selected socio-demographic variables. Odds ratio was used to find out the pattern of abnormality in the children.

RESULTS

Table 1 show that percentage of males and females having FVC below cut off was more in high polluted group as compared to low polluted group (23.5% vs. 15.4%), (39.4% vs. 26%), p≤0.05.

Table 1: Gender wise distribution of abnormal FVC.

Group	Total males	Males with FVC below cut off n (%)	Males with normal FVC	x ²	p -value
High polluted	191	45 (23.5%)	146		
Low polluted	201	31 (15.4%)	170	4.149	0.042
Total Females		Females with FVC below cut off n (%)	Females with normal FVC	x ²	p value
High polluted	109	43 (39.4%)	66		
Low polluted	100	26 (26%)	74	4.266	0.039

Test applied: Chi square test

Table 2: Gender wise distribution of abnormal FEV₁.

Group	Total Males	Males with FEV ₁ below cut off n (%)	Males with normal FEV ₁	x ²	p value
High polluted	191	36 (18.8%)	155		
Low polluted	201	17 (8.5%)	184	9.043	0.003
Total females		Females with FEV ₁ below cut off n (%)	Females with normal FEV ₁	x ²	p value
High polluted	109	38 (34.8%)	71		
Low polluted	100	21 (21%)	79	4.947	0.026

Test applied: Chi square test

Table 2 depicted that percentage of males and females having FEV_1 below cut off was more in high polluted

group as compared to low polluted group (18% vs. 8.5%), (34.8% vs. 21%), $p \leq 0.05$.

Table 3: Gender wise distribution of abnormal FEV_1 %.

Group	Total Males	Males with FEV_1 % below cut off n (%)	Males with normal FEV_1 %	χ^2	p value
High polluted	191	14 (7.3%)	177	6.374	0.012
Low polluted	201	4 (2%)	197		
	Total Females	Females with FEV_1 % below cut off n (%)	Females with normal FEV_1 %	χ^2	p value
High polluted	109	11 (10.1%)	98	4.197	0.041
Low polluted	100	3 (3%)	97		

Test applied: Chi square test

Table 3: shows that percentage of males and females having FEV_1 % below cut off was more in high polluted

group as compared to low polluted group (7.3% vs. 2%), (10.1% vs. 3%), $p \leq 0.05$.

Table 4: Gender wise distribution of abnormal FEF_{25-75} %.

Group	Total Males	Males with FEF_{25-75} % below cut off n (%)	Males with normal FEF_{25-75} %	χ^2	p value
High polluted	191	12 (6.3%)	179		
Low polluted	201	8 (4%)	193	1.072	0.300
	Total Females	Females with FEF_{25-75} % below cut off n (%)	Females with normal FEF_{25-75} %	χ^2	p value
High polluted	109	10 (9.2%)	99		
Low polluted	100	7 (7%)	93	0.330	0.566

Test applied: Chi square test

Table 5: Gender wise distribution of abnormal PEFR.

Group	Total Males	Males with PEFR below cut off n (%)	Males with normal PEFR	χ^2	p value
High polluted	191	93 (48.7%)	98		
Low polluted	201	71 (35.3%)	130	7.192	0.007
	Total Females	Females with PEFR below cut off n (%)	Females with normal PEFR	χ^2	p value
High polluted	109	61 (56%)	48		
Low polluted	100	54 (54%)	56	0.081	0.776

Test applied: Chi square test

Table 6: Gender wise obstructive pattern in Pulmonary Function Tests.

Group	Total no. of children	Obstructive disease process n (%)	Odds ratio	p -value
Males				
High polluted	191	11 (5.8%)	3.01	
Low Polluted	201	4 (2%)	(CI= 0.942 to 9.621)	0.063
Females				
High polluted	109	8 (7.3%)	7.842	
Low Polluted	100	1 (1%)	(CI= 0.963 to 63.86)	0.054

Table 4 shows that percentage of males and females having FEF_{25-75} % below cut off was more in high polluted

group as compared to low polluted group (6.3% vs. 4%), (9.2% vs. 7%), $p \geq 0.05$.

Table 5 shows that percentage of males having PEFR below cut off was more in high polluted group as compared to low polluted group (48.7% vs. 35.3%) $p \leq 0.05$, (56% vs. 54%), $p \geq 0.05$. Table 6 this table shows that 5.8% of males in high polluted group had obstructive

pattern of abnormality as compared to 2% in low polluted group and 7.3% of females in high polluted group had obstructive pattern of abnormality as compared to 1% in low polluted group p value was > 0.05 , which was statistically not significant.

Table 7: Gender wise restrictive pattern in pulmonary function tests.

Group	Total no. of children	Restrictive disease process n (%)	Odds ratio	p-value
Males				
High polluted	191	42 (22)		
Low Polluted	201	31 (15.4)	1.546 (CI= 0.925 to 2.583)	0.096
Females				
High polluted	109	40 (36.7)		
Low Polluted	100	24 (24)	1.836 (CI= 1.006 to 3.351)	0.048

Table 7 this table shows that 22% of males in high polluted group had restrictive pattern of abnormality as compared to 15.4% in low polluted group; p value was > 0.05 36.7% of females in high polluted group had restrictive pattern of abnormality as compared to 24% in low polluted group; p value was < 0.05 , which was statistically significant.

DISCUSSION

The present study was conducted in adolescent children who were studying in schools located in high and low polluted areas according to Ambient Air Quality Standards as reported by the PPCB. Lung function testing was done on apparently healthy and asymptomatic adolescents (10 -18 years) who had been studying in these schools for more than 3 years. A total of 601 children (300 in high and 301 in low polluted areas) were tested.

In present study, FVC was below the cut off value in 23.5% of males in the high polluted group as compared to 15.4% in the low polluted group ($p = 0.042$; significant). The corresponding values for females were 39.4% and 26% respectively ($p = 0.039$; significant). Similar trends in FVC have been reported in earlier studies conducted by Hsieh et al, Wang et al.^{10,11}

In the present study, a higher percentage of children had FVC below cut off value for normal as compared to previous two studies. This difference in results could be due to the difference in study designs. Though methodology was the same, but their study subjects were of lower age group and sample size was also smaller (<200) as compared to present study.

It is possible that children in present study were in higher age group and hence had been exposed to air pollution for a longer time. Further, in the present study the ambient air quality data given by the PPCB showed that only SPM levels were high whereas in the study by Wang et al the

polluted areas had higher concentration of SO_2 and NO_2 (with no association described with SPM) which could explain the difference.¹¹

In the present study, FEV_1 was below the cut off value in 18.8% of males in high polluted group as compared to 8.5% of males in low polluted group ($p = 0.003$; significant). The corresponding figures in females were 34.8% and 21% respectively ($p = 0.026$; significant). The trends observed in present study are similar to previous studies conducted by Hsieh et al, Wang et al in primary school children aged 12 yrs.^{10,11} The difference in these observations with the present study may be attributed to greater temporal exposure to pollution.

In the present study the mean percentage of FEV_1 values were lower in the high polluted group than in the low polluted group by 3.3% in males ($p = 0.025$; significant) and 1.7% in females ($p = 0.478$; not significant). Gauderman et al have also shown a cumulative reduction of 3.4% in FEV_1 in a study showing the effects of exposure to SPM, NO_2 and SO_2 on lung function growth in adolescent children.¹² Similarly, a longitudinal study done in China in 2010 on effects of air pollution on lung function growth in school children by Qi-Qiang et al observed that children living in the higher polluted districts showed significant deficits in the annual growth rates for FEV_1 .¹³ This was a prospective study and followed same subjects over a period of time. Although, present study was a cross-sectional study, we included only those children who had been studying in that school for more than 3 years so that the long-term effects of air pollution on pulmonary functions could be assessed.

In the present study, $\text{FEF}_{25-75\%}$ was below the cut off value in 6.3% of males in high polluted group as compared to 4 % of males in low polluted group. ($p= 0.300$; not significant). The corresponding figures in females were 9.2% and 7% respectively ($p = 0.566$; not significant). However, the mean percentage of $\text{FEF}_{25-75\%}$ values were lower in the high polluted group

than in the low polluted group by 7.5% in males ($p = 0.003$; significant) and 4.6% in females ($p = 0.095$; not significant). Therefore, in present study only males showed a significant fall in mean percentage of $FEF_{25-75}\%$. Other authors have also observed the effect of air pollution on $FEF_{25-75}\%$. Gauderman et al have also shown a cumulative reduction of 5% in $FEF_{25-75}\%$ in a study showing the effects of exposure to SPM, NO_2 and SO_2 on lung function growth in adolescent children.¹² Although it is a longitudinal study done over a 4- yr study period in a cohort of 3,035 children (aged 10 -15 years), the results are comparable. Gao et al in a cross-sectional study observed that primary-school-age boys (aged 8 -10 years) in the high- pollution district (HPD) had significantly reduced $FEF_{25-75}\%$ when compared to low pollution district (LPD) and moderate pollution district (MPD), while the adverse effects among girls were not significant.¹⁴ These observations are similar to present study as in both only males had a significant reduction in $FEF_{25-75}\%$ in high polluted group.

In the present study, PEFR was below the cut off value in 48.7% of males in high polluted group as compared to 35% of males in low polluted group ($p = 0.007$; significant). The corresponding figures in females were 56% and 54% respectively ($p = 0.776$; not significant). Similar trends in the pulmonary function abnormalities have been reported in the earlier studies also. Linares et al also found a 4% deficit in PEFR in both sexes while comparing children from two schools, one 1100 m from air pollution source and another 7300 m away from the pollution source (petrochemical industrial zone).⁸ The difference in observation may be due to difference in study designs as it was a longitudinal study.

Restrictive pattern abnormality in males was present in 22% in the high polluted group as compared to 15.4% in low polluted group ($p = 0.096$; not significant). The corresponding figures in case of females were 36.7% and 24% ($p = 0.048$; significant). Obstructive pattern abnormality in males was present in 5.8% in high polluted group as compared to 2% in low polluted group ($p = 0.063$; not significant). The corresponding values for females were 7.3% and 1% respectively ($p = 0.054$; not significant). Hsue et al observed restrictive pattern in 11.9% of preadolescent children, whereas only 1.1% had obstructive pattern.¹⁰ This difference could be because of the region of study and the type of air pollutants. In Punjab, wheat/ paddy residue burning is rampant, and the main air pollutant is SPM.

This is corroborated by the data provided by PPCB for present study. Linares et al observed that the principal alteration in lung function was obstructive in type.⁸ About 10.4% of children in the high polluted group had obstructive pattern as compared to 5.3% in the low polluted group. This is different from present study as we have observed restrictive pattern to be more common. This difference could also be because of the region of study and the type of air pollutants. The percentage of the

willingness to participate in the present study was very high (94%) and therefore, the children included should reasonably be representative of all children of a similar age in South Western Punjab. However, the bias, intentional or recall, in answering the questionnaires may be the reason for seeing pulmonary function abnormalities in low polluted group also. Longitudinal follow up studies are recommended to see the effect of air pollution on lung function growth in this region because abnormalities at this age can have long term effect on lung morbidity. We also recommend a study on the reversible nature of these abnormalities in lung function by using bronchodilators.

CONCLUSION

From this cross-sectional study, it is concluded that in South Western Punjab, air pollution has detrimental effect on pulmonary functions (FVC, FEV_1 , $FEV_1\%$, $FEF_{25-75}\%$ and PEFR) in healthy adolescents. The children from schools located in high polluted area had higher level of abnormal pulmonary functions as compared to the children from schools located in low polluted area. After analysing the results of pulmonary functions, we concluded that higher pollution levels have detrimental effect on both large and small airways in these adolescents. This study will act as a stepping stone for further longitudinal studies on the effects of air pollution on lung function growth in children in this region.

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