International Journal of Community Medicine and Public Health
Barall D et al. Int J Community Med Public Health. 2020 Jul;7(7):2607-2612
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: http://dx.doi.org/10.18203/2394-6040.ijcmph20202984

Original Research Article

Effects of industrial air pollution on lung functions of primary school children in Himachal Pradesh

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Received: 07 May 2020
Accepted: 11 June 2020

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ABSTRACT

Background: Industrial air pollution is one of the most evident environmental problems experienced by all. Air pollution leading to respiratory illnesses is a significant cause of morbidity and mortality with children more susceptible to its effects. Spirometry can be used to estimate their lung function and aid in the diagnosis of certain respiratory disorders in children.
Methods: Cross sectional assessment of the lung functions of the primary school children using spirometer was done in the severely polluted industrial area. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEFR) for each child was measured after their anthropometric measurement.
Results: Emission records for the year 2017-18 showed respirable suspended particulate matters (RSPM) level at as high as 286.3 ug/m^3. We analyzed 464 spirometry results with equal number from industrial and non-industrial area. We observed that the Industrial areas had the significantly higher number of children with abnormal levels of all observed spirometry parameters except for FVC. Obstructive pattern of spirometry in the industrial area was significantly higher (odds ratio of 4.00, 95%, CI 1.78-8.95, p<0.05) than children in non-industrial area.
Conclusions: It was concluded with the estimated overall distribution of 3.01% of probable obstructive illness, 2.58% of restrictive illness and 1.51% of mixed pattern of illness.

Keywords: Air pollution, Industrial pollution, Pulmonary function, Spirometry in children

INTRODUCTION

Industrial pollution is one of the most evident environmental problems experienced by all industrialized and the newly industrializing economies today. Pollution of natural environment not only affects people but also have adverse impact on economic growth lately. Total pollution load from manufacturing sector in India has increased almost six times in the post reform period during 1990-2010. Air pollution is a complex mixture of different gaseous and particulate components and can cause several health effects. Both long- and short-term exposure to air pollution can cause respiratory diseases including asthma and chronic obstructive pulmonary disease and may lead to significant morbidity and mortality.[1] Children are more susceptible to the effects of air pollution due to their under developed pulmonary metabolic capacity.[2] Moreover, children are in general more exposed because of greater physical activity as well as greater time spent outdoors. As per literature, coarse particles (respirable suspended particulate matters (RSPM) or PM 10) consisting mainly of organic material, silicates and larger carbon aggregates, cause damage to larger airways and provoke higher inflammatory response than smaller particles while deficits in the lung function are correlated with a set of pollutants that include nitrogen oxide, sulphur dioxide, ozone, ammonia and fine particulate matter (PM 2.5) that reach the alveoli.[3,4]

Spirometry, which means “the measuring of breath,” is a routinely used pulmonary function test (PFT) that measures the amount and speed of air that a person can inhale and exhale. The spirometry test requires the subject to exhale as forcefully as possible after taking in a full, deep breath. The subject’s effort is called the forced expiratory manoeuvre. Results from the test can be used to estimate lung function and aid in the diagnosis of certain respiratory disorders.

The objective of study was to estimate any difference in the spirometry pattern of the primary school children in industrial and non-industrial area due to industrial air pollution.

METHODS

A case-control study was done in severely polluted area (SPA) in the state of Himachal Pradesh which included the industrial area of Parwanoo and Baddi in district Solan and Kala Amb industrial area in district Sirmour.

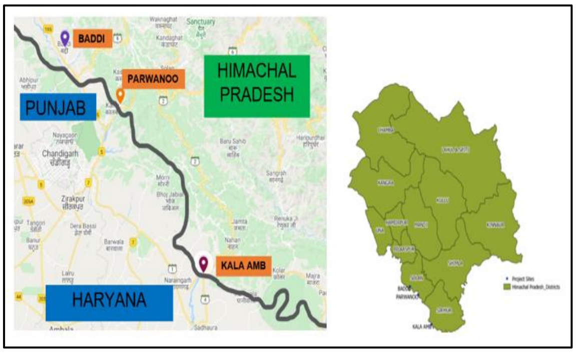

Figure 1: SPA in Himachal Pradesh.

Control area

For each of the industrial area, control area was chosen.

Study population

All eligible children from the selected primary schools fulfilling the inclusion criteria were enrolled in the study.

The study was done for six months from June 2019 to November 2019. Sample size was calculated using Open Epi, version 3, open source calculator-SSCC5 sample size was calculated with the assumption of two-sided confidence level (1-alpha) of 95%, 80% Power for detecting Odds ratio of at least 2.30 for the 08% hypothetical proportion of controls with exposure and ratio of control to case of 1. The minimum sample size for the study came out to be 450 with equal participants from industrial and non-industrial area.

Instrument

Indigenously developed portable spirometer, spirotech+ (plus) CMSP-02 (manufactured by Clarity Medical Private Limited) with Indian predicted equations was used. The instrument had air flow range (L/sec) from -8 l/sec to +12 l/sec, maximum volume range of 5 litre with measurement accuracy of ±1%. Measurement was done with flow integrated mouthpiece and transducer with bi-directional turbine cartridge. It was operated through laptop mode with the feature of auto interpretation, storage and transfer of the reports in pdf and excel format. It is based on the National Health and Nutrition Examination Survey (NHANES) spirometry component sponsored by the Centres for Disease Control and Prevention, National Institute for Health Statistics (CDC/NCHS), the National Heart, Lung, and Blood Institute (NHLBI), and the National Institute for Occupational Safety and Health (NIOSH). It has been widely used in research relating to occupational pulmonary disease and the effects of air quality on spirometry function and in evaluation of asthma and COPD prevalence and their risk factors.

Process

The list of government primary schools in the study area was taken from the respective deputy director elementary education of the Solan and Sirmour district. Schools were selected randomly from the central location in the industrial area and control schools were taken located far from the industrial area preferably within the same health block with no or bare minimum exposure to industrial pollution. 3 schools from industrial area and 4 schools from non-industrial area were selected for the study. They were intimated in advance for the consent of the parents. On the day of visit, all present and eligible students in the age group of 6 to 10 years (primary section) were assessed for their pulmonary functions. Students were briefed about the purpose and scope of study. On the day of examination, they were enrolled after taking the consent forms duly signed by their parents. The children underwent the standardised and calibrated anthropometric measurement for height and weight.

All spirometry measurement was done with the subject standing in a well-ventilated room with the comfortable ambient temperature and humidity without any tight clothes to restrict his/her respiratory effort. They were demonstrated the act of breathing into the spirometer in their understandable language and was then asked to perform the same holding the mouthpiece in their own hand. They were encouraged to exhale the maximum volume of air forcefully after a maximum inspiration. We measured forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and peak expiratory flow (PEFR) for each child.

Before interpreting the PFT results, it was confirmed form the volume-time curve that the child has put full effort to reach a plateau with maximum expiratory effort ideally lasting up to 3 seconds. The results were found consistent with the repeated efforts (maximum of 7) and two best efforts were within 0.2 l of each other. Lastly the flow-volume loops were checked for any artefacts or abnormalities.[6] In the current spirometry study, the primary measurement used to assess probable obstructive lung disorders was the ratio of forced expiratory volume in 1 second to forced vital capacity expressed as a percentage or FEV1/FVC%. Such children were assigned further testing and evaluation if their baseline spirometry testing results exhibited the FEV1/FVC% less than 85 percent.[7] For all other measurements, values less than 80% of their predicted was considered as abnormal. PEFR values were mainly used to assess the participant's effort as the enrolled children were healthy and without any symptoms of respiratory obstruction or restriction. The guidelines of American Thoracic society (ATS) system for grading the severity of the abnormality using the measurement levels for FEV1 was used.[8,9]

Data analysis

The data were entered in the excel sheets and analysed with the help of computer software Epi-Info version 7.2.3.1 for windows. For analysis purpose, the values of forced vital capacity (FVC), forced expiratory volume in 1s (FEV1), FEV1/FVC, and peak expiratory flow rate (PEFR) were included in this study. Odds ratio with 95% confidence interval was calculated to ascertain the strength of association. Chi-square test was applied to evaluate statistical significance, $p<0.05$ was considered statistically significant. Confounding factors were dealt with appropriately.

Quality assurance

Quality of the data collection was ensured by pretesting the tools and equipment's before the start of study and training of all the investigating teams for its use. The instrument was calibrated before each session using 3L syringe.

RESULTS

Exposure to air pollution was assessed from the air quality monitored in the study area by State Pollution Control Board through seven stations under National Ambient Air Quality Monitoring Programme. Emission records were taken from the official annual report for the year 2017-18 from the departmental website. It revealed that the highest emission of sulphur dioxide (SO_2) and nitrogen oxide was 29.4 ug/m^3 and 58.8 ug/m^3 against the acceptable annual mean limit of 50 and 40 ug/m^3 respectively. The RSPM (respirable suspended particulate matters) was recorded above the acceptable limit of 60 ug/m^3 at as high as 286.3 ug/m^3 with annual average level of 121.79 ug/m^3.

663 children were enrolled for the spirometry from the government primary schools located within the industrial area and its adjacent non-industrial area. Consent forms were given to each one of them to get it signed by their parents and bring on the day of examination.

Table 1: Baseline characteristics of enrolled children.

Baseline characteristics	Industrial area (n=232)	Non-industrial area (n=232)	P value
Gender (male/female)	105/127	122/110	0.13
Age (years)	8.19±1.45	8.19±1.45	1.00
Weight (kg)	20.06±5.89	20.76±4.65	0.15
Height (m)	1.21±0.11	1.20±0.11	0.31
BMI	13.32±2.34	14.11±1.56	0.10
FEV1 (%p)	97.16±24.08	106.01±26.09	0.0002
FVC (%p)	95.53±21.98	96.51±22.48	0.63
FEV1/FVC (%p)	102.97±17.50	110.87±15.73	0.000
PEFR (%p)	127.26±63.56	153.24±85.30	0.0002

Table 2: Spirometry measurements.

Spirometry measurements	Industrial area (n=232)	Non-industrial area (n=232)	ODDs ratio (95% CI)	P value
	N (%)	N (%)		
FEV1/FVC ratio <85%	33 (14.23)	11 (4.74)	3.33 (1.64-6.76)	0.0008
FVC <80%	38 (16.37)	44 (18.96)	0.83 (0.51-1.35)	0.54
FEV1 <80%	26 (11.20)	13 (5.61)	2.12 (1.06-4.24)	0.045
PEFR <80%	48 (20.69)	21 (9.05)	2.62 (1.51-4.54)	0.0006

Table 3: Severity grading of the abnormal spirometry pattern.

Severity	Obstructive (n=37)	Restrictive (n=75)	Mixed (n=7)	Total (n=119)
	N (%)	N (%)	N (%)	N (%)
Mild	5 (13.51)	9 (12.00)	0	14 (11.76)
Moderate	6 (16.21)	3 (4.00)	1 (14.28)	10 (8.41)
Moderately severe	3 (8.11)	0	3 (42.85)	6 (5.04)
Severe	0	0	3 (42.85)	3 (2.52)
Very severe	0	0	0	0

The students with history of cardiorespiratory illness and those with any deformity of the chest wall were excluded. 54 children couldn't get their consent form signed and were excluded. Children having no comparable age group were also excluded. For analysis, we included only those children having the spirometry satisfying the desired ATS standard. After fulfilling the exclusion and inclusion criteria and matching for the age, we had 464 spirometry results with equal number of children from each area.

The children were in the age group of 6 to 10 years. They were comparable among themselves in regards to their gender, weight, height and BMI with no significant statistical difference. All of the observed spirometry parameters (mean of the percentages of predicted values of FEV1, FVC, FEV1/FVC ratio and PEFR) were higher among the children of non-industrial area with the significant difference except for the percentage predicted values of FVC.

Our study revealed that 44 children had their FEV1/FVC ratio below the normal level. Similarly, 82 children had abnormal FVC, 39 had abnormal FEV1 and 69 had abnormal PEFR. We observed that the Industrial areas had the significantly higher number of children with abnormal levels of all observed spirometry parameters except for FVC.

The overall observation of obstructive spirometry pattern (with lower ratio and normal FVC) in our study was 7.97% (37). Similarly, the restrictive spirometry pattern (with normal ratio and lower FVC) was seen in 16.16% (75) and the mixed pattern of spirometry (lower ratio and lower FVC) was seen in 1.51% (7) of the children.

The number of children with Obstructive pattern of spirometry in the industrial area was significantly higher (Odds ratio of 4.00, 95% CI 1.78-8.95, $p<0.05$) than children in non-industrial area. Whereas, the difference in distribution of mixed and restrictive pattern was not significant in the two areas.

Out of 37 children with obstructive pattern of spirometry, 14 children (<40%) were found to have their FEV1 measurements below normal level. They had mild to moderately severe FEV1 measurements. Rest of the children had normal FEV1 measurements. Similarly, 12 (16%) children with restrictive spirometry pattern were found to have below normal FEV1 measurements with mild to moderate severity. All 7 children with mixed spirometry pattern had moderate to severe below normal FEV1 measurements.

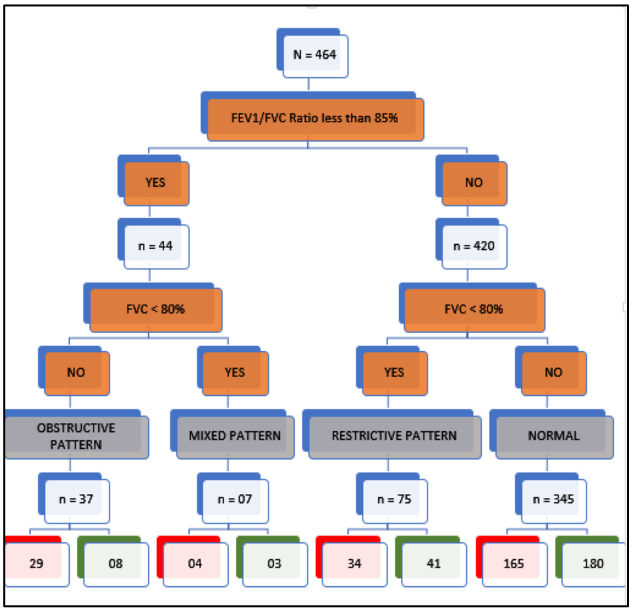

Figure 1: Spirometry interpretation.
(Red blocks= industrial area) and (green blocks= non-industrial area).

Taking into consideration the severity grading of the spirometry pattern, we estimated the overall distribution of 3.01% of probable obstructive illness with significantly higher number of children in industrial area (12 vs 2). Similarly, it was 2.58% (5 vs 7) and 1.51% (4 vs 3) for restrictive and mixed pattern of illnesses respectively but the difference was not found to be significant for these measurements.

DISCUSSION

We included 464 children with 227 boys of 6 to 10 years from government primary schools similar to the 424 school children of 7 to 13 years enrolled in industrial town of Netherlands10 and 400 normal healthy school going children in the age group of 8 to 12 years of Lucknow city whereas other similar studies had included 354 boys and 278 girls, age 6 to 15 years of different socioeconomic group in Bombay and 670 normal children of 6-17 years of north Indian parentage from Delhi.[11-13]

The participants were matched for their ages as the pulmonary function varies with the change in the age structure of the participants.[14] Other independent variables were not matched but found comparable in both the groups with no statistical significance minimising their confounding effects on the results.[15] Singh et al matched their participants for the age, sex, height and weight in their case-control study among adolescents in Faridkot, Punjab. The information on the household pollution factors including the use of biomass fuel and exposure to second hand smoking, was lacking in our study and it remained the limitation of our study.[16,17]

In the present study, 14.23% of children in industrial area had abnormal FEV1/FVC ratio as compared to 4.74% in non-industrial area (p=0.0008). The corresponding figures in the previous studies were 28% versus 21%.[18] Similarly, in the present study, 11.2% of children in industrial area had abnormal FEV1 as compared to 5.61% in non-industrial area (p=0.045). The corresponding figures in the previous studies were 27% and 14%, 16.5% versus 7.2% and 17% versus 3.2%.[19-21]

We observed a difference in the measurement of the spirometry parameters among the children of industrial and non-industrial area similar to the observation made in the residents of Korean industrial complexes. The difference was significant for all observed parameters except FVC which was also not significant along with the FEV1/FVC ratio in the Korean study.[22]

We observed 7.97% of children with obstructive spirometry pattern, 16.16% with restrictive pattern and 1.51% with mixed spirometry pattern. Singh et al observed restrictive pattern in 42% and 29% of adolescents in their study. In our study, the difference was significant for obstructive pattern with 12.5% among the children in industrial area and 4.45% in non-industrial area. The number of children with restrictive pattern was, however, higher in proportion in both areas of our study but without any significant difference whereas it was observed proportionately higher and significant in the adolescents of north west India.[23] The reason for the higher number of restrictive pattern in our study i.e. normal FEV1/FVC ratio and low FVC, could be due to the submaximal effort of forced expiration supported by their low peak expiration flow rates resulting in lower observed value of FEV1.[24] Although it should not simply rule out the underlying disorder, if any and needed to be evaluated further. These findings are similar to the BOLD study that observed a restrictive pattern not only in India but also in other low and middle-income countries that was mainly attributed to poor socioeconomic status which is an indirect marker for nutritional status.[25]

Many studies have attributed the exposure to the air pollution, both ambient and indoor including environmental tobacco smoke for the development of obstructive pattern in industrial area.[26] Although we had no sufficient information to match previous studies and with no intention to undermine their importance, significant observation of obstructive pattern in our study is mainly attributed to the higher exposures to outdoor air pollutants owing to the location and other sources of air pollution in the study area.

After grading for the severity of the observed abnormal spirometry pattern and excluding the children with normal FEV1 levels, the distribution of obstructive, restrictive and mixed pattern of illness was 3.08%, 2.58% and 1.51% respectively in our study participants which is around the overall weighted mean prevalence of 2.74 in Indian children.[27]

The study, with all its limitations has sufficiently brought forward the ongoing demerits of increasing air pollution with all its deleterious effects on the health of the growing children. It is high time to realize the situation and initiate the meaningful efforts to curb this impending disaster at an early stage before it turns out to be the irreparable loss carried to our next generation.

CONCLUSION

The study concluded with the overall distribution of 3.01% of obstructive, 2.58% of restrictive and 1.51% of mixed respiratory illness among the observed children. The difference in distribution was found to be significant for the obstructive illness.

ACKNOWLEDGEMENTS

Authors would like to thank the state health field officers and workers, department of education and all the participating children for their enthusiasm and support.

Funding: HP State Pollution Control Board through Director Health Services, Department of Health and Family Welfare, Government of Himachal Pradesh
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Barall D, Mazta SR, Kashyap R, Goyel P. Effects of industrial air pollution on lung functions of primary school children in Himachal Pradesh. Int J Community Med Public Health 2020;7:2607-12.