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Effects of agriculture crop residue burning on children and young on PFTs in North West India

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ABSTRACT

Variations in pulmonary function tests (PFTs) due to agriculture crop residue burning (ACRB) on children between the age group of 10 to 13 years and the young between 20 to 35 years are studied. The effects of exposure to smoke due to rice–wheat crop residue burning on pulmonary functions like Force Vital Capacity (FVC), Force Expiratory Volume in one second (FEV_1), Peak Expiratory Flow (PEF) and Force Expiratory Flow in 25 to 75% of FVC ($FEF_{25-75\%}$) on 40 healthy subjects of rural/agricultural area of Sidhuwal village of Patiala City were investigated for a period from August 2008 to July 2009. Measurements were taken by spirometry according to the American Thoracic Society standards. High volume sampler (HVS) and Anderson Impactor were used to measure the concentration levels of SPM, PM_{10} and $PM_{2.5}$ in ambient air of the Sidhuwal village. A significant increase in the concentration levels of SPM, PM_{10} and $PM_{2.5}$ was observed due to which PFTs of the subjects showed a significant decrease in their values, more prominently in the case of children. PFTs of young subjects recovered up to some extent after the completion of burning period but the PFT values of children remained significantly lower ($p<0.001$) even after the completion of burning episodes. Small size particulate matter ($PM_{2.5}$ and PM_{10}) affected the PFTs to a large extent in comparison to the large size particulate matter (SPM). The study indicates that ACRB is a serious environmental health hazard and children are more sensitive to air pollution, as ACRB poses some unrecoverable influence on their PFTs.

1. Introduction

The health effects of agriculture crop residue burning (ACRB) on the respiratory system of humans have been a matter of concern since the past few decades in the developing countries as this is the most cost effective way to dispose off the residue from the agriculture farms (Cancado et al., 2006). It is a common practice in the northern regions of India, especially in Uttar Pradesh and Punjab where, due to modernization, large amounts of agricultural residues are produced which are disposed off by burning in open fields (Mittal et al., 2009; Sahai et al., 2007; Singh et al., 2010). This process continues for more than one month depending upon the metrological conditions. During the exhaustive period of ACRB due to less combustible conditions, large amount of smoke is produced that is seen clearly in the form of thick cloud over fields and the residential areas (Ezcurra et al., 2001). Chemical agents that are released due to ACRB into the environment, affect human health adversely, mainly respiratory system (Cancado et al., 2006; Dennis et al., 2002; Lara et al., 2005; Long and Manfreda, 2006; Mohammad et al., 2002; Regalado et al., 2006). Since the respiratory system is one major route whereby chemical and toxic agents enter the body and cause disorders, and in severe cases may lead to mortality (Donaldson and Macnee, 2003; Nicod, 1999; Olivieri and Scoditti, 2005). The respiratory tract is their first target, because it comes into direct contact with the air and to protect the body itself it mobilizes defense mechanisms. Due to increase in the concentration of pollutants in the ambient air, oxidative stress and inflammation of lung tissues occur that may affect the proper functioning of the lungs (Brunkreef and Holgate, 2002; He et al., 1993; Olivieri and Scoditti, 2005; Macnee and Donaldson, 2003).

Several investigations on the respiratory status were done on the basis of hospital admissions, survey and respiratory symptoms (Cao et al., 2009; Cho et al., 2000; Jeffrey et al., 1997; Larrieu et al., 2007; Regalado et al., 2006). Most of the investigations are reported which take into account the ill-effects of pollution due to automobiles or industrialization (Chan and Kwok, 2001; Cho et al., 2000; Hoek et al., 2002; Roosbroeck et al., 2006) but effects of ACRB on health lag behind these types of studies. ACRB is particularly dangerous since most of the particulate are smaller than 10 microns (PM_{10}) in size and are easily able to penetrate deep into the lungs causing significant increase in the levels of respiratory and heart problems (American Thoracic Society, 1996; Hauck et al., 2004; Kim et al., 2005; Lee et al., 2007; Macnee and Donaldson, 2003; Makkonen et al., 2010; Moris, 2001). Therefore, there is a need of systematic study to investigate the ill-effects of agriculture crop residue burning on health. In the present

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investigations, Pulmonary Function Tests (PFTs) of the healthy subjects were done continually for 12 months and attempt are made to compare the variations on PFTs of the young and children to see the effect of ACRB.

2. Methodology

2.1. Study area

Study was conducted at Sidhuwal village of Patiala district of Punjab. It is a rural/agricultural area located between 3021′ N and 7627′ E. Sidhuwal site is surrounded by agriculture land and has minimal traffic density. There is not even small industry within 10 km radius and national highway is away by about 10 km circumference from the selected position of the ambient air sampling. Location of study was selected to cover maximum agricultural area around it so that during ACRB, influence can be clearly checked. Rice and wheat are the two major crops of this region with a combined cropping area of more than 86%. The total biomass generated in Patiala from all sources like agriculture crop residues, forest and other wastelands and agro-industry is 3,792,252 MT/year. Out of total biomass generation in Patiala, crop residue contributes 90.4% (TERI, 2003).

2.2. Subjects

Forty healthy subjects (male and female) having no lung disease between age from 10 to 35 years with mean age of 17 year were continually tested for a period of one year from August-2008 to July-2009. Lung function capacity of human being generally increases from birth up to the age of 20 years and after this it decreases slowly up to 40 but after the age of 40 years a sharp decrease is seen in their values (Knudson et al., 1976, 1983). On the basis of these facts, total subjects in the present study were divided under two categories; children (10 to 13 years) and young (20 to 35 years) and their demographic characteristics at the start of the study are presented in Table 1. Before including the subjects in the study, prior consent of the young and children (from parents) were collected. Prior to testing all subjects were questioned for their habits like smoking, health status, occupational and medical history. Children under observation were students of sixth and seventh standards in a senior secondary school located in the Sidhuwal village. All the subjects were non-smokers and none of the subjects had any existing medical problem, respiratory illness or symptoms and were of North Indian ethnicity.

2.3. Pulmonary Function Test

Pulmonary Function Tests (PFTs) like Force Vital Capacity (FVC), Force Expiratory Volume in first Second (FEV_1), Peak Expiratory Flow Rate (PEF) and Force Expiratory Flow in 25 to 75% ($FEF_{25–75\%}$) were carried out by using portable Spirometer (Spirobank-G, IIa, MIR, Roma, Italy). Spirometry of children was performed at their school and remaining subjects in their homes during morning hours between 9 to 12 PM, according to the American Thoracic Society (ATS) standards (Miller et al., 2005). Initially, each subject was instructed and maneuver was demonstrated. Each subject was advised to take a deep breath and then exhale in the sensor with force for as long as possible and then inhale maximum volume of air. With each subject, five to eight maneuvers were carried out in an attempt to achieve three acceptable flow-volume loops. From a minimum of three valid maneuvers (difference between two value of FVC not more than 200 ml), Spirometer selected the best possible values of FVC, FEV_1, PEF and $FEF_{25–75\%}$ based on the maximum value of FVC + FEV_1. Respiratory parameters of subjects were measured in a room for at least two times in a month by using individual mouthpieces. Data was recorded after entering ethnicity, age, height, weight and gender of the subjects, Spirometer predicts values according to the E.R.S.′93 Knudson (Knudson et al., 1983; Quanjer et al., 1993). To account the variation due to age factor, data have been presented as percentage of predicted value during different type of analysis. ATS Standards were followed for the selection of subjects for the study, according to which person whose FVC/FEV_1 value is found to be greater than 75% comes under the category of normal/healthy in terms of pulmonary diseases, hence subjects whose FVC/FEV_1 value were found to be greater than 80% were selected for the study.

Table 1
Demographic measurements of studied group.

	Children	Young	Total
Age range (years)	10 to 13	20 to 35	10 to 35
N	23	17	40
Male	15	15	30
Female	8	2	10
Age (years)	11 ± 0.94	24 ± 5.49	17 ± 7.40
Height (cm)	136 ± 4.39	168 ± 6.38	150 ± 16.92
Weight (kg)	34 ± 5.68	64 ± 12.29	47 ± 17.70

Data are presented as mean ± stdv.

2.4. Ambient Air Sampling

To access air pollution, SPM, PM_{10} and $PM_{2.5}$ were monitored on the roof of the same target secondary school by using high volume sampler (HVS) and eight stages Anderson Impactor. Standardized methods were used to measure the concentration of particulate matter (IS: 5182 (Part XV), (1974)). To ensure the measurement studies of pollutants reflected the pollutant exposure with higher accuracy, the subjects were selected within 2 km of the air quality monitoring site.

2.5. Statistical Analysis

For statistical analysis, Statistical Package for Social Sciences (SPSS) (for windows, version 15) was used and standard methods were applied. To analyze the difference for different parameters at different time interval, Paired t-test was used. Method of linear regression was applied to calculate the association between different size particulate matters on PFTs. Origin 7.5 was used for plotting different types of graphs. All statistical significance tests were 2-tailed and confidence index was set at 95%. A level of p-value ≤ 0.05 was considered to be statistically significant. Descriptive statistics were shown as mean and standard deviation. PFTs of a particular period were calculated in two steps: (i) calculating average of different values of one subject in respective month and (ii) taking mean of average values of all subjects in respective periods.

3. Results and discussion

The Harmful effects of ACRB on PFTs of the healthy subjects have been reported earlier (Agarwal et al., 2010). The effect of ACRB on PFTs (FVC, FEV_1, PEF and $FEF_{25–75\%}$) of children (10–13 years age) and young (20–35 years) were reported here. For comparison between two different age groups and to account for age factor, data for PFTs is expressed as percentage of predicted value (% pred).

Monthly mean value of PFTs of children and young subjects from August 2008 to July 2009 are shown in Fig. 1. For the category of young subjects (Fig. 1A), the value of PFTs decreased in October and November 2008. After November, PFTs show increase till March with slight decrease in January 2009. Again sharp fall was observed in April 2009. Once again PFT value increase gradually up to July 2009.

In Children (Fig. 1B), the values of PFTs shows slight increase from August to September followed by major decrease in October–November 2008 which again increases in December 2008. After December 2008, there is slight decrease in January–February 2009.

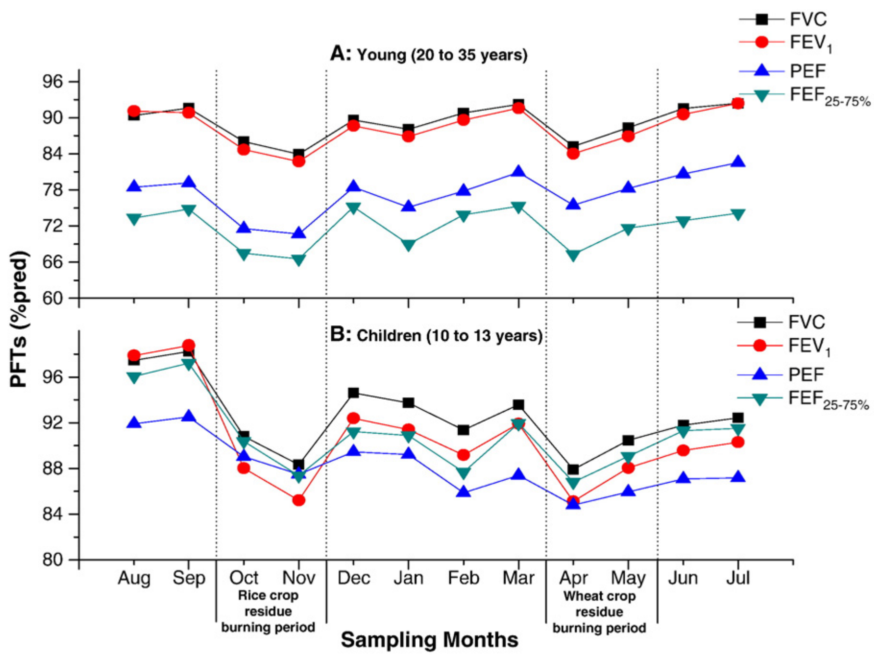

Fig. 1. Monthly variation of PFTs %pred of children and young subjects from August 2008 to July 2009.

There is another sharp dip observed in the PFT values during April 2009. All the PFTs show similar trends i.e., significant decrease in the October–November and April–May during the rice and wheat crop residue burning, but with different magnitude. Fig. 1(A and B) clearly show that crop residue do have an appreciable effect on PFTs. Effect of crop residue burning is precisely more prominent for children as their lung function capacities suffers more permanent damage as the FVC of 98% in the month of August 2008 drops to 92% at the end of July 2009.

Fig. 2 represents the monthly average levels of SPM, PM_{10} and $PM_{2.5}$ at Sidhuwal village. SPM levels were minimum in August and start increasing from September till November due to exhaustive burning of rice crop residue. This increase in SPM level till November was followed by decrease up to March as there was no burning activity during this period. Again an abrupt rise in the concentration of SPM level was observed in the April–May during the wheat crop residue burning activity. PM_{10} and $PM_{2.5}$ variations were found to be almost same as that of SPM during the crop residue burning months i.e., October–November and April–May.

Concentration of different size particulate matter were found to be elevated during October–November and April–May in comparison to pre and post crop residue burning months, which clearly indicates that the crop residue burning had a prominent effect on the ambient air quality (Fig. 2) as documented earlier (Mittal et al., 2009; Singh et al., 2010). For better understanding the effects of crop residue burning, results of 12 months were expressed into 6 periods on the basis of burning time of rice and wheat crop residue; BRBP: before rice crop residue burning period (August–September); DRBP: during rice crop residue burning period (October–November); ARBP: after rice crop residue burns (December–January); BWBP: before wheat crop residue burning period (February–March); DWBP: during wheat crop

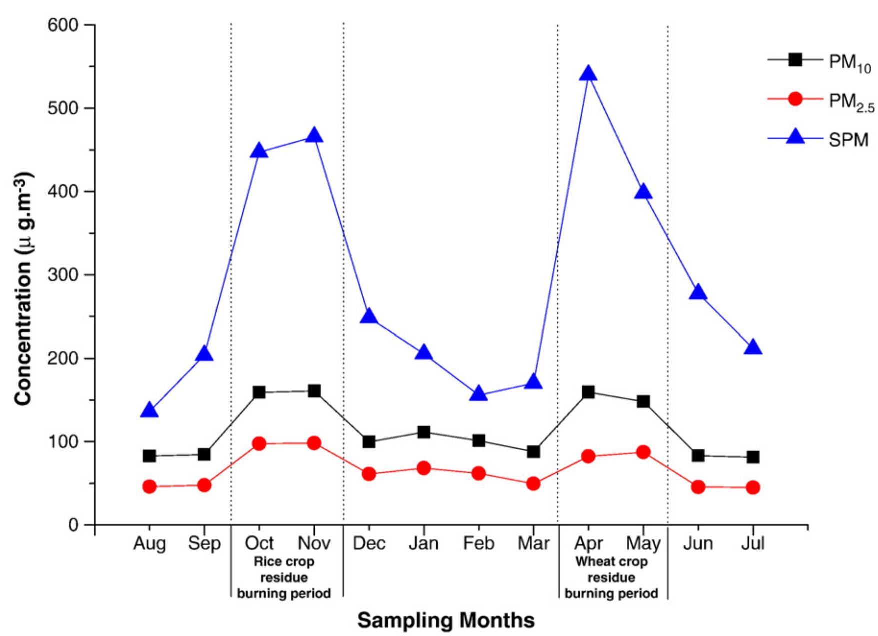

Fig. 2. Monthly variation of particulate matter (SPM, PM_{10} and $PM_{2.5}$) from August 2008 to July 2009.

residue burning period (April–May); AWBP: after wheat crop residue burns (June–July).

Table 2 shows the bimonthly mean value of PFTs like FVC, FEV_1, PEF, $FEF_{25–75\%}$ and SpO_2, and particulate matter like SPM, PM_{10} and $PM_{2.5}$ for each measured period. All pulmonary function indices were lower DRBP and DWBP than those taken in other periods (BRBP, ARBP, BWBP and AWBP). As expected, values of environmental parameters like SPM, PM_{10} and $PM_{2.5}$ are higher DRBP and DWBP than in other periods. It is seen from Table 2 that concentration levels of almost all parameters after increasing from before burning period of rice and wheat to during rice and wheat burning period fall down after the completion of exhaustive burning period. It was found from Table 2 that the momentous decreases in PFTs and increases in the concentration of different size particulate matter were seen during the rice and wheat crop residue burning. During one third period of year (April–May and October–November), concentration of particulate matter remains higher than the prescribed safe limit of 200, 100 and 60 μgm^{-3} as per National ambient air quality standards for SPM, PM_{10}, $PM_{2.5}$, respectively. Hence, common peoples are at higher risk during this period. Variation in the level of SPM, PM_{10} and $PM_{2.5}$ support the hypothesis that the changes in the PFTs are the result of variation in levels of particulate matter in the ambient air.

In order to check whether the observed decreased values of PFTs during rice and wheat crop residue burning episodes are significant or not, difference in PFTs between BWBP with other periods of children and young age group were calculated by using paired T-test and shown in Table 3. Significant decrease was seen in all PFTs of young and child age group during rice and wheat crop residue burning in comparison to BRBP. For lower age group (children), difference for FVC value found significantly lower during the burning periods. Difference was observed as 8.272 and 8.658 ($p<0.001$) for DRBP and DWBP, respectively. These values recovered up to some extent during the non-burning periods but were significantly lower (3.666, 7.298, and 5.737) for ARBP, BWBP and AWBP. Trends in other PFTs were almost same as that of FVC in children.

In case of young age group, value of PFTs were significantly lowered in DRBP, but only FVC and FEV_1 values were found to be significant low in ARBP (4.105, 5.334, $p<0.001$) where as in BWBP non-significant ($p>0.05$) change were seen in all PFTs with a positive value observed in case of FEV_1. All the PFTs show significant difference DWBP. Differences (BRBP − AWBP) were found to be non-significant negative in all PFTs except $FEF_{25–75\%}$ in which non-significant positive difference were found. Negative values in the difference of BRBP with BWBP and AWBP of some pulmonary functions in case of young subjects indicate that there is recovery in their PFTs indices. Whereas, for lower age group, difference between BRBP and AWBP were found to be significant positive ($p<0.001$) in all PFTs which shows that due to ACRB, PFTs did not recover completely even after the completion of burning episode and caused some permanent affect in the children .

Results (Table 3) illustrate that PFTs of children have large and unrecoverable decrease in their PFTs which give evidence that increase in the pollution level during ACRB; children have more ill-effect on their respiratory system in comparison to young subjects. The airways epithelium of growing children is more permeable to air pollutants and lung defenses against particulate and gaseous pollution are not fully evolved. Children also have a differential ability to metabolize, detoxify and excrete environmental agents (Schwartz, 2004), and perform a greater level of physical activity than young; hence, their intake of air into the lungs is much greater than that of young subjects (Stanojevic et al., 2008; Ulrik and Backer, 1999). Children spend more time outside the home, particularly in the late afternoon, which significantly increases their exposure and intake of ambient air, compared to the young. Children have higher resting metabolic rate of oxygen consumption per unit body weight than the young because they have large surface per unit body weight and because they are growing rapidly. An additional consideration is the smaller lung surface area/kg of body mass in the early stages of development. Thus, higher amounts of inspired air will affect a relatively smaller area of lungs tissue. On the basis of body weight, the volume of air passing through the lungs of a child is more than that of young under the same conditions and more atmospheric pollutant could reach the lung of child. Moreover, children have narrower airways, thus irritation caused by air pollution would produce only slight response in young which can result potentially significant obstruction in the airway of child (Moya et al., 2004; Staurt, 1984). Among children and young, children are more susceptible to the harmful effects of air pollution; this may be the possible reason that PFTs of children were affected more in comparison to young.

Significant negative correlation is found between different size particulate matter and PFTs. To find which size particulate matters have more effect on PFTs, association between different sized particulate matter and PFTs were calculated. The relationship between the monthly average concentration of different size particulate matter and monthly average PFTs value of 40 subjects was developed using linear regression and considering PFTs as dependent and particulate matter as independent variables, respectively.

Table 4 shows the change in the PFTs with respect to the 10 μgm^{-3} increment of each type of particulate matter. The increase in the concentration of SPM, PM_{10} and $PM_{2.5}$ by 10 μgm^{-3} was significantly related ($p<0.05$) to all PFTs, except for SPM with $FEF_{25–75\%}$. Negative value of change shows that with the increase in the concentration of particulate matter, there is a significant decrease in the value of all PFTs. A close look on the decrease in the values of PFTs resulting from increase in pollutant levels (SPM, PM_{10} and $PM_{2.5}$) indicates that

Table 2
Periodical variation of PFTs and different size particulate matter.

	BRBP	DRBP	ARBP	BWBP	DWBP	AWBP
Child (N = 23)						
FVC (%pred)	97.85 ± 3.7	89.58 ± 4.4	94.19 ± 3.8	92.48 ± 6.1	89.19 ± 6.3	92.12 ± 6.1
FEV_1 (%pred)	98.33 ± 5.5	86.62 ± 7.3	91.90 ± 4.4	90.55 ± 6.9	86.59 ± 7.6	89.95 ± 7.1
PEF (%pred)	92.22 ± 11.7	88.27 ± 11.6	89.34 ± 3.8	86.64 ± 11.7	85.38 ± 11.5	87.14 ± 11.5
$FEF_{2575\%}$ (%pred)	96.65 ± 9.8	88.88 ± 9.9	91.06 ± 6.1	89.81 ± 11.3	87.94 ± 11.3	91.42 ± 11.2
Young (N = 17)						
FVC (%pred)	95.10 ± 13.1	88.96 ± 11.7	90.24 ± 13.9	87.43 ± 10.4	87.20 ± 11.3	90.84 ± 10.8
FEV_1 (%pred)	93.99 ± 13.8	86.61 ± 12.6	87.53 ± 11.6	87.52 ± 12.5	86.02 ± 12.3	90.03 ± 10.7
PEF (%pred)	79.09 ± 15.2	72.42 ± 15.9	75.98 ± 13.2	78.11 ± 15.9	77.92 ± 18.2	80.26 ± 17.2
$FEF_{2575\%}$ (%pred)	79.73 ± 24.5	72.52 ± 21.3	73.40 ± 17.7	71.72 ± 18.6	71.82 ± 19.5	74.60 ± 23.5
$PM_{2.5}$(μgm^{-3})	47 ± 1.12	98 ± 1.49	65 ± 4.89	56 ± 8.73	85 ± 3.54	45 ± 1.54
PM_{10} (μgm^{-3})	84 ± 1.10	160 ± 1.31	106 ± 8.36	95 ± 9.34	154 ± 7.98	82 ± 1.35
SPM (μgm^{-3})	170 ± 47.77	456 ± 13.00	227 ± 30.33	163 ± 10.98	469 ± 78.45	244 ± 46.54

BRBP: before rice crop residue burning period (August–September); DRBP: during rice crop residue burning period (October–November); ARBP: after rice crop residue burns (December–January); BWBP: before wheat crop residue burning period (February–March); DWBP: during wheat crop residue burning period (April–May); AWBP: after wheat crop residue burns (June–July); Data are presented as mean ± stdv.

Table 3
Difference in PFTs values of children and young age group BRBP[a] with respect to different periods[a] (by using t-test).

PFTs (%)	Period	Children (11 to 13 years)				Young (20 to 35 years)			
		Difference[b]	(95% CI)	t	p	Difference[b]	(95% CI)	t	P
FVC	DRBP	8.272	(7.462; 9.081)	20.579	<0.001	5.998	(4.737; 7.258)	9.681	<0.001
	ARBP	3.666	(3.301; 4.031)	20.238	<0.001	2.131	(1.074; 3.186)	4.105	<0.001
	BWBP	7.298	(5.310; 9.285)	7.396	<0.001	−0.518	(−1.529; 0.494)	−1.04	0.306
	DWBP	8.658	(7.118; 0.197)	11.329	<0.001	4.195	(3.041; 5.348)	7.397	<0.001
	AWBP	5.737	(4.247; 7.227)	7.756	<0.001	−0.999	(−2.653; 0.655)	−1.23	0.228
FEV_1	DRBP	11.710	(10.690; 12.729)	23.137	<0.001	7.262	(5.589; 8.933)	8.838	<0.001
	ARBP	6.434	(5.926; 6.942)	25.512	<0.001	3.215	(1.988; 4.441)	5.334	<0.001
	BWBP	7.777	(6.319; 9.234)	10.748	<0.001	0.343	(−1.264; 1.949)	0.434	0.667
	DWBP	11.737	(10.150; 13.323)	14.898	<0.001	5.497	(3.935; 7.058)	7.161	<0.001
	AWBP	8.386	(6.871; 9.899)	11.156	<0.001	−0.516	(−2.744; 1.713)	−0.47	0.641
PEF	DRBP	3.955	(3.594; 4.315)	22.094	<0.001	7.711	(5.550; 9.871)	7.261	<0.001
	ARBP	2.882	(2.664; 3.099)	26.653	<0.001	2.033	(−0.927; 4.993)	1.397	0.172
	BWBP	5.580	(3.818; 7.341)	6.381	<0.001	−0.547	(−2.667; 1.573)	−0.53	0.603
	DWBP	6.842	(5.107; 8.575)	7.948	<0.001	1.954	(−0.725; 4.633)	1.484	0.147
	AWBP	5.079	(3.336; 6.820)	5.873	<0.001	−2.778	(−5.535; −0.019)	−2.05	0.048
$FEF_{25–75\%}$	DRBP	7.768	(7.040; 8.496)	21.487	<0.001	7.078	(3.860; 10.295)	4.476	<0.001
	ARBP	5.587	(5.214; 5.959)	30.211	<0.001	2.010	(−2.107; 6.127)	0.993	0.328
	BWBP	6.834	(5.365; 8.301)	9.376	<0.001	−0.497	(−3.001; 2.005)	−0.4	0.689
	DWBP	8.712	(7.226; 10.198)	11.812	<0.001	4.609	(0.683; 8.534)	2.389	0.023
	AWBP	5.224	(3.741; 6.705)	7.1	<0.001	0.547	(−2.888; 3.981)	0.324	0.748

[a] BRBP: before rice crop residue burning period (August–September); DRBP: during rice crop residue burning period (October–November); ARBP: after rice crop residue burns (December–January); BWBP: before wheat crop residue burning period (February–March); DWBP: during wheat crop residue burning period (April–May); AWBP: after wheat crop residue burns (June–July).
[b] Mean difference between the PFTs values obtained at each measurement period and those in BRBP.

decrease in PFT values is in the order $PM_{2.5}>PM_{10}>SPM$. Results show that effect of small size particulate matter is found to be higher as compared to larger size particulate matter. The nasal turbulence mechanism for removing particles from air is so effective that almost no particle larger than 10 μm in diameter enters the lung through the nose but respiratory filtration system could not entrap particular matter with size less than 2.5 μm which pass the respiratory filtration system and enter the alveoli, diffuse through the walls of the alveoli and adhere to alveolar fluid. Due to this, available surface area for gas exchange mechanism gets affected and hence PFTs show significant decrease in their values with the increase of small size particulate matter i.e., $PM_{2.5}$.

One possible factor for decrease in PFTs could be quality of lung function maneuvers that might have decreased over time because of decreased efforts of the subjects. If decreasing efforts was the only reason for the decline in the value of PFTs, then the values should have continued to decline after the completion of burning of wheat and rice residue; however, results showed that after the completion of exhaustive burning period i.e. in December and June the value of PFTs increased. Variation of PFTs over time was not influenced by the technical effects (e.g. possible irregularity in taking sample), because necessary care like minimum of three acceptable maneuvers with less then 5% difference between consecutive maneuvers were done during the whole study period of the measurement.

Table 4
Association between pulmonary function value and different size particulate matter.

Particulate matter type	PFTs (%)	Changes[a]	(95% CI)	p-value
$PM_{2.5}$ (Increment 10 μgm^{-3})	FVC	−0.943	(−1.718, −0.169)	<0.05
	FEV_1	−1.251	(−2.149, −0.353)	<0.05
	PEF	−0.725	(−1.152, −0.299)	<0.05
	$FEF_{25–75\%}$	−0.939	(−1.801, −0.076)	<0.05
PM_{10} (Increment 10 μgm^{-3})	FVC	−0.625	(−1.068, −0.181)	<0.05
	FEV_1	−0.804	(−1.326, −0.281)	<0.05
	PEF	−0.433	(−0.703, −0.163)	<0.05
	$FEF_{25–75\%}$	−0.584	(−1.107, −0.061)	<0.05
SPM (Increment 10 μgm^{-3})	FVC	−0.151	(−0.260, −0.041)	<0.05
	FEV_1	−0.192	(−0.323, −0.062)	<0.05
	PEF	−0.092	(−0.168, −0.017)	<0.05
	$FEF_{25–75\%}$	−0.122	(−0.260, 0.016)	0.07

[a] Pulmonary function mean value change for 10 μgm^{-3} increments of different size particulate matter.

There are several limitations in this study including the lack of personal exposure data, small number of subjects and the possibility of other air pollutants effect. Since significant decrease in the value of PFTs were seen two times in the study, first in the period of rice crop residue burning and second time during the wheat crop residue burning, which illustrate that ACRB induced negative effect on the PFTs of healthy inhabitants. Moreover, large significance level ($p<0.001$) for the mean difference in the PFT values of subjects before and after the burning period of rice and wheat residue burning increase the reliability of the results. Current study is in good agreements with other studies, in which increase in pollution due different reasons affect the health status (hospital admission or respiratory symptoms or mortality and morbidity rate) (Cao et al., 2009; Hoek et al., 2002; Jeffrey et al., 1997; Moris, 2001; Ostro, 1984; Schwartz et al., 1996; Schwartz, 2004).

4. Conclusion

Open burning of agriculture crop residue is episodic but still a serious issue for both health and environment perspectives. Present study reveals that due to ACRB there is a significant increase in the concentration of particulate matter, which had a negative effect on the PFTs of the healthy subjects with higher contribution of $PM_{2.5}$ and PM_{10}. Increase in pollution level due to ACRB posed more and unrecoverable decrease in PFTs of the children as compared to young age group. Study showed that children are at higher risk due to ACRB and possess some permanent decrease in their PFTs by the increase in pollution level. In the initial stage of life, if any permanent effects are added, proper development of lung function would be affected which in due course of time may lead to lowering the respiring capacity of the adult and cause a major epidemiological hazard. Thus, ACRB is really big and serious health issue on which necessary steps must be taken and if this is not controlled at present it will become a more serious health issue in coming years, because with time new technique and machinery would be used for harvesting that might produce more residues on fields. Therefore, health research strategies should focus on how to control this open crop residue burning.

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