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Mohd Golshan
Isfahan University of Medical Sciences

Payam Dadvand
Barcelona Institute for Gloal Health (ISGlobal)

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Early effects of burning rice farm residues on respiratory symptoms of villagers in suburbs of Isfahan, Iran

MOHAMMAD GOLSHAN, MEHRI FAGHIHI, TOORAJ ROUSHAN-ZAMIR, MOHAMMAD MASOOD MARANDI, BEHNOOSH ESTEKI, PAYAM DADVAND, HOOSHMAND FARAHMAND-FAR, SHARAREH RAHMATI and FIROUZEH ISLAMI

Isfahan University of Medical Sciences, Isfahan, Iran

Villagers residing in areas with rice farms are exposed to smoke from burning of agricultural waste that may affect respiratory health. To assess respiratory effects of this smoke-induced air pollution, a cross-sectional study has been conducted in three randomly selected villages of Isfahan rural areas. A physician-administered health questionnaire was completed for 433 male and 561 female villagers aged 1–80 years, followed by physical examinations and spirometry in symptomatic cases, before and after a rice burning episode in October 2000. Total particulate and respirable particulate maters (PM10) was doubled during burning episode. Prevalence rates for respiratory symptoms before smoke were: recent asthma attacks (7.7%), using asthma medications (3%), sleep disturbed by dyspnea and cough (7.4%), exercise-induced cough (13.3%), which increased to 9.5, 7.1, 9.3 and 17%, respectively. Mean initial values (as percent of prediction) for; FEV1, FEV1/FVC, PEFR, and FEF25–75 were: 85.9 ± 22.7, 81.7 ± 8, 86.2 ± 26.2 and 60 ± 26.4, respectively. The mentioned values decreased to to 83.2 ± 19.5, 76.5 ± 10.3, 85.5 ± 21.1 and 54.3 ± 26.4, respectively. All of the clinical and spirometric changes were statistically significant. Study findings suggest increased respiratory morbidity associated with rice burning episodes among all people living in the area.

Keywords: Air-pollution; rice; farm; burning; burn; respiratory; symptom; respiratory-health.

Introduction

Acute smoke inhalation as a result of fires is a major problem in urban areas (American Academy of Pediatrics 2000) and has been well studied during the last two decades. Acute exposure to heat, particulate matter (soot), and gases such as carbon monoxide and hydrogen cyanide can result in respiratory tract burning, asphyxia, and poisoning (Haponic 1993). Chronic exposure to air pollution, especially in larger cities, which is usually related to the internal combustion engine (Steerenberg *et al.* 2001) is also known, and its deleterious effects on the tracheobronchial tree and resultant disorders have been frequently studied all over the world. Severe structural and functional impairments both in the upper (Caldern-Garcidueas *et al.* 2001) and lower (Tzankis *et al.* 2001) respiratory tract are recorded in those exposed to air pollution.

Correspondence: Mohammad Golshan MD, PO Box 81655/755, Isfahan, Iran. Tel.: +98311-6276101/2228204; Fax: +98311-2228204; E-mail: golshan@medscape.com

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Both short-term (Schindler *et al.* 2001; Smith *et al.* 2000), and long-term (Mukae *et al.* 2001; Pauwels *et al.* 2001) exposures can induce clinical and/or functional respiratory impairments. However, subacute smoke inhalation, which usually happens to those living in the neighborhood of fires, not close enough to be grossly injured, have been seldom discussed (McCurdy *et al.* 1996; Jacobs *et al.* 1997; Long et al. 1998).

Every October in Isfahan after harvesting the rice farms, farmers burn the rice residues (straw and stubble) to prevent the growth of insect larvae. The serial burning in the area lasts for a few weeks. At these times, a thick cloud of smoke covers the fields and households of a large area in the villages, close to Isfahan suburbs, which potentially can injure the respiratory tract of the healthy inhabitants, and more obviously aggravate the pre-existing respiratory disorders.

The purpose of this study is to compare the respiratory health status of the inhabitants of the villages of the rice farms before and after burning the rice residues, to elucidate the possible respiratory risk of this kind of sub-acute smoke inhalation.

Subjects and methods

The Committee for Medical Ethics at Isfahan University of Medical Sciences approved the protocols and methods.

Assuming a 5% prevalence rate of airways diseases in the population, 680 people residing in the area were estimated to be sufficient for the study. Three of the 78 villages found in the map of the area were randomly selected for the study. All people living in these three villages were considered to be enrolled in the study. When these three villages were visited, the actual total population was 1,127 individuals who were all included in the group.

A four-step approach was used for the survey. For the first step, four interns of Isfahan Medical School attended the villages, visited all houses, and asked all people living in the houses to come to local public health office for a free medical interview and physical examinations. Since many of the family members may not have been home at first visit, they repeated the visits on several occasions and at different times to see all members. The medical interview and physical examinations were performed by interns. To make uniform interviews and medical recordings the interns used a popular respiratory questionnaire (Fishman *et al.* 1998) as the backbone of the interview.

For the second step, those participants complaining of respiratory symptoms, and/or having evidence of airway diseases other than recent colds, were referred to the pulmonary clinic of St. Zahra Medical Center for a free visit with a pulmonolgist and a routine spirometry if the subject was co-operative enough to perform the standard maneuvers. At this second stage, 134 subjects were invited.

Spirometric parameters that were recorded for comparisons included: forced vital capacity (FVC), forced expiratory flow in the first second of expiration (FEV1), the ratio of FVC/FEV1, peak expiratory flow rate (PEFR), and mean expiratory flow rate at middle half of expiration (FEF 25–75).

One hundred and six cases completed the second stage. The response rate for the second stage was 79%.

Steps one and two were completed during August and September 2000.

The amount of air-suspended particulate maters (PM10) in 14 randomly selected outdoor loci in the area were measured, both before and a few weeks later, during the active phase of burning process. PM10 dust measurements were performed using Teflon filters of 37 mm diameter and 1 μm pore size, and three pieces cassette holder connected to a personal sampling pump (SKC, model 224-PXR3) operating at a flow rate of 1.5 l/min. Respirable dust samples were collected using a 10-mm Dorr-olive cyclone on series with 37-mm Teflon filters and the above pump at a flow rate of 1.7 l/min. The mass of dust in all samples was determined gravimetrically.

One week after completion of the latest burns, all of the procedures of the first two steps were repeated to complete the study.

In the fourth step, all of the stage two cases and also newly symptomatic persons were invited for interview and spirometry. However, pulmonary function test or auscultation comparisons were applicable only in those with a set of two spirometries and/or two physical examinations.

Broncho-alveolar lavage (BAL) was performed in one patient with cough and hemoptysis after a burn episode, which showed a mild increase in cell population of the lavage fluid with 26% lymphocytes and 8% neutrophils.

The findings were collected in a database and analyzed by the statistical package for the social sciences (SPSS for Windows, ver 10.05, SPSS Chicago, IL). Dependent samples *t*-test was used to compare nominal or categorical variables. Numerical variables were compared using compare means of the package.

Multivariate analysis was used to determine the association of post-pollution symptoms with previous histories of respiratory illnesses and also air pollution.

Results

Of the initially invited 1,127 inhabitants of the area, 994 (88.2%) accepted enrolment in the study. The major reason for refusal was having no time to come to the clinic.

The final subjects who successfully completed the first stage of the study comprised 561 female and 433 male subjects, ranging in age from 1month to 80 years (Mean $\pm$ SD $= 25.2 \pm 17.5$). The data available from the initial, phase one interview suggested that a higher proportion of non-responders ($n = 105/133$) were male. Response rates for male and females in first phase were 80.5 and 95.2%, respectively.

In the second stage, the 28 non-responders were generally less symptomatic (as judged by the initial phase one interview) than were responders. For example, the prevalence of wheeze or whistle in the chest in the last 12 months was 11.3% in the non-responders in comparison with 42.3% in the responders ($P < 0.0001$).

Table 1. Demographic characteristics of the population sample

	n	%
Sex		
Male	433	43.6
Female	561	54.4
Age		
≤ 20	521	52.4
21–50	362	36.4
≥ 51	111	11.2
Current smokers	72	7.8
Ex-smoker	13	1.4

Table 2. Upper and lower respiratory tract symptoms before and after burning rice residues

Illness or symptom	*Before burn*		*After burn*		*P value*
	(n)	*(%)*	*(n)*	*(%)*	
Using asthma medication at the time of interview	30	3	71	7.1	<0.000
Asthmatic attacks in last 3 weeks	77	7.7	94	9.5	<0.006
Recent disturbing cough	170	17.1	194	19.5	<0.000
Recent wheezy breathing	81	8.1	100	10.1	<0.002
Sleep disturbed by dyspnea and/or cough	74	7.4	93	9.3	0.002
Exercise induced cough	132	13.3	169	17	0.004
Nose block	114	11.5	151	15.2	0.049
Rhinorrea	55	5.5	135	13.6	0.01
Sneezing	119	12	129	13	0.003
Conjunctivitis	99	10	141	14.1	0.002
Obstructive pattern in spirometry* (FEV1/FVC ratio <75%)	16	22.2	28	35.9	0.001

* Percent calculated from the tested cases.

The response rates for stages 3 and 4 were 87.8 and 79%, respectively, which are close to the first two stages.

The study population, according to demographic factors, smoking status and number of subjects satisfactorily completing pulmonary function testing, is presented in Table 1.

Nearly all of the women were housewives also involved in farm jobs, with 10 teachers, three hairdressers, and four tailors in the group.

Most of the men were farmers; however, many of them were also involved in small industrial and/or clerical jobs and office services in the area. Unfortunately many of the recorded men's extra job titles were poorly defined and could not disclose the possible pulmonary risks. So they were not used for risk estimations.

The frequency of respiratory disorders and related symptoms in stages 1 and 2, and changes observed after burning of the residues (stages 3 and 4) are summarized in Table 2.

In the second stage, only 79 of the 134 invited cases (58.9%) underwent pulmonary function testing, others (mostly young children) were unable to perform satisfactory forced vital capacity

Table 3. Mean values of spirometric parameters before and after burning rice residues

Spirometric parameter	*Before smoke episode (Mean ± SD)*	*After smoke episode (Mean ± SD)*	*Significance*
FVC	92.9 ± 19.7	93.2 ± 13	= 0.69
FEV1	85.9 ± 22.7	83.2 ± 19.5	< 0.000
FEV1/FVC ratio	81.7 ± 8	76.5 ± 10.3	< 0.000
PEFR	86.2 ± 26.2	85.5 ± 21.1	< 0.002
FEF25–75	60 ± 26.4	54.3 ± 26.4	< 0.000

Table 4. Mean concentrations of ambient air particulate maters in the studied villages

Particulate matter (mg/m3)	*Before smoke episode (Mean ± SD)*	*During smoke episode (Mean ± SD)*	*Significance*
Total particulate matter	2.36 ± 0.95	4.61 ± 1.56	< 0.000
Respirable particulate matter	1.11 ± 0.46	2.27 ± 0.65	< 0.000

maneuvers. Fortunately all of these 79 were able to complete the later two stages, and fairly analyzable data were collected.

The main parameters of spirometric recordings of the 79 cases (Mean ± SD) before and after burning the residues are summarized in Table 3.

Most of the new sufferers of dyspneal attacks, and night dyspnea and/or cough, as recorded in stages 3 and 4 of the study, had previous histories of similar conditions; however, two toddlers experienced wheezy respiratory illness for the first time in life in these smoke exposure days. In multivariate analysis, recent wheezy dyspneal attacks and night sleep disturbance due to respiratory symptoms after burning episode were significantly associated with previous histories of: cigarette smoking ($P < 0.01$), chronic bronchitis ($P < 0.05$), asthma ($P = 0.007$) or related symptoms ($P < 0.01$–0.001).

The results of particulate matter (PM10) measurements are included in Table 4.

Discussion

Smoke inhalation is an important cause of acute lung injury in humans and is associated with a high mortality rate (Laffon *et al.* 1999). Smoke inhalation affects both pulmonary endothelial and epithelial barriers (Laffon *et al.* 1999).

A large number of the lower-molecular weight constituents of smoke are toxic to the bronchial mucosa and alveoli because of their physical and/or chemical properties, or their ability to form free radicals. Examples include ammonia, aldehydes, chlorine, hydrogen chloride, SO_2, NO, NO_2, phosgene and many other known or even unknown agents (Haponic *et al.* 1988). The smoke constituents when inhaled in sufficient concentrations tend to produce acute neutrophilic airway inflammation associated with symptoms consisting of cough, bronchorrhea, dyspnea and wheezing (Laffon *et al.* 1999), the symptoms may appear early or with a significant delay after exposure (Haponic *et al.* 1988). Increased alveolo-capillary permeability, impaired lymphatic flow (Laffon *et al.* 1999), and pulmonary edema may also ensue after heavy exposures (Soejima *et al.* 2001).

However, repeated exposures to lower concentrations of smoke may not induce acute injuries and can contribute to development of chronic respiratory illnesses including asthma (Kinsella *et al.* 1991), chronic bronchitis and COPD (Pauwels *et al.* 2001).

Subacute smoke inhalation with borderline concentrations can result in both; acute respiratory derangement and prepare the victims to develop chronic respiratory illness. In a previous survey in Canada, deleterious effects of smoke arising from burning agricultural residues had been observed on aggravation of previous respiratory symptoms of patients suffering COPD (Long *et al.* 1998). However, they did not elucidate the possible effects on respiratory health of asymptomatic inhabitants in the area.

In the present study, randomly selected people were enrolled and classic medical interviews were carried out, from which the responses to respiratory questions were extracted and the involved interns completed the questionnaires in all stages. Therefore, the answers recorded in the questionnaires are more likely to represent the facts.

As seen in Tables 2 and 3, significant increases both in the number of symptomatic cases and the severity of the previous disorders, as reflected in reduced FEV1 and FEF25–75 of the symptomatic cases, can be observed. These data confirm that exposure to smoke produced by burning agricultural residues induces pulmonary symptoms in previously asymptomatic inhabitants, possibly due to acute inflammation of airways, and also can aggravate previous symptoms in susceptible patients. The latter finding looks more obvious, since symptomatic individuals are more likely to seek medical assistance, but late morbidities associated with repeating exposures of uncomplaining persons to such contaminated air have been frequently reported (Long *et al.* 1998; Dow *et al.* 1999; Gold *et al.* 2000), and should be of concern for communities and physicians, especially in developing countries.

Significant increases in suspended particulate maters (PM10) were recorded in the ambient air in the area during the burning episode (Table 2), which seems to be responsible for the observed pulmonary symptoms.

The findings of the present study are in accord with previous reports on the deleterious pulmonary effects of smoke induced by burning of agricultural residues or biomass fuels used in developing countries (Bruce *et al.* 2000; Gold *et al.* 2000).

A recent study has established that the burning agricultural or forest residues can expose local communities to relatively high levels of pollutants (Reinhardt *et al.* 2001).This high level of air pollution does not remain local and confined to nearby areas; it can affect places many kilometers away from the burning sources (Lelieveld *et al.* 2001).

There is evidence confirming that prolonged subacute exposure to biomass smoke can induce chronic pulmonary parenchymal (Amoli 1998; gold *et al.* 2000), and/or chronic obstructive pulmonary disease (Bruce *et al.* 2000).

Conclusions

Air pollution associated with the burning of agricultural residues is capable of aggravating pre-existing dyspnea, cough, night cough, night chest discomfort and exercise-induced cough in patients with chronic respiratory illnesses. Furthermore, smoke exposure can induce all of the above-mentioned symptoms in previously asymptomatic subjects. Also, obstructive spirometric patterns are more often recorded after smoke exposure.

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