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Original Article

Lung Function Impairment Among Firefighter After Wildfire in Riau, Sumatra

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Abstract

Background: *The 2015 forest fire disaster affected almost 2.6 million hectares of land in Indonesia, and Riau was among the worst. Firefighters were the first responders to deal with the disaster, but a little was known about the influence of extinguishing forest fire activities with their health. This study aimed to evaluate respiratory symptoms and lung function among firefighters 6 months after forest fire exposure.*
Methods: *Interviews were conducted regarding sociodemographic factors, respiratory symptoms, and history of forest fire exposure during the disaster. Spirometry and chest X-ray were also carried out with standard techniques. Statistical analysis was performed based on the existing data. Ninety firefighters participated in this study, most were male with mean age of 33 years old. About 66% were smoker, had been working as firefighters for 2 to 10 years, and had been on extinguishing forest fire duty around 2–5 hours/day during the disaster.*
Results: *All firefighters reported respiratory symptoms after 3 months. Pulmonary function was abnormal in 50% of subjects with mild restrictive characteristic. The analysis showed that body mass index (BMI) and duration of exposure had a significant correlation with pulmonary function abnormality.*
Conclusion: *Pulmonary function was found abnormal in most subjects 6 months after forest fire exposure in Riau.* ***(J Respirol Indones 2021; 41(4): 221–7)***
Keywords: *Firefighter, forest fire, Indonesia, lung function.*

Gangguan Fungsi Paru Para Pemadam Kebakaran Setelah Bencana Kebakaran Hutan di Riau Sumatera

Abstrak

Latar Belakang: *Bencana kebakaran hutan tahun 2015 mencakup hampir 2.6 juta hektar lahan di Indonesia, dan Riau merupakan salah satu daerah terburuk. Pemadam kebakaran merupakan profesi utama yang menangani bencana tersebut, namun sedikit diketahui mengenai pengaruh kegiatan pemadaman kebakaran hutan dengan kesehatan mereka. Penelitian ini bertujuan menilai gejala respirasi dan fungsi paru 6 bulan pascakebakaran hutan.*
Metode: *Wawancara dilakukan untuk mengetahui faktor sosiodemografis, keluhan respirasi dan riwayat pajanan selama bencana kebakaran hutan. Spirometri dan foto toraks juga dilakukan dengan teknik standar. Analisis statistik dilakukan menggunakan data yang ada. Sembilan puluh petugas pemadam kebakaran turut serta dalam penelitian ini, sebagian besar laki-laki dengan rerata usia 33 tahun. Sekitar 66% subjek adalah perokok, telah bekerja sebagai pemadam kebakaran antara 2-10 tahun, dan bertugas memadamkan kebakaran hutan 2-5 jam/hari selama bencana.*
Hasil: *Semua pemadam kebakaran melaporkan keluhan respirasi setelah 3 bulan. Ditemukan penurunan fungsi paru pada 50% subjek penelitian dengan karakteristik restriksi ringan. Analisis statistik menunjukkan bahwa indeks massa tubuh (IMT) dan durasi pajanan kebakaran hutan memiliki hubungan bermakna dengan kelainan fungsi paru.*
Kesimpulan: *Ditemukan penuruan fungsi paru pada sebagian besar subjek 6 bulan setelah kebakaran hutan di Riau.* ***(J Respirol Indones 2021; 41(4): 221–7)***
Kata Kunci: *Pemadam kebakaran, kebakaran hutan, Indonesia, fungsi paru.*

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INTRODUCTION

Forest fires/wildfires in Indonesia have become a regional problem especially in Southeast Asia. Almost every year forests in Indonesia are affected by fire, particularly in the long dry season. In 1997, forest fires were very severe, estimated to hit an area of up to 300,000 hectares. In June to December 2015, forest fires in Indonesia were greater as it was estimated that 2.6 million hectares of land consisting of peatlands, palm oil plantation and tropical forests were burned. Riau, Sumatra was among the worst area affected by wildfires in 2015.[1] According to the Meteorological, Climatology and Geophysics Agency report, in September 2015, Tera and Aqua satellites monitored 390 hotspots on Sumatra Island and 14 of them were in Riau Province. During wildfires, one of the institutions authorized to extinguish the fire was the firefighter department.[2]

Firefighter is a very high-risk occupation with potential direct occupational hazard and accidents, also sometimes with fatal consequences such as permanent disability or death.[3] In addition, long term health effect of smoke exposure could directly increase the risk of respiratory diseases, cardiovascular diseases or cancer. During forest fires, firefighters have increased risks of noxious gas and haze exposure and have the potential to increase the health problems risks, including in short-term, medium-term and long-term period.[3]

This study aimed to assess mid-term effect of lung function among firefighters 6 months after the occurrence of wildfires on 2015 in Riau, Sumatra.

METHOD

Cross sectional study was conducted at Department of Firefighter in Pekanbaru, Riau on May 2016, six months after wildfires in Riau, Sumatra. Accessible population was all firefighters who were still active in Pekanbaru, had served actively in extinguishing fires and were exposed to forest fires smokes during June to December 2015 in Riau province. Sampling was carried out by consecutive sampling in which every affordable population that met the study criteria was included as a subject to meet the required sample size after signing the informed consent.

Indonesian version of American Thoracic Society (ATS) respiratory questionnaire was administered to measure pulmonary symptoms that consisted of cough, productive cough with sputum, difficulty in breathing or dyspnea, and wheezing.[4] We interviewed each subject over the last 3 months period. Smoking status was defined as “smoker “if subjects smoked 100 cigarettes during his or her lifetime; and ‘Non-smoker’ if never smoked or smoked less than 100 cigarettes during lifetime. Brinkman index (BI) was measured by the number of cigarettes smoked per day multiplied by the number of years of smoking and classified as mild if BI 1–200; moderate if 201–600, and severe if >600.

Duration of working as firefighter was defined as the duration of duty since registered as a firefighter and recorded in year. We measured duration of forest fire exposure based on the log book in Department of Firefighter Pekanbaru Riau during the disaster in June to December 2015 which recorded daily duty activities in forest fire. Exposure time was measured by total hours on duty divided by number of days on duty during the disaster period and categorized as follows: <2 hours/day; 2–5 hours/day; 5–8 hours/day and >8 hours/day.

Protective equipment used during wildfire smoke exposure were also obtained by asking the face mask usage during interview and classified as routine if subjects wear it more than 4 days in a week of working days, otherwise it was classified as rarely. Body Mass Index (BMI) was measured by dividing the weight (kg) per square meter of height and classify as obese if BMI >25; overweight if BMI 23–24.9; normoweight if BMI 18.5–22.9 and underweight if BMI <18.5.

Pulmonary function test of forced vital capacity (FVC) maneuvers was measured by spiroanalyzer ST 95, Fukuda Sangyo Japan in compliance with American Thoracic Society standard procedure recommendation.[5] The best of at least three technically appropriate measurements for forced expiratory volume in one second (FEV_1), FVC, and FEV_1/FVC were recorded. The results were classified

as restrictive type if FVC <80% of the predicted values; obstructive type if FEV_1 <80% of the predicted values; and combined type if both criteria were fulfilled. The severity of pulmonary function abnormalities was classified as mild (70–79%), moderate (60–69%), and severe (<60%).

Chest X-ray postero-anterior view (CXR-P/A) was performed to screen lung abnormality and examined by radiologist. The CXR was categorized as abnormal if there was an abnormal finding in lung and/or the thoracic cage structures.

Data were processed and analyzed using the Statistical Package for Social Sciences (SPSS) program 17. Descriptive analysis were shown using tables describing the frequency and percentage for categorical data as well as median and distribution values for numerical data. Statistical analysis was carried out appropriately based on the data characteristics with *P*<0.05 (two-tailed) considered as significant and a Power of 95%.

RESULTS

This study recruited 90 firefighters with the following distribution of subjects' characteristics: the majority of the subjects were male (96.7%), with median age of 33 years old, (ranged from 21 to 48 years old). About 66% of subjects were smoker and 51% used personal protective equipment (PPE) routinely but mostly only ordinary face masks, as seen in Table 1. We measured the duration of exposure based on the log book and most subjects worked for 2-5 hours a day in the frontline. In addition, there were less than 10 small forest fire spots and less than 10 household fires in Pekanbaru Riau between January and May 2016.

After 6 months off duty in wildfires in Riau, all firefighters reported respiratory symptoms during the last 3 months period. The most common respiratory symptoms reported were productive cough of 33.3% (30 subjects), followed by dyspnea 32.2% (29 subjects), wheezing 20% (18 subjects) and cough 14.4% (13 subjects). Almost all subjects had normal CXR images (89 subjects or 98.9%), as shown in Table 2.

Table 1. Characteristics of firefighters in Pekanbaru Riau (N=90)

Characteristics	N	%
Age		
<30 years old	32	35,4
30–39 years old	49	53,8
40–49 years old	9	10,8
Sex		
Male	87	96,6
Female	3	3,4
Education		
High school	66	73,3
College	24	26,7
Personal protective device usage		
Routine	46	51,1
Rarely	44	48,9
Body Mass Index		
Underweight	8	8,9
Normoweight	29	32,2
Overweight	14	15,6
Obesity	39	43,3
Duration of extinguishing forest fire during the disaster		
<2 hours/day	6	6,7
2–5 hours/day	53	58,9
5–8 hours/day	20	22.1
>8 hours/day	11	12,2
Duration of work as firefighter		
<5 years	18	20,0
5–10 years	61	67,7
10–15 years	5	5,5
>15 years	6	6,2
Smoking status		
Non smoker	31	34,4
Smoker	59	66,2
Brinkman index		
Mild	24	26,7
Moderate	30	33,8
Severe	5	5,4

Based on spirometry results, the pulmonary function of subjects 6 months after the wildfires in Riau were found abnormal in 50% (45 subjects) with mostly mild restrictive characteristic in 41.5% (37 subjects). Another spirometry parameters found were: vital capacity (VC) of 3922.36±622.30 ml (mean±SD), FVC of 3207.97±613.52 ml (mean±SD) and FEV_1 of 3163.21±3304.3 ml (mean±SD).

The correlation of sociodemographic characteristics with pulmonary function in firefighters in Pekanbaru can be observed in Table 3. The analysis pointed that statistically, sociodemographic factors of gender, age, education, PPE usage, smoking status did not have significant differences (*P* >0.05), while BMI and duration of exposure showed a significant correlation with pulmonary function abnormality, as seen in Table 3.

Table 2. The correlation of sociodemographic characteristics with pulmonary function test abnormality

Characteristics	Normal	Restrictive	Obstructive	Mixed pattern	*P*
Age					
<32 years old	15	18	2	2	0.523
≥32 years old	29	21	2	1	
Sex					
Male	43	37	4	3	0.853
Female	1	2	0	0	
Educational level					
High school	36	32	4	2	0.713
College	8	7	0	1	
PPE usage					
Routine	26	17	1	2	0.336
Rarely	18	22	3	1	
Smoking status					
Smoker	27	27	3	2	0.929
Non smoker	10	7	1	1	
Ex-smoker	7	5	0	0	
BMI					
Underweight	2	4	0	2	[a]0.035
Normoweight	17	9	2	1	
Overweight	8	6	0	0	
Obese	17	20	2	0	
forest fire exposure					
<2 hours/day	4	0	0	2	[a]0.006
2-5 hours/day	26	24	2	1	
5-8 hours/day	11	7	2	0	
>8 hours/day	7	4	0	0	

Note: [a]Kruskal Wallis test; BMI: body mass index; PPE: personal protective equipment

Table 3. Distribution of respiratory symptoms, CXR, and pulmonary function in firefighters in Riau (n=90)

Variables	N	%
Respiratory symptoms		
Cough	13	14.4
Productive cough	30	33.3
Dyspnea	29	32.2
Wheezing	18	20
No symptoms	0	0
Chest X-ray		
Normal	89	98.9
Abnormal	1	1.1
Spirometry		
Mild obstructive pattern	3	3.3
Restrictive	39	43.3
Mild restrictive pattern	37	94.9
Moderate restrictive pattern	2	5.1
Mixed	3	3.3
Normal	45	50

The analysis of the correlation between respiratory symptoms with pulmonary function in firefighters showed that subjects with cough (13 subjects) had restrictive pattern in 9 subjects (69.2%), subjects with productive cough (30 subjects) had obstructive pattern in 2 subjects, restrictive pattern in 12 subjects and mixed pattern in 1 subject. Subjects with symptoms of dyspnea (29 subjects) had spirometry result of obstructive pattern in 1 subject, restrictive pattern in 14 subjects and mixed pattern in 2 subjects. Meanwhile, subjects with wheezing (18 subjects) had obstructive type and mixed type result in 1 subject of each and restriction type in 6 subjects. In this study, there were no significant correlation between subjects' respiratory symptoms and pulmonary functions (*P*=0.582).

DISCUSSION

Firefighter is a job with very high occupational risk and the clinical outcomes could appear immediately/acute, mid-term or long term after the exposure. Firefighters in Riau Province were one of the very active units who contributed in extinguishing forest fires disaster in 2015. They also had the risk of being exposed to large amounts of forest fires haze compared to ordinary people. This study evaluated

mid-term respiratory effects of firefighters 6 months after wildfires.

All subjects recruited had reported respiratory symptoms during the past 3 months. The most common respiratory symptoms were productive cough (33.3%) followed by dyspnea (32.2%), wheezing (20%) and cough (14.4%). Our study was similar to Austin, et al. who discovered that both acute and chronic respiratory symptoms did occur after forest fires exposure in firefighters as stated that 76% of the subjects experienced respiratory symptoms i.e., cough, wheezing, and dyspnea; and 70% of them experienced at least one of the neurological symptoms such as vertigo, headaches, balance disorders, dizziness, and even loss of consciousness.[6] Gaughan, et al. in 2005 explained that acute respiratory symptoms often arose and experienced by firefighters due to exposure to smoke from forest fires. The symptoms could even be chronic in nature and lasted for years.[7]

Based on smoking habits, 66.2% of firefighters in Riau were smokers. A study conducted by Austin, et al. pointed out that firefighters who actively smoked or were exposed to cigarette smoke without proper protection would easily experience carbon monoxide (CO) intoxication and had more respiratory symptoms.[6] Adetona, et al. showed that more firefighters in their study were active smokers than non-smokers, but there were no significant differences in lung function impairment.[8] A possible explanation might be that cigarette smoking did induce lung function impairment after long period of time, but not in short term for exposure to less than 5 years. Smoking is still needed to be overcome since it causes the health risks not only for the respiratory system but also another system in the body as well.[8]

Of all the demographic characteristics in this study, it was found that BMI was significantly different ($P < 0.05$). The duration of being firefighters and age did not significantly correlate with lung function impairment in this study. This was likely due to 58.9% of the firefighters in our study were currently overweight or obese. This finding was in accordance with the pathophysiology that overweight subjects were more likely to have restrictive pattern[9] and in this study 43.3% of the subjects had restrictive pattern. Obesity problem should be the focus of these firefighters since it could induce other unhealthy morbidity, -such as diabetes and heart problem-, and reduce the working capacity in this highly, -fit and resilience-needed occupation.

In performing their duty to extinguish forest fires, firefighters in Riau had understood the importance of wearing PPE masks. This was proven by 95.6% of firefighters in Riau who had used masks, although they were still not in accordance with standard N95 mask. This was because the availability of the standard N95 masks was difficult, and some firefighters felt uncomfortable with the use of standard N95 masks on duty. Study by Austin, et al. stated that a better respiratory protection for firefighters was the N95 mask that was in accordance with the International Standards Organization (ISO) 2002 standard. Austin, et al. also explained that the improper use of respiratory protections which were not standard would not protect a person from the effects caused by fires, therefore, proper self-protections corresponding to the standards were needed for the firefighters.[6] More educations related to PPE usage were also needed in this study group.

The important finding of this study was a significant difference ($P <0.05$) between the duration of exposure during wildfires and lung function impairment in firefighters. Exposure duration was the length of time firefighters exposed to forest fires smoke or on duty extinguishing forest fire during June and December 2015. Based on the duration of exposure, on average the firefighters were exposed for more than 2 hours/day in 58.9% of subjects, more than 5 hours/day in 34.3% subjects and less than 2 hours/day in only 6.7 % of subjects. Austin, et al. found that the mean exposure time of firefighters in carrying out their duties in the event of a major catastrophic fire was around 8 hours.[6]

This occasion required proper self-protection to prevent any direct and indirect effects which could occur. Our study was similar to the explanation of the National De Santé Publique Du Quebec article which

stated that short-term exposure to several days of exposure could cause various respiratory symptoms from acute to chronic symptoms.[9] Ferguson, et al. described spirometry results in firefighters at three different times including before, during, and one day after the fires. The study found that FVC and FEV_1decreased.[10] Study in Korea also observed the similar result of which pulmonary function declined in firefighters compare with non-firefighters.[11] Lung function among firefighters also declined after prescribed burns in Australia. This study showed that the impairment of lung function could be detected even after 6 months post-exposure.[12]

Based on the CXR, only 1.1% have abnormalities with bronchovascular and infiltrates in the upper left lung field, while the other 98.9% were normal. Our study was dissimilar with studies in South Korea.[11] Almost all studies assessed radiological examinations after firefighters experienced chronic symptoms that required radiological examination, however, in our study almost all CXR results were normal since they were evaluated in all subjects including non-symptomatics subjects. Chest x-ray abnormalities could be found in acute diseases such as pneumonia, or in chronic diseases, so it takes a long time for firefighters to experience abnormalities in their CXR.

Based on the literature, increased levels of gas components and smoke particles from forest fires in the air were associated with increased respiratory symptoms, reduced lung function, increased acute exacerbation of bronchial asthma and chronic obstructive pulmonary disease (COPD), increased visits to emergency departments, increased hospitalization, and possibly even death.[13] The chemicals that have been observed in biomass smoke of forest fire include major inorganic gases, hydrocarbons, oxygenated hydrocarbons, trace metals and particulate matters. Wildland fire smoke could also contain persistent organic compounds such as dioxins and furans.[8] Based on analysis of $PM_{2.5}$ component in forest fires smoke in Borneo, the major components of $PM_{2.5}$ in peat smoke haze consisted of sulphur, biomass burning component (BC, K), and crustal components (Al, Fe, Si). Sulphur mainly comes from the peat as it is the earliest stage of transition from compressed plants to the coal formation. The characteristics of forest fires in Sumatra and Borneo were mostly from peat-land and different from forest fires outside Indonesia. Long term effects in humans related to the chemical composition of this type need to be evaluated in the future.[14]

Limitations of this study included the study design that was a cross-sectional study with consecutive sampling. This design was selected based on the consideration of funds, time and available facilities. Regarding the pulmonary function test, we did not have the baseline spirometry value of these firefighters since it was not a routine test during recruitment, so we did not understand the changes compared with the baseline. We recommend the screening of lung function impairment regulary in this highly susceptible group.

Pulmonary diseases due to inhalation of toxic substances usually begin as a disorder in the parenchyma related to the defects in oxygen diffusion capacity. This early abnormality can be detected using pulmonary diffusion capacity (DLCO) examination. Spirometry abnormalities could only be detected if the spectrum of the parenchymal or airway disorders is large enough. The assessment of lung function in this study was based on spirometry data only, nevertheless, the results were sufficient to reflect the pulmonary abnormalities which occurred in the firefighters even after 6 monthsdealing with 2015 wildfires. Further studies are urgently required to follow the long-term health effects after wildfires of this vulnerable firefighters to determine the nature of the pulmonary impairment and its effect on firefighters' wellbeing.

The authors would like to thanks the Department of Firefighter, Riau Province, for the technical support in this study.

CONCLUSION

Respiratory symptoms were commonly reported by firefighters in Riau 6 months after the 2015 wildfires (midterm effect) and this was in line with

lung function impairment obtained by spirometry in half of the subjects. Although most were mild impairments, it is important to follow up the respiratory function to better understand its nature and most importantly to support the firefighters' wellbeing in the future.

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