Analysis of the impact of harmful factors in the workplace on functioning of the respiratory system of firefighters

Magdalena Witt¹, Mariusz Goniewicz², Witold Pawłowski³, Krzysztof Goniewicz⁴, Wiesława Biczysko⁵

¹ Department of Rescue and Disaster Medicine, Poznan University of Medical Sciences, Poland
² Medical University of Lublin, Department of Emergency Medicine, Poland
³ Medical University of Warsaw, Department of Disaster Medicine
⁴ Polish Air Force Academy, Faculty of National Security and Logistics
⁵ Department of Pathomorphology, Poznan University of Medical Sciences


Abstract

Introduction and objective. Firefighters are considered a healthy and fit group of individuals, well-prepared for taking action in disaster situations. While working, they suffer from exposure to certain toxic agents, especially combustion products generated when a fire takes place. Among them, the most frequent and the most toxic are: carbon monoxide, hydrogen cyanide, ammonia, and those resulting from PVC combustion – hydrochloride, phosgene and chloride. Additionally, fire-extinguisher powder can be inhaled and lead to certain lesion in the airways. The aim of study was to ascertain the influence of toxic agents present at the scene of fire on the lung tissue of firefighters, and also to study this on an animal model.

Materials and methods. The study group consisted of firefighters who had a minimum of 10 years service. After completing a questionnaire, their clinical status was ascertained based on a general examination, laboratory tests and lung function tests.

Results. Questionnaire analysis showed a high percentage of pathological symptoms in the studied group. The incidence of the symptoms correlated with the duration of occupational exposure to toxic agents. Among other results, obstruction of flow in medium airways in about 30% of the studied individuals represented the most important finding. Experimental tests were next performed on male Wistar rats, aged 3 months. They were insufflated with the solution of powdered fire-extinguisher, after which morphology specimens of lung tissue were studied. Evidence for disseminated fibrosis was obtained, which supported the previous clinical findings in the firefighters.

Conclusion. The above shows correlation between occupational exposure and respiratory system involvement in firefighters. This justifies covering the group of firefighters with special medical care focused on prophylaxis, early detection and therapy of pulmonary diseases.

Key words
firefighters, occupational environment, respiratory system, biological test, pathomorphologiae

INTRODUCTION

For some time, the occupational group of firefighters has been the object of medical research, aimed at finding the relationship between occupational exposure and its effects on the fireman’s body. It was found that the occupational exposure factors to which firefighters are exposed are primarily high temperatures, irritating, suffocating and toxic gases, vapours and dusts produced in the area of fire and extinguishing fire-extinguisher, after which morphology specimens of lung tissue were studied. Evidence for disseminated fibrosis was obtained, which supported the previous clinical findings in the firefighters.

The most important of harmful ingredients in the firefighters working environment is fire smoke. During the past 20 years, a long list of toxic substances released during a fire has been created and their adverse effects on the human body. Next to carbon monoxide and carbon dioxide, the following are mentioned: hydrogen cyanide, ammonia, hydrogen chloride, phosgene, chlorine, halogen acids, and many others [2].

An additional element which determines the dangers of the firefighter’s workplace are powder extinguishers. The dry chemical composition consists mainly of alkali metal bicarbonates, sulfates (especially potassium), orthophosphates and ammonium bisulfate, as well as silica and talc. Because of the fragmentation, the powder extinguishing agents have the ability to hang in the air in the form of dust for a long time. This dust, in people exposed to it, can easily penetrate into the respiratory system, causing irritation [3, 4].

Analyzing the acute impact which occupational exposure factors have on the respiratory tract of firefighters, inhalation injury is mentioned in the first place. This phrase stands for changes in the respiratory tract, arising as a result of thermal and/or chemical injury associated with the inhalation of fire smoke. However, in cases of chronic, long-time exposure to the noxious agents discussed above, other problems may...
occur, such as the development of non-specific bronchial hyperreactivity, bronchiectasis, chronic obstructive pulmonary disease (COPD), asthma, occupational asthma or lung cancer [5, 6]. COPD in patients who are particularly vulnerable, can lead to the development of pulmonary heart disease and severe heart failure. Silica and talc, also present in powder agent extinguishers, following many years of exposure can lead to the development of pneumoconiosis collagen: silicosis and t alcosis [3, 4]. The described changes are not only irreversible, but tend to spontaneously progress, even after the interruption of further exposure. Silica has been recognized by the International Agency for Research on Cancer as a probable carcinogen [7, 8].

OBJECTIVE

The aim of the study was to analyze the influence of harmful factors in the workplace of firefighters on the clinical and functional status of the respiratory system, and the morphological status of lung tissue of experimental animals.

MATERIALS AND METHOD

The first stage was conducted among the firefighter of the City Headquarters of the State Fire Service in Poznan, whose period of employment was a minimum 10 years, in a subjective examination of the survey type. The group comprised 160 men, of whom 119 were vocationally active and 41 were retired; 78 respondents (48.6%) smoked, 51 (31.9%) were former-smokers (i.e., those who in the course of the study did not smoke, but had smoked at least one cigarette a day or a pipe for a period of one year, based on the 'Questionnaire on respiratory symptoms' by MRC), and 31 (19.4%) firefighters were non-smokers. The control group consisted of 80 men aged 28–84 years – 68 active and 12 retired professionals. Their vocation performed in Poznan was not associated with the risks specific to the study group of firefighters. Both groups were subjected to an examination using the ‘Questionnaire on Respiratory Symptoms’ by the Medical Research Council (MRC), personally modified.

During the next stage, the selected group who presented symptoms justifying the suspected presence of lesions within the respiratory system, underwent a physical examination and additional tests. 78 of them (including 6 who had retired) acceded. Additional tests performed on the respondents were: morphology of peripheral blood erythrocyte sedimentation rate (ESR), ECG and chest X-ray. A blood gas test of capillary blood from the fingertip was performed, as was the analysis of the ECG of heart muscle showing no exponents characteristic of respiratory failure (Tab. 1).

Subjective and additional tests. In most cases, except for a few firefighters from the group of retirees, the physical examination did not produce any deviations from normality in terms of the respiratory and circulatory system. The results of a complete blood count and ESR were also located well within the normal laboratory range. At the same time, the blood gas test of arterialized capillary blood from the finger showed no exponents characteristic of respiratory failure among the study group. Analysis of the ECG of heart muscle did not demonstrate any significant deviations (in 93.6% of cases the record was in the normal range), and 93.6% of patients showed no deviation from the normal condition in their chest radiographic image.

Analysis of the data obtained on the basis of the functional study was to assess the results in terms of belonging to the

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Study group</th>
<th>Control group</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning cough</td>
<td>31.3%</td>
<td>10.0%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Cough during the day or at night</td>
<td>21.3%</td>
<td>2.5%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Morning expectoration</td>
<td>44.4%</td>
<td>16.3%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Expectoration during the day or at night</td>
<td>32.5%</td>
<td>13.8%</td>
<td>P&lt;0.0002</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>56.3%</td>
<td>20%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Paroxysmal  dyspnea with wheezing</td>
<td>25.0%</td>
<td>2.5%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Night attacks/ breathlessness</td>
<td>17.5%</td>
<td>1.3%</td>
<td>P&lt;0.0001</td>
</tr>
<tr>
<td>Symptoms of bronchial hyperreactivity</td>
<td>38.3%</td>
<td>15.0%</td>
<td>P&lt;0.0001</td>
</tr>
</tbody>
</table>
Table 2. Percentage distribution of functional parameters in the group of firefighters with regard to changes in the distribution of mild, moderate and severe deviations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
<th>Mild deviation</th>
<th>Moderate deviation</th>
<th>Severe deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>76 respondents (97.4%)</td>
<td>-</td>
<td>-</td>
<td>2 respondents (2.6%)</td>
</tr>
<tr>
<td>FEV1%</td>
<td>69 respondents (88.5%)</td>
<td>9 respondents (11.5%)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FEV1</td>
<td>4 respondents (94.9%)</td>
<td>1 respondent (1.3%)</td>
<td>2 respondents (2.6%)</td>
<td>1 respondent (1.3%)</td>
</tr>
<tr>
<td>MVV</td>
<td>74 respondents (94.9%)</td>
<td>1 respondent (1.3%)</td>
<td>2 respondents (2.6%)</td>
<td>1 respondent (1.3%)</td>
</tr>
<tr>
<td>FMF</td>
<td>50 respondents (64.1%)</td>
<td>12 respondents (15.4%)</td>
<td>9 respondents (11.5%)</td>
<td>7 respondents (9.0%)</td>
</tr>
</tbody>
</table>

* – for FVC, FEV1, MVV, FMF, FEF obtained as a percentage of the predicted: a standard 100–80%, mild deviation 79–70%, moderate deviation 69–50%, heavy <50%; for Tiffaneau expressed as % of FVC: standard = 70%

Table 3. Disorders of airflow in airway of examined firefighters

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>FVC, FEV1 FVC, FEV1</th>
<th>Reduced</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>70 respondents (89.3%)</td>
<td>20 respondents (25.6%)</td>
<td>50 respondents (64.1%)</td>
</tr>
<tr>
<td>Obstruction</td>
<td>6 respondents (7.2%)</td>
<td>6 respondents (7.2%)</td>
<td>-</td>
</tr>
<tr>
<td>Restriction</td>
<td>1 respondent (1.3%)</td>
<td>1 respondent (1.3%)</td>
<td>-</td>
</tr>
<tr>
<td>Mixed</td>
<td>1 respondent (1.3%)</td>
<td>1 respondent (1.3%)</td>
<td>-</td>
</tr>
</tbody>
</table>

range defined as normal, benign, moderate and severe. Also analyzed was the percentage distribution of functional parameters examined in the study group with regard to the individual compartments. The results of this analysis are shown in Table 2.

Results of the analysis of variations in the flow of air in the airways of respondents, tested with regard to changes of an obstructive, restrictive and mixed nature, and the quality of the flow in medium and small airways, is shown in Table 3.

Morphological tests. The results of the morphological evaluation of lung tissue of rats are as follows:

- there was an outbreak of fibrosis alternating with accompanying foci of emphysema;
- in large areas of the lung parenchyma, outside the foci of fibrosis, a small increase of stroma was found;
- foci of emphysema and red blood cell haemorrhaging fields were found.

DISCUSSION

Firefighting is a profession which has high health demands and whose representatives are perceived as healthy and very fit physically. Although the symptoms identified in firefighters during this survey may seem surprising, in the literature similar results were observed by Horsfield et al, Markowitz and others [5, 9, 10]. As for causes leading to the discussed pathology, in first place, environmental factors leading to the development of respiratory diseases should be noted. The first of these factors is cigarette smoking, which is the most important, the most common and best documented etiopathogenic factor [11, 12]. Cigarette smoking causes inflammation in every smoker, but only 15–20% of this group reaches the development of obstructive changes [13]. Therefore, it cannot be justified that these results are caused solely through exposure to tobacco smoke. Support for this hypothesis may be found in a paper in which a group of non-smoking firefighters reported symptoms similar to those described above [14]. The second element of etiological disease processes in the respiratory tract is air pollution, both at home and at work [12]. It is believed that in addition to smoking, air pollution has a huge impact on the incidence of respiratory diseases, although the effect is much smaller (5–6 times) than the effect of cigarette smoking [15, 16]. It appears that environmental exposure can affect the adverse effects cigarette smoke has and/or affect independently and act similarly to the above mentioned. Another factor is the place of work, which draws the attention of study authors, who confirm the presence of respiratory disease symptoms associated with occupational exposure in firefighters [5, 6]. In terms of etiological mechanisms responsible for the appearance of the symptoms discussed above, it must be taken into account that the overlap, spread over years of work, of small inhalation injuries, which at one time did not lead to acute changes, but may initiate or aggravate chronic pathological processes that will reveal themselves in the future [17, 18].

The second stage of the study pertained to clinical and laboratory tests in patients in whom a subjective test revealed the presence of symptoms such as cough, sputum, shortness of breath. The fact that the physical examination, with the exception of a few retired employees, showed no deviations in the respiratory or circulatory tracts seems to be justified. Firefighters are a occupational group subjected to annual mandatory periodic inspections. Any deviations in these regards are immediately detected, and the patients receive a diagnosis which, if it confirms disease processes, leads to the removal of the patient from further exposure to harmful factors. It seems that this is not contrary to the symptoms reported in the subjective study, because either they are not noticed by the interested parties and treated as 'normal' in smokers (e.g., cough, sputum production), or they are deliberately ignored or suppressed (e.g. shortness of breath) in fear of losing their job. The lack of significant deviations from the normal condition in the subjective test may indicate both their actual absence, as well as a stage of advancement of the disease, where it cannot be detected through a subjective test. It is known that both the subjective tests and routine physical tests have a low sensitivity of detection or exclusion of moderate obstructive changes [11].

The blood test results received in the next stage of the study, as well as a radiological examination of the chest and...
electrocardiogram of the heart, excluded the justification for the survey ascertained symptoms of cardiac or pulmonary disease, causing deviations in the afore-mentioned research. It is worth realizing that in the early stages of obstructive lung disease, both chest radiographic and electrocardiographic examination may not reveal any pathological changes [12].

The next stage of the research involved functional tests. The authors of many studies confirm a significant decline in the value of these parameters in the discussed occupational group, which is essential evidence of the adverse effects of the work environment of firefighters, visible especially among non-smokers [19, 20]. The results of the assessment of spirometric FVC, FEV\textsubscript{1}, FEV\textsubscript{1}/FVC (89.7% standard) and MVV (94.9% standard) did not demonstrate significant deviations in the group. On the other hand, the finding that 35.9% of respondents had flow disturbances within the medium-sized and small bronchi (FMF25 -75 %) may indicate the development of chronic obstructive changes. The decrease in exhaust flow is one of the earliest evidences of the presence of functional disorders occurring in patients with normal spirometry, even in the absence of clinical signs of the disease [21].

It should be assumed that no significant decrease in FEV\textsubscript{1} and FVC parameters can be associated with low precision capability to detect any ongoing disease processes in the small airways. This is particularly important given the fact that the obstructive changes may be a more serious consequence of inhalation trauma than is commonly believed, and that fact may have substantial long-term consequences, particularly in individuals with variations within the respiratory tract that were previously present [22]. Because in this occupational group at any stage, both during preliminary as well as periodic tests, a functional assessment is not performed, it is very likely that any disease processes that may develop within them will go unnoticed until the disease reaches an advanced stage, which may occur after reaching retirement age.

To complement the clinical observations, as well as the analysis of the impact factors of occupational exposure had on the study group, experimental studies on animals were performed. The presence of the exponents of sclerosis progressive fibrosis is an experimental confirmation of the presence of harmful factors in the work environment of firefighters. Very important from the point of assessing the impact of the environment on a professional living organism is the observation that the formation of fibrosis clumps in the preparations evaluated under microscope light, in which a definite advantage as to the occupied area is observed in collagen fibrils, seems to be a permanent change, not removed by cells of the immune system capable of collagenase and elastase. The pathology of chronic fibrotic lung parenchyma syndromes indicates that such changes, inherent in occupational exposure to harmful factors, are one of the leading departments standing guard round the clock over the life and health of citizens.

CONCLUSIONS

1. In the group of firefighters there was found a statistically higher presence than in the control group of symptoms in the respiratory system, and its relationship with both the number of years of occupational exposure and professional activity.
2. The presence of flow disturbances in the medium and small airways of firefighters and morphological changes in rats exposed to powder extinguishing agents, can attest to the emergence of disease processes in the respiratory tract in connection with occupational exposure.
3. At this stage of research it is difficult to assess the percentage of each pathogenetic component in discussed pathology in the analyzed occupational group.
4. It would be advisable to continue the extensive research on the working environment of firefighters and its impact on the living organism.
5. Particular care should be extended to those who in the study presented flow abnormalities in the bronchi, it would be appropriate on the one hand to provide them with frequent periodic monitoring of their health status, and on the other, to attempt to assess the flows in their small airways using modern diagnostic methods.

REFERENCES