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Respiratory findings in gun factory workers exposed to solvents

Aytül Çakmak[a], Aydanur Ekici[b], Mehmet Ekici[b,*], Mesut Arslan[b], Ahmet Iteginli[b], Ercan Kurtipek[b], Türkan Kara[b]

[a]*Department of Public Health, Medical Faculty, Kırıkkale University, Turkey*
[b]*Department of Pulmonary Medicine, Medical Faculty, Kırıkkale University, Turkey*

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Summary *Objective*: Gun factory workers are exposed to many solvents (toluene, acetone, butanol, xylene, benzene, trichloroethylene). We investigated whether chronic exposure to solvents had adverse effect on respiratory system.

Material and methods: The workers were questionnaired by modified Medical Research Council's respiratory questionnaire before morning start shift. Then physical examination and measurement of pulmonary functions by portable dry rolling spirometer were performed. The study group consisted of 1091 gun factory workers. The workers were grouped according to their smoking habits (smokers, [exposed *n*: 353 vs. unexposed *n*: 339] and non-smokers [exposed *n*: 58 vs. unexposed *n*: 341]). Asthma-related symptoms were defined as either definite asthma, probable asthma, and possible asthma.

Results: In non-smokers, the report of asthma-related symptoms was more prevalent in exposed workers than unexposed (39.7% vs. 21.7% OR 2.4[1.3–4.3], respectively $P = 0.003$). In smokers, the report of asthma-related symptoms was more common in exposed group than unexposed (50.7% vs. 42.5% OR 1.4[1.0–1.9], respectively $P = 0.03$). Logistic regression analysis showed that smoking (OR 2.8 [2.0–3.8] $P = 0.00001$) and exposure to solvents (OR 1.4[1.1–1.9] $P = 0.01$) were independent risk factors for asthma-related symptoms, after adjusting for age. Logistic regression analysis identified that smoking (OR 3.3[2.3–4.6] $P = 0.00001$) was independent risk factors for chronic bronchitis. Multiple linear regression analysis of lung-function parameters (% forced expiratory volume (FEV_1), FEV_1/forced vital capacity, $FEF_{25–75}$) indicated significant effects of smoking.

Conclusion: Present study indicated significant effects of smoking and exposure to solvents, with the smoking effect being the most important on asthma-related symptoms of gun factory workers.

Introduction

Exposures to solvents are common in both industrialized and industrializing countries because of their wide usages.[1] It is well known that exposure to organic solvents produces central nervous system toxicity,[2,3] hepatic,[4] renal[5] and dermatologic damage,[6] but the respiratory effects of solvent exposure are poorly investigated. Studies on animals have also demonstrated that exposure to solvents had adverse effects in the respiratory system.[7–9] A number of population-based studies have showed a significant association of occupational

*Corresponding author. Ataturk Bulvarı 9 sok, Hacı Mustafa Bey Ap No. 2/2, Kırıkkale, 07100, Turkey. Tel.: +90-532-6419801; fax: +90-318-2244683.
E-mail address: mehmetekici_@hotmail.com (M. Ekici).

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solvent exposure with respiratory symptoms, impaired pulmonary function, but analysis of these studies is limited by self-reported exposure data.[10–12] Solvents are implicated as causative agents for occupational asthma in a few studies.[13,14] It is well known that irritant-induced asthma can be produced by high-level unintentional respiratory irritant exposures at work or outside the workplace.[15] However, lower levels of exposure to respiratory irritants at work are more common, but there are little studies that determine the airway effects of such exposures.

Gun factory workers are exposed to many solvents. We investigated whether long-term low-level exposures to solvents had adverse effect on respiratory system.

Materials and methods

There were 2350 male workers in different sections in the gun factory. The study was performed on a total of 1091 workers splitted into two groups as exposed to only solvents and non-exposed (control group) who work on assistance sections such as security, office and departments related to engineering. In the study, we excluded workers such as, welders, carpenters, lathe operators, etc. In this factory, gun pieces are produced from raw materials in workshops. These produced pieces are cleaned with solvents and workers are exposed to toluene, acetone, butanol, xylene, benzene and trichloroethylene during their work shift (continually 8 h/day, 5 day on a week).

All the workers were grouped according to their smoking habits as smokers and non-smokers. Each of these groups was separated into two subgroups as exposed and non-exposed workers according to the exposure to solvents. Smokers also consisted of ex-smokers and current smokers. Chronic respiratory symptoms were recorded using a modified British Medical Research Council questionnaire on respiratory symptoms, during the morning work shift.[16] In all workers, a detailed occupational history, as well as questions about their smoking habits, were recorded. Chronic bronchitis were defined as cough and phlegm for a minimum of 3 months a year and for not less than 2 successive years.

Asthma definitions: For the purposes of this study, ''definite asthma'' was defined as positive responses to all three of these questions (ATS questions 20A, 20B, and 20C3): (1) ''Have you ever had asthma?'' (2) ''Do you still have it?''; and (3) ''Was it confirmed by a doctor?''.

''Probable asthma'' was defined as positive responses to both of the following questions: (1) ''Have you had wheezing or whistling in your chest at any time during the last 12 months?'' (2) ''Have you felt chest tightness or been breathless when the wheezing noise was present?'' This category excludes those with a current asthma diagnosis, as defined above. ''Possible asthma'' was defined as a positive response to the question, ''Have you had wheezing or whistling in your chest at any time during the last 12 months?'' and a positive response to one of the following two questions: (1)''These breathing symptoms were brought on or made worse by exposure to any one of the following: exercise or exertion; dust, smoke, or fumes?''; and (2) ''Do you often wake up several times a night with trouble breathing or coughing?'' This category of probable asthma excludes those with definite or possible asthma.[17]

Asthma-related symptoms were defined as either definite asthma, probable asthma, and possible asthma.

For the purposes of subsequent analyses, workers with at least one of these asthma-related respiratory symptoms (yes/no) or chronic bronchitis (yes/no) were grouped separately.

Study subjects took the spirometric tests in the standing position. Each worker was instructed how to take the pulmonary function test, before the test. Spirometric tests were performed by portable dry rolling (MIR spirobank ITALY). Maximal expiratory flow-volume (MEFV) curves were recorded. On these MEFV curves, the forced vital capacity (FVC), 1-s forced expiratory volume (FEV_1), and mean maximum flow rates at 50% and the last 25% of the vital capacity were measured. The percentage of predicted value for each spirometric value was calculated according to the worker's age, sex, weight and height. Measurements were performed during the morning work shift.

The chi-square test (or, when appropriate, Fisher's exact test), was used for testing differences in the prevalence of respiratory symptoms between groups. Prevalence odds ratios (ORs) (and their 95% confidence intervals (95% CIs)) were calculated with the Mantel–Haenszel method.

Logistic regression was used to calculate OR and 95% CI for the association between other respiratory symptoms (no = 0; yes = 1) or asthma-related symptoms (no = 0; yes = 1) with smoking (never smoked = 0; former/current smokers = 1), exposure (no = 0; yes = 1) and age (median = 42 yr, young <42; old $\geqslant 42$).

Results of ventilatory capacity tests were analyzed by applying a multiple regression analysis

with age, exposure, and smoking as predictors, and FVC, FEV_1 and $FEF_{25–75}$ as criteria variables.

For comparisons of continuous variables a *t*-test was performed. A *P* value <0.05 was considered significant.

Results

Table 1 presents the prevalences of chronic respiratory symptoms in the non-smoker workers. In non-smokers, there were significantly higher prevalences for asthma-related symptoms in exposed, compared with unexposed workers ($P = 0.002$).

Table 2 presents the prevalences of chronic respiratory symptoms in the smoker workers. In smokers, there were significantly higher prevalences for asthma-related symptoms in exposed, compared with unexposed workers ($P = 0.03$).

Table 3 presents the logistic regression analysis for chronic respiratory symptoms. Logistic regression analysis showed that smoking and exposure to solvents were independent risk factors for asthma-related symptoms, after adjusting for age. Logistic regression analysis identified that smoking was independent risk factor for chronic bronchitis.

Table 4 shows the findings of multiple regression analysis with exposure and smoking as predictors, and lung-function parameters as outcome variables.

This table shows smoking to be a highly significant predictor of FEV_1, FEV_1/FVC, and $FEF_{25–75}$. Exposure was not a significant predictor for any of the parameters.

Lung-function parameters in groups and in subgroups were presented in Table 5.

Table 1 Characteristics and respiratory symptoms of workers according to exposure in nonsmokers.

	Nonsmokers		OR	95% CI	*P* value
	Exposed *n*: 58	Unexposed *n*: 341			
Mean age	40.6±7.3*	39.1±10.1			
Exposure duration (yr)	16.9±7.9(1-33)	0			
Asthma-related symptoms	23 (40.4)†	74 (21.7)	2.4	1.4–4.4	0.002
Chronic bronchitis	12 (20.7)	47 (13.8)	1.6	0.8–3.3	NS‡

*Values are mean±standard deviation.
†Values are percentages, with the number of subjects in parentheses.
‡NS, not significant.

Table 2 Characteristics and respiratory symptoms of workers according to exposure in smokers.

	Smokers		OR	95% CI	*P* value
	Exposed *n*: 353	Unexposed *n*: 339			
Mean age	40.8±6.7	41.3±7.6			NS*
Cigarette pack-year	15.6±12.1	16.1±11.7			
Exposure duration (yr)	16.4±7.1(1–30)	0			
Asthma-related symptoms	179 (50.7)†	144 (42.5)	1.4	1.0–1.9	0.003
Chronic bronchitis	153(43.3)	138(40.7)	1.1	0.8–1.5	NS

*NS: not significant.
†Values are percentages, with the number of subjects in parentheses.

Table 3 Respiratory symptoms in relation to age exposure, and smoking in all subjects—logistic procedures.

	OR, smoking	95% CI	*P* value	OR, exposure	95% CI	*P* value
Asthma-related symptoms	2.8	2.0–3.8	0.00001	1.4	1.1–1.9	0.01
Chronic bronchitis	3.3	2.3–4.6	0.00001			NS

In smokers, the ratio of current smoker was not different between exposed and unexposed subgroups (71.8%, 75.5% $P>0.05$).

The mean cigarette pack-years of current smokers was not different between exposed and unexposed subgroups (14.4 ± 0.7, 14.6 ± 0.6 $P>0.05$).

The mean cigarette pack-years of ex-smokers were not different between exposed and unexposed subgroups (4.8 ± 0.5, 4.3 ± 0.4 $P=0.479$).

The pulmonary functions in smokers did not differ significantly between exposed and unexposed subgroups.

The prevalence of chronic cough (18.8% vs. 6.5% $P=0.0001$), chronic bronchitis (38.0% vs. 15.8% $P=0.0001$), possible asthma (39.5% vs. 16.1% $P=0.0001$), dyspnea (47.9% vs. 29.5% $P=0.0001$) in smokers was higher than non-smokers.

The mean FEV_1% value of smokers was lower than those of the non-smokers (97.2 ± 14.7 vs. 101.9 ± 13.20 $P=0.0001$).

Discussion

Asthma-related symptoms in exposed groups of non-smokers and smokers were more common than control groups. The higher prevalence of asthma-related symptoms among exposed groups may be a result of the sensitizer effect of these solvents. A logistic regression analysis performed on asthma-related symptoms of gun factory workers indicated significant effects of smoking and exposure, with the smoking effect being the most important. However, logistic process showed only significant effects of smoking on chronic bronchitis.

Studies have demonstrated that solvents cause mucosal irritation of the eyes and upper airways, but the respiratory effects of solvent exposure were poorly documented.[1] Lee et al.[18] found that the newspaper pressworkers who were exposed to solvents had significantly more respiratory symptoms than control group, even though the degree of exposure was within the current permissible exposure limits. Zuskin et al.[19] also found that the high prevalence of respiratory symptoms was primarily a consequence of exposure to the numerous organic solvents found in the work-place in the leather shoe manufacturing industry. Wieslander et al.[20] indicated that exposure to solvent-based paint might cause an increase in respiratory symptoms among painters but water-based paint did not. Talini et al.[21] found that spray painters exposed to low concentration of diisocyanates and solvents had higher prevalence of chronic cough than control, and a trend in increasing the prevalence of shortness of breath with wheeze, dyspnea, and asthma. Paggiaro et al.[22] showed that occupational exposure to organic solvents might cause chronic airway impairment with non-specific bronchial hyper-responsiveness in three shoe factory workers. In line to ours, above studies demonstrated that chronic exposure to solvents may cause adverse effects on respiratory system. In contrast, Akbar-Khanzadeh and Rivas[23] showed that no significant difference was in proportion of respiratory symptoms between the solvent-exposed group and non-exposed group in polyurethane molding process workers.

Multiple linear regression analysis of lung-function parameters indicated significant effects of smoking, but not exposure. According to this, it

Table 4 Regression analysis of ventilatory capacity tests in all workers.

	P value	R^2
FEV_1%		
Intercept	0.0001	0.034
Exposure	NS	
Smoking	0.0001	
FEV_1/FVC		
Intercept	0.0001	0.033
Exposure	NS	
Smoking	0.0001	
MMF%		
Intercept	0.0001	0.030
Exposure	NS	
Smoking	0.0001	

Table 5 Ventilatory capacity measurements of workers according to exposure.

	Nonsmokers			Smokers		
	Exposed *n*: 58	Unexposed *n*: 341	*P* value	Exposed *n*: 353	Unexposed *n*: 339	*P* value
FEV_1%	102.2 ± 10.8	100.9 ± 13.3	NS	97.5 ± 15.5	96.4 ± 14.6	NS
FEV_1/FVC	83.7 ± 4.9	84.3 ± 6.7	NS	81.90 ± 7.4	82.1 ± 7.3	NS
MMF	103.8 ± 24.6	102.7 ± 29.3	NS	93.88 ± 28.2	94.2 ± 29.0	NS

suggests that smoking has more important effect than exposure on pulmonary function in workers. Similarly, the spirometric results in newspaper pressroom workers did not significantly differ between the exposed to solvent and control group (both group have the same cigarette pack-year).[18] The difference in pulmonary function was not observed between non-exposed subjects and those exposed only to organic solvents in workers in a polyurethane molding process.[23] In contrast, the measured ventilatory capacity values in exposed workers to solvents were significantly lower in comparison to control in shoe manufacturing workers.[19]

Provided that we had evaluated the atopy and bronchial hyper-responsiveness in workers and measured the concentrations of the chemical irritants in the environment would be better for an improved assessment. Besides, effects on respiratory systems of exposure to solvents should be more investigated with longitudinal studies in larger groups.

Present study suggests that chronic exposure to solvents may cause increase in asthma-related symptoms. In order to prevent respiratory disorders among gun factory workers, we suggest that, medical observation, including pre-employment and periodic medical controls, should be performed and should include pulmonary function tests. This medical screening can protect workers from developing chronic respiratory disorders by allowing the early recognition and possibly the removal of sensitive workers from the working place before chronic impairment develops.

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