

CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN NEVER-SMOKING WELDING WORKERS

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ABSTRACT

Introduction: Results from several studies indicate that workplace exposure to welding fumes is associated with increased frequency of chronic obstructive pulmonary disease (COPD) in exposed workers.

Objective: To assess the prevalence and characteristics of COPD in never-smoking welders.

Methods: A cross-sectional study including 53 never-smoking male welders (aged 35–60 years) was performed, and an equal number of never-smoking male office workers were studied as a control. Evaluation of examined subjects consisted of the completion of a questionnaire, baseline spirometry, and bronchodilator reversibility testing.

Results: We found a higher prevalence of respiratory symptoms in welders, with significant differences in cough and phlegm. The majority of the chronic respiratory symptoms in welders were work-related. The mean values of all measured spirometric parameters registered with both pre and post-bronchodilator spirometry in welders were significantly lower than in office workers. The prevalence of COPD was significantly higher in welders than in office workers (15.1% versus 3.8%, $p=0.041$). COPD in both welders and office workers was similar in those aged <45 years.

Conclusion: Our findings support data about the relationship between workplace exposure to welding fumes and persistent airflow limitation.

Keywords: Airflow limitation, baseline spirometry, bronchodilator reversibility testing, questionnaire, welders.

INTRODUCTION

Over recent decades, chronic obstructive pulmonary disease (COPD) has become an important public health problem at a global level. According to the projection of the Global Burden of Disease Study, COPD, which ranked as the sixth leading cause of death in 1990, will become the third leading cause of death worldwide by 2020.¹ Across the world, cigarette smoking is the most commonly encountered risk factor of COPD, with a clear dose-response relationship. Although cigarette smoking is a major risk factor of COPD, there is consistent evidence that a substantial proportion of COPD cases cannot be explained by smoking. Other noxious particles and gases, such as workplace dust, vapours, fumes or gases,

indoor air pollution from burning biomass fuels (caused by cooking and heating), and urban outdoor air pollution are important risk factors of COPD. According to the available evidence, the contribution of workplace exposure to noxious particles and gases to the development of the disease is estimated as being 15–20% of all COPD cases; around 4,000 COPD deaths every year are related to workplace exposures, 40% of COPD patients are below retirement age, and a quarter of those below retirement age are unable to work at all.^{2,3}

The development of COPD as a consequence of workplace exposure is a matter of growing interest, importance, and even controversy. There is no doubt that certain workplace exposures enhance

the risk of COPD, and may do so independently of, or in concert with cigarette smoking. The evidence is most coherent for work that entails exposure to coal, silica, welding fumes, cadmium fumes, cotton dust, farming dusts, grain dust, or wood dust. For other occupations the evidence is less conclusive and warrants further studies, particularly in roles that entail exposure to diesel fumes, diisocyanates, polycyclic hydrocarbons, asbestos, and iron/steel fumes.⁴⁻⁶ This study aimed to assess the prevalence and characteristics of COPD in never-smoking male workers exposed to welding fumes.

METHODS

Study Design and Setting

The study compared respiratory symptoms in the last 12 months, spirometric findings, and prevalence of COPD between a group of welding workers and a group of office workers in a cross-sectional analysis. The study took place from September 2014–January 2015 at the Institute for Occupational Health of the Republic of Macedonia (IOH of RM), Skopje.

Subjects

The examined group of welding workers included 53 males (age 35–60 years, duration of employment 14–27 years) working in stainless steel (SS) welding. They worked in a metallurgic plant in two work shifts, each lasting for a period of 8 hours. Their working tasks included welding and cutting SS, i.e. steel containing nickel and chromium, which was performed in a large working area (approximately 160 m²) with a central ventilation system. The welding technique used is known as flux core arc welding, a welding method used for carbon steels, low alloy steels, and SS. In this welding process the consumable electrode (the welding rod) is continuously fed from a spool and an electric arc flows between the electrode and the base metal. This type of welding is characterised by the generation of a large amount of fumes, due to the high electrical currents and the flux-cored electrode. During the work shift, the welding workers used protective clothing, gloves, masks, and glasses. All examined welders were never-smokers, i.e. individuals who have never smoked at all, or have never been daily smokers and have smoked <100 cigarettes in their lifetime.^{7,8} In addition, data from 53 never-smoking males employed as office workers, matched to the welders by age, served as controls. No individual

from either group had been diagnosed with chronic respiratory disease by a physician (such as asthma, COPD, bronchiectasis, etc.), nor were they treated with bronchodilators and/or corticosteroids.

Questionnaire

An interviewer-led questionnaire was completed by all study subjects. The questionnaire consisted of five parts: respiratory symptoms in the last 12 months and their work-relatedness, work history, passive smoking, accompanying diseases, and history of COPD or chronic bronchitis in first-degree relatives (parents and/or siblings). Overall and specific respiratory symptoms (cough, phlegm, dyspnoea, wheezing, and chest tightness) in the past 12 months were defined according to the European Community for Coal and Steel Questionnaire (ECCS-87), and the European Community Respiratory Health Survey (ECRHS) questionnaire.^{9,10} The work-relatedness of the respiratory symptoms was defined as having worsened during or after the work shifts and their improvement in the periods away from work.¹¹ The work history was described through questions about current and previous jobs, work activities at the current workplace, characteristics of the exposure at the current workplace, and the use of protective equipment. Passive smoking or exposure to environmental tobacco smoke (ETS) was defined as an exposure to tobacco smoke from smoking by others, i.e. being in the presence of at least one smoker in the household and/or at the workplace.^{12,13}

Spirometric Measurements

The spirometric measurements included baseline (pre-bronchodilator) spirometry and bronchodilator reversibility testing (post-bronchodilator spirometry). They were performed using a Ganshorn SanoScope LF8 (Ganshorn Medizin Electronic GmbH, Germany). Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV₁), FEV₁/FVC, and maximal expiratory flow (MEF) at 75%, 50%, 25%, and 25–75% of FVC (MEF₇₅, MEF₅₀, MEF₂₅, and MEF₂₅₋₇₅, respectively) were measured, recording the best result from three measurements of FEV₁, all of which were within 5% of each other. According to the recommendations of the European Respiratory Society (ERS) and the American Thoracic Society (ATS), the results of the spirometric measurements were expressed as percentages of the predicted values.^{14,15}

Table 1: Characteristics of the examined groups.

Variable	Welders (n=53)	Office workers (n=53)
Age (yrs)	48.4±5.8	49.2±5.1
<45	25 (47.2%)	24 (45.3%)
>45	28 (52.8%)	29 (54.7%)
Body mass index (kg/m ²)	25.9±1.9	26.2±1.7
<25	26 (49.2%)	25 (47.2%)
>25	27 (50.8%)	28 (52.8%)
Duration of employment at the workplace (yrs)	21.8±3.9	20.5±4.3
Duration of employment <20 yrs	24 (45.3%)	26 (49.2%)
Duration of employment >20 yrs	29 (54.7%)	27 (50.8%)
Family history of COPD or CB	8 (15.1%)	6 (11.3%)
Passive smoking	21 (39.6%)	18 (33.9%)
Accompanying diseases		
Arterial hypertension	9 (16.9%)	8 (15.1%)
Diabetes mellitus Type 2	5 (9.4%)	6 (11.3%)
Peptic ulcer	3 (5.7%)	5 (9.4%)

Numerical data are expressed as mean value with standard deviation; frequencies as number and percentage of study subjects with certain variables.

COPD: chronic obstructive pulmonary disease; CB: chronic bronchitis.

Post-bronchodilator spirometry, i.e. bronchial reversibility testing, was performed according to the Global initiative for chronic Obstructive Lung Disease (GOLD) spirometry guide.¹⁴ Spirometric measurements were performed 20 minutes after the administration of 400 µg salbutamol by metered dose inhaler through a spacer and by comparing registered values with those registered by baseline (pre-bronchodilator) spirometry. Persistent airflow limitation was considered if the post-bronchodilator FEV₁/FVC remained <0.70, independent of the degree of FEV₁ reversibility. In addition, the degree of FEV₁ reversibility was calculated as a percentage of FEV₁ reversibility ($[\text{post-bronchodilator FEV}_1 - \text{pre-bronchodilator FEV}_1] / \text{pre-bronchodilator FEV}_1 \times 100$).

Chronic Obstructive Pulmonary Disease Diagnosis

According to the GOLD recommendations, COPD was considered when post-bronchodilator FEV₁/FVC was <0.70 in symptomatic subjects (dyspnoea, chronic cough, or sputum production) with a history of exposure to risk factors for the diseases (noxious particles and gases).

Statistical Analysis

Statistical analysis was performed using SPSS v.20 (IBM, New York, USA) version 11.0 for Windows.

Continuous variables were expressed as mean values with standard deviation and the nominal variables as numbers and percentages. Analyses of the data included testing the differences in prevalence, comparison of the means, testing the association between COPD and studied variables by chi-square test (or Fisher's exact test where appropriate), and independent samples t-test. A p-value <0.05 was considered as statistically significant.

RESULTS

Demographic characteristics of the study subjects were similar in both examined groups (Table 1). While we found a higher prevalence of overall respiratory symptoms in welders than in office workers, the results were not statistically significant. Particular chronic respiratory symptoms were more prevalent in welders, with a statistically significant difference for cough and phlegm (Table 2). The majority of respiratory symptoms in the last 12 months in welders were related to their work (86.4%), with the highest reported for cough (73.3%) and phlegm (80.0%). Such work-related symptoms were reported by 16.7% of the office workers with respiratory symptoms.

The mean values of all measured spirometric parameters registered with baseline spirometry

were significantly lower in welders. The mean post-bronchodilator values of all spirometric parameters were also significantly lower in welders (Table 3). In addition, the mean FEV₁ reversibility (percentage of FEV₁ reversibility) was significantly higher in welding workers (8.7±2.3 versus 3.8±0.9; p=0.000; independent samples t-test).

Eight subjects among the welders and two subjects among the office workers met the criteria for diagnosis of COPD (15.1% versus 3.8%, p=0.041; Fisher's exact test). All welders with COPD reported that their symptoms were work related. According to the GOLD classification of COPD severity, all welders and office workers with established COPD can be classified as subjects with mild COPD (FEV₁/FVC <0.70; FEV₁ ≥80% predicted), i.e. as a GOLD 1.¹⁶

All COPD cases in both examined groups were aged >45 years. The duration of employment at the workplace in six welders with COPD (87.5%) was >20 years. In addition, in 1 of the 2 office workers with COPD, duration of employment at the workplace was registered as >20 years. There was no significant association between COPD and other variables (body mass index, family history for COPD or chronic bronchitis, and passive smoking) in subjects with COPD from both examined groups.

DISCUSSION

There is strong evidence that COPD due to occupational exposures has markedly increased during the last few decades, becoming an important cause of morbidity and mortality in

many occupations. Workplace agents considered as risk factors for COPD include: mineral dusts (coal, silica, silicates, oil mist, and man-made fibres), organic dusts (cotton, grain, wood, and paper dust), metals (welding fumes, cadmium, and vanadium), gases (sulfur dioxide and ammonia), and smoke (internal combustion engine exhaust), as well as mixed exposure, poorly defined as industrial vapours, gases, dusts, and fumes.^{17,18} This study assessed the impact of specific occupational exposure in welding workers on the development of COPD. A control group consisted of an equal number of male office workers, matched to welders by age and smoking status.

As we aimed to exclude the effect of smoking on the COPD development, we examined only never-smoking workers to avoid use of regression analyses. The examined groups included subjects with similar demographic characteristics. More than one-third of the subjects in both examined groups were exposed to ETS; this is similar to the prevalence of passive smoking among workers in the Republic of Macedonia documented in our previous studies.^{19,20}

Welding fumes are a complex mixture of metallic oxides (chromium, nickel, iron, copper, etc.), silicates, and fluorides. Fumes are formed when a metal is heated above its boiling point and its vapours condense into very fine particles. The composition of welding fumes can be changed by the vapours and fumes that come from coatings and residues on the metal being welded (cadmium plating, lead oxide primer paints, zinc on galvanised steel, plastic coatings, vapours from paints and solvents, etc.).²¹

Table 2: Prevalence of overall and specific respiratory symptoms in the last 12 months.

Respiratory symptoms in the last 12 months	Welders (n=53)	Office workers (n=53)	P-value*
Overall respiratory symptoms	22 (41.5%)	12 (22.6%)	0.067
Cough	15 (28.3%)	5 (9.4%)	0.013
Phlegm	8 (15.1%)	2 (3.8%)	0.046
Dyspnoea	6 (11.3%)	4 (7.5%)	0.506
Wheezing	5 (9.4%)	3 (5.7%)	0.462
Chest tightness	5 (9.4%)	5 (9.4%)	1.000

Data are expressed as number and percentage of study subjects with certain variables.

*Tested by chi-square test (or Fisher's exact test where appropriate).

Table 3: Mean baseline and post-bronchodilator values of spirometric parameters.

Spirometric parameter	Baseline spirometry			Post-bronchodilator spirometry		
	Welders (n=53)	Office workers (n=53)	P-value*	Welders (n=53)	Office workers (n=53)	P-value*
FVC (%pred)	91.7±11.2	95.9±9.8	0.042	92.9±11.4	98.3±10.1	0.011
FEV ₁ (%pred)	75.7±7.8	84.3±11.3	0.011	78.9±12.8	87.6±10.7	0.009
FEV ₁ /FVC	0.76±0.05	0.83±0.03	0.008	0.76±0.04	0.84±0.04	0.003
MEF ₇₅ (%pred)	65.4±10.7	76.4±12.8	0.001	67.8±13.1	78.1±8.3	0.000
MEF ₅₀ (%pred)	60.2±12.1	70.3±13.1	0.000	63.1±13.9	71.7±10.7	0.000
MEF ₂₅ (%pred)	53.2±12.8	64.1±11.2	0.000	54.9±12.4	66.7±13.1	0.000
MEF ₂₅₋₇₅ (%pred)	62.3±13.9	76.7±14.1	0.000	66.8±14.7	78.7±12.8	0.000

Data are expressed as mean value of certain spirometric parameter with standard deviation.

*Tested by independent-samples t-test.

FVC: forced vital capacity; FEV₁: forced expiratory volume in one second; MEF₇₅, MEF₅₀, MEF₂₅, MEF₂₅₋₇₅: maximal expiratory flow at 75%, 50%, 25%, and 25-75% of FVC, respectively; %pred: percentage of predicted value.

The prevalence of overall respiratory symptoms in the welders was higher than in the office workers. Prevalence of specific respiratory symptoms was also higher in the welders, with a statistically significant difference for cough and phlegm. The majority of respiratory symptoms in the welders were work-related, reaching >70% for cough and phlegm.

The results from spirometric measurements demonstrated significantly lower mean values of all measured spirometric parameters in welders than in office workers. These findings were registered by both baseline and post-bronchodilator spirometry. In addition, we found significantly higher mean FEV₁ reversibility in welders than in office workers. The effect of workplace exposure to welding fumes on the lung function of exposed workers has been documented in several studies. In a cross-sectional analysis of 106 subjects working as welders for 4–34 years and 80 matched controls, Bogadi-Sare²² found significantly lower FEV₁/FVC values in exposed workers, independent of their smoking status. In addition, in a study that included 657 shipyard workers exposed to welding fumes, Gennaro et al.²³ found a significant impairment of lung function in the workers with a duration of exposure >20 years as compared with lung function of the workers with shorter workplace exposure. The higher mean FEV₁ reversibility in welders compared with the office workers registered in the present study may be

due to the higher degree of airflow inflammation in workers exposed to welding fumes than in the unexposed controls.

COPD prevalence in never-smoking subjects working in dusty occupations obtained from the studies performed at the IOH of RM varied between 10.8% in grain workers, 11.4% in cotton workers, and 14.9% in bricklayers. At the same time, COPD prevalence in the office workers studied as a control varied from 2.3–4.3%.²⁴⁻²⁶ Despite controls in these and the present study, never-smokers with no occupational exposure to noxious particles and gases, the influence of other COPD risk factors (e.g. genetic factors, childhood respiratory infections, household exposure to ETS, etc.) could not be excluded. In the present study, COPD prevalence in welders was 15.1%; around 3-fold higher than its prevalence in matched office workers (3.8%). COPD in both welders and office workers was similar in those aged <45 years. Similar results (i.e. COPD prevalence of around 15%) were registered by Koh et al.²⁷ in a study including a group of male welders working at two shipyards (mean age 48 years, mean duration of exposure 15 years, and mean cumulative exposure 7.7 mg/m³). Odds ratios for COPD were significantly higher in the middle and high exposure groups compared with the low fume exposure group.²⁷

The present study must be interpreted within the context of its limitations: a relatively small

number of the subjects in the study groups could have certain implications on the data obtained and its interpretation; the impact of the healthy workers' effect on the data obtained should also not be excluded (the healthy workers' effect is recognised as the most common selection bias in occupational studies, and it may partially or completely mask excess mortality and morbidity caused by harmful workplace exposure); and finally, environmental measurements were not performed, so the effects of the type and the level of exposure to welding fumes on the examined variables could not be documented. The strength of the study is its extensive examination of respiratory effects of workplace exposure associated with a certain welding technique on never-smoking workers.

In conclusion, this cross-sectional study found a higher prevalence of respiratory symptoms in the last 12 months, significantly higher mean values of spirometric parameters, and significantly higher prevalence of COPD in never-smoking welding workers, than in matched office workers. COPD in welding workers was closely related to age and duration of employment at the workplace. Our results confirm the need for constant improvement of preventive measures, i.e. proper engineering control and respiratory protective equipment, as well as regular periodical medical examinations of exposed workers, in order to protect their health from the risks of welding exposure.

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