Spirometric indices and respiratory symptoms in welders

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Abstract: Welders comprise one percent of the total workforce in industrialized countries. Since inhaled welding contaminants are accompanied by respiratory and non-respiratory effects, this study was conducted to determine Spiro metric indices and respiratory symptoms in welders exposed to contaminants in Zahedan. In this cohort study conducted on welders in Zahedan's industrial park, first, level of exposure to welding fumes was assessed using NIOSH organization standards, and then, the prevalence of respiratory symptoms and pulmonary function disorders among 250 male workers (140 exposed, 110 case group) were studied using the localized American Lung Association questionnaire and spirometer. The data were analyzed using student t-test, chi-square, Fisher's Exact test, and linear multivariate regression model. The exposed mean fume concentrations were 8.13 mg/m^3, which were more than the recommended allowable threshold of 5 mg/m^3 (ACGIH). The results showed that there was a significant difference in respiratory symptoms between exposed and non-exposed groups ($P<0.05$) in favor of the exposed group. Also, many of the pulmonary function parameters were significantly less in the exposed group compared to the case group, and there was a significant correlation between FEV1 and FEV1/FVC results in these people according to age, work history, smoking, respiratory disorders, and Personal Protective Equipment (PPE). The results of this study showed that there is a significant correlation between exposure to welding fumes and pulmonary function disorders.

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Introduction

It has been estimated that half to one percent of welding electrodes are converted into metallic oxides, dust and fume pollutants. Accordingly, annually about 700 tons of pollutants from welding process is created in the U.K alone [1]. Furthermore, welders comprise one percent of the total workforce in industrial countries. Welding process creates gases, aerosols of metallic alloys, metallic oxides, and other evaporated chemicals from molten metal and at the welding spot [2], and welders are exposed to these pollutants. Welding fumes are able to find their ways into distal airways of the lungs and air sacs, leading to absorption of metallic oxidizers crystals at the level of ozone and nitric oxide gases, and eventually, lung's epithelial cells and airways are exposed to these chemically highly active particles. The damage mechanism is as follows [3]:

The inhaled welding fumes enter respiratory tract and air sacs, and through contact with lung tissue epithelial cells, destroy airways cilia, resulting in accumulation of mucus in the small airways and induced restriction of the airways, causing reduction in FVC and eventually, uneven growth and change of the path of small airways. Also, there is evidence of hexavalent metals as catalysts in destruction of cell membranes. Therefore, the most vulnerable parts of the respiratory system are the airways leading to air sacs and the air sacs themselves [4]. Destruction of cilia, and accumulation of mucus in small airways (each linked to nearly 5000 air sacs) leads to obstruction of small airways, and if increased, the obstruction will remain permanently. The important characteristic of these complications is reduced expiratory flow rate [5, 6]. In obstructive diseases, the percentage of expiratory volume in the first second (FEV1), and the ratio of expiratory volume in the first second to the total volume of air forced out of lungs (FEC1/FVC) are reduced [7-11]. In mild obstructive diseases, FVC rate is normal, but in severe cases, due to retention of air in airways, FVC rate is also reduced.

Materials and methods

This was a historic study conducted among all welders employed at the Zahedan industrial park, with control group members matched for age and other confounding factors. Those with chronic respiratory disease, asthma, or a history of chronic respiratory infection were excluded from the study, to minimize the role of confounding variables. The present study was carried out in accordance with the Declaration of Helsinki and its amendments [21]. None of the study subjects had any history of respiratory diseases, chest surgery, or lung damage. To investigate the prevalence of respiratory symptoms, workers were interviewed in their workplace, and with slight modification, the respiratory symptoms questionnaire was completed for them according to the recommendations of the American Association of Lung Specialists [12]. To determine workers' level of exposure to welding fumes, the concentration of these pollutants was measured in the subjects' breathing area based on standards [23]. Pulmonary Function Tests (PFTS) were conducted including Vital Capacity (VC), Fast Vital Capacity (FVC), Fast Vital Capacity in the first second (FEV1), and Peak Expiratory Flow (PEF), according to the American Association of Lung Specialists' guidelines [13] using a portable spirometer (England, 2021). The tests were conducted twice daily, at the beginning and end of the shift (to assess cross-shift changes) using a calibrated standard spirometer.

To compare quantitative variables means in exposed and non-exposed groups, student t-test was used, and to evaluate frequencies in these groups, either chi-square or Fisher's Exact test was used. The variance analysis ANOVA test was used to compare mean percentage of pulmonary function measurements at different times (beginning and end of the shift) in the exposed group. The correlation between pulmonary parameters, in addition to exposure status with independent variables such as age, duration of exposure, and intensity of smoking (light, less than 15 packets per year; heavy, more than 15 packets per year), was assessed using linear multivariate regression model. To investigate independent variables' (age, duration of exposure, and intensity of smoking) role in chance of respiratory diseases, in addition to exposure status, logistic regression model was used.

Results

The exposed and non-exposed groups, in terms of age and number of smokers were statistically different, but in respect to other variables, they were not (table 1).

Table 1: Demographic details, smoking, and level of exposure to welding fumes

The assessment of respiratory symptoms status is presented in table 2. It can be seen that frequency of all symptoms in exposed group was significantly higher than that in non-exposed group ($P<0.05$). Also, many of the pulmonary function parameters in exposed subjects (at two different times) were statistically lower than that in the case group table 3.

These parameters were also compared at the beginning and end of the working shift in the exposed group. As can be seen in table 3, severe exposure caused reduction in VC, FEV1, and PEF. There was a significant difference between the mean values of parameters mentioned at the beginning and end of the shift. The correlation between these parameters at the beginning of the shift, in addition to exposure status, and independent variables of age, duration of exposure, and intensity of smoking (number of packets per year) was examined using linear multivariate regression model (table 4).

Table 2: The frequency of abnormal clinical findings in exposed and non-exposed subjects

Table 3: The results of pulmonary function parameters measurement in exposed and non-exposed subjects

Table 4: The effects of exposures to smoking and its intensity (packet per year) on pulmonary function with linear multivariate regression (n=260)

This evaluation showed that exposure to welding fumes has a linear correlation with all parameters, and has caused their reduction. Smoking intensity (packet per year) had a linear correlation with FEV1, PEF, and FEV1/FVC, and caused a reduction in these parameters. Also, the correlation between exposure to welding fume and the incidence of respiratory symptoms was found using logistic regression model (table 5).

Table 5: The results of assessment of exposure status and smoking intensity (packets per year) on respiratory symptoms using logistic regression test (n=260)

It can be seen in table 5 that there was a significant correlation between exposure to welding fumes and cough with phlegm and wheezing ($P<0.05$), but no such correlation was observed between exposure and cough or mucus clearance ($P>0.05$).

The mean respiratory function indices in exposure group were FVC=83%, FEV1=79%, and FEV1/FVC=85%, indicating a significant reduction in these indices compared to normal respiratory function values. The statistical results obtained indicate a significant difference in mean values of these indices between the exposed and non-exposed groups, which is the consequence of complications associated with airways, due to inhaling welding fumes. Also, according to the results of Pearson correlation test, there was a significant correlation between work history of exposed group subjects and respiratory function indices, and also with FEV1 ($P=0.021$, $r=0.505$). The independent t-test results for the exposed group revealed a significant correlation between mean FEV1, FEV1/FVC and shortness of breath ($P=0.036$, $P=0.03$).

The same test showed a significant correlation between respiratory function indices and smoking ($P=0.045$, $P=0.036$, $P=0.03$). Kruskal Wallis test showed no significant correlation between mean respiratory function indices and personal protective equipment ($P=0.507$, $X^2=1.308$).

Discussion

The mean concentration of welding fumes (table 1) showed that workers' level of exposure to these pollutants exceeds the allowable threshold of 5 mg/m^3. Therefore, it appears that long-term exposure to high concentration of welding fumes has caused an increase in the prevalence of respiratory disease symptoms (cough, phlegm, cough with phlegm, wheezing, and shortness of breath), and reduced pulmonary function capacities in workers.

The increased prevalence of respiratory disease symptoms was in agreement with the results obtained by Ijadinola et al. and also some other studies [15, 22]. The reduced pulmonary function capacity is also similar to the results of other studies [23, 27]. In the present study, a linear correlation was not observed between duration of exposure and reduction in parameters of pulmonary function. This could be explained by the fact that the average incubation period of chronic bronchitis and obstructive lung lesions caused by exposure to welding fumes is approximately 10 years [28]. Furthermore, work history of a significant proportion of workers (almost 67%) in this study was over 10 years, so they were exposed to very high concentrations of fumes, which tends to lighten the role of this factor in statistical calculations.

The results presented in table 3 are in line with reports of some authors [29, 34] such as Eich et al. in qualitative terms [35]. They showed the mean of pulmonary function parameters in workers exposed to welding fumes was significantly less than non-exposed group. Given that exposed group subjects were older and that high percentages of them were smokers, to control the effect of these covariates on pulmonary capacities, linear multivariate regression model was used. It can be seen in table 5 that after controlling the effect of these covariates, exposure to welding fumes caused a reduction in pulmonary capacities. In addition, this regression model showed that in addition to exposure to welding fumes, smoking intensity (packets per year) had the same effect on pulmonary capacities, and smoking one packet per year caused a reduction of 12.27 units in FEV1, 10.33 in FEV1/FVC, and 11.79 units in PEF. Regarding the effect of welding fumes on the prevalence of respiratory disease symptoms (table 6), it was found that after controlling other covariates, exposure to welding fumes significantly increased the chance of incidence of these symptoms (wheezing, cough with phlegm). This finding is in agreement with results of previous studies [35, 37].

Given that the exposed and non-exposed groups matched, and the results of the independent t-test, it can be asserted that reduction in respiratory function indices in workers was due to exposure to welding fumes, primarily because of non-standard working conditions. Also, the significant difference between the exposed subjects in terms of the mean respiratory function indices and smoking indicates the reducing effects of smoking on these indices due to obstruction of respiratory tracts and reduced volume of exhaling air from the lungs in the first second. Given the significant difference in the exposed group subjects in terms of mean respiratory function indices and work history, showing a reduction in these indices in people with longer work history indicates that work history is an effective factor in respiratory diseases (especially obstruction of respiratory tracts) among these workers.

The independent t-test results showed that between the mean respiratory function indices and respiratory disorders, there was a significant and direct correlation with shortness of breath only. Also, Kruskal Wallis test revealed no significant correlation between mean value of these indices and using personal protective equipments.

Conclusion

The results of the present study provide significant evidence and reasons for confirmation of the hypothesis that long-term exposure to high concentration of welding fumes can cause a significant increase in symptoms of respiratory disorders, and a significant decrease in pulmonary function parameters (a combination of semi-reversible acute lesions and reversible chronic lesions).

Recommendations

It appears further studies with larger sample size and longer exposure are necessary to more accurately evaluate (in absence of confounding factors) the nature of pulmonary function complications and respiratory symptoms in workers of both sexes. To prevent advancement of respiratory lesions in workers and also to prevent incidence of these disorders in newly employed workers in this industry, it is recommended that exposure to these pollutants be reduced through engineering control methods (local and general ventilation) and protective equipments be used in order to prevent and/or minimize these problems.

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Table 1: Demographic details, smoking, and level of exposure to welding fumes

Parameter		Exposed N=140	Non-exposed 110=N	P-Value
Age (years)		45.6±8.77	41.31±11.4	0.037
Weight (kg)		70.32±10.28	65.07±7.8	0.082
Height (cm)		175.47±5.3	170.2±9.26	0.444
Work history (years)		15.12±2.5	12.8±5.43	0.316
Concentration of welding fumes		8.34	-	-
Frequency in terms of marital status	Married	94	88	0.43
	Single	46	22	
Frequency in terms of smoking	Yes	64	43	0.005
	No	76	67	
Intensity of smoking	Light	73	86	0.084
	Heavy	27	14	

Table 2: The frequency of abnormal clinical findings in exposed and non-exposed subjects

Symptom		Exposed (140=n)	Non-exposed (110=n)	Chance ratio (confidence interval 95%)	P-Value
Cough	Yes	94	34	21.27	0.003
	No	46	76	(3.28-114.4)	
Phlegm	Yes	120	25	24.5	0.003
	No	20	85	(5.3-104.67)	
Cough with phlegm	Yes	53	30	15.77	0.007
	No	87	80	(2.16-111.6)	
Wheezing	Yes	71	43	19.33	0.003
	No	69	67	(3.14-130.22)	
Shortness of breath	Yes	87	90	4.7	0.005
	No	53	20	(2.41-33.2)	

Table 3: The results of pulmonary function parameters measurement in exposed and non-exposed subjects

Parameter	Non-exposed (110=n)	Exposed, beginning of shift (140=n)	Exposed end of shift (140=n)	P-Value
VC	86.57±8.0	79.93±7.5	75.38±8.4	0.003
FVC	89.4±4.4	74.02±16.18	77.17±10.86	0.114
FEV_1	88.93±12.7	63.85±12.7	66.1±12.2	0.007
FEV1/ FVC	104.17±4.33	88.98±10.15	90.33±9.89	0.110
PEF	60.4±11.5	59.56±18.13	61.08±15.86	0.028

Table 4: The effects of exposures to smoking and its intensity (packet per year) on pulmonary function with linear multivariate regression (n=260)

Parameter	Independent variable	Coefficient of B	Standard error	P-Value	95% CI
VC	Constant	79.5	7.75	0.003	57.34-67.75
	History of exposure to fumes	15.61	6.1	0.007	5.4-20.7
FVC	Constant	50.15	4.13	0.001	37.44-62.0
	History of exposure to fumes	17.44	5.7	0.004	4.41-33.16
FEV_1	Constant	57.42	15.1	0.001	31.14-80.5
	History of exposure to fumes	25.4	7.05	0.002	8.47-26.51
	Smoking intensity	-15.8	4.57	0.026	-33.34--0.736
FEV_1/ FVC	Constant	85.07	6.5	0.002	74.26-110.75
	History of exposure to fumes	14.04	4.9	0.02	4.68-25.05
	Smoking intensity	-13.74	4.04	0.037	-20.57--4.1
PEF	Constant	68.8	6.17	0.001	50.24-87.65
	History of exposure to fumes	14.55	7.23	0.032	3.66-22.28
	Smoking intensity	-16.4	5.44	0.02	-25.36- -2.53

Table 5: The results of assessment of exposure status and smoking intensity (packets per year) on respiratory symptoms using logistic regression test (n=260)

Symptom	βcoefficient of (SE)	Chance ratio (Confidence interval 95%)	P-Value
Wheezing	2.08(0.65)	9.07 (2.32-42.19)	0.03
Cough with phlegm	2.32 (1.05)	15.17 (2.85-81.26)	0.027
Cough	0.84 (0.33)	6.28 (0.28-4.16)	0.237
Mucus clearance	0.5 (0.55)	2.93 (0.36-4.12)	0.461

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