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ORIGINAL ARTICLE

Oxidative Stress and Pulmonary Function Status among Industrial Welders

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ABSTRACT

BACKGROUND: Welding is a process to connect different parts using various techniques. In industrial settings, shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and tungsten inert gas welding (TIG) are the most common types of electric arc welding. In all these procedures, welders are exposed to a range of hazards such as gases and fumes that may affect their pulmonary function and oxidative stress status. This case-control study was conducted to investigate lipid peroxidation, oxidative stress, and pulmonary function status in industrial welders.

METHOD: Case participants worked in one of three types of welding (SMAW, GMAW, TIG) (52 men), and control participants (40 men) were not exposed to welding hazards. Blood biomarkers MDA and TAC were evaluated to determine antioxidant levels, and FVC, FEV1, and FEV1/FVC indices were considered for pulmonary function.

RESULTS: The results showed that there was a significant difference in the levels of MDA, FVC, and FEV1 between the welders and the control group, but no significant difference was observed in the levels of TAC. It seems that among welder groups, the mean levels of MDA, FVC, and FEV1 in SMAW welders were significantly different compared to the other groups. Finally, MDA had a significant relationship with all pulmonary indices, and FVC had a significant relationship with all biomarkers of oxidative stress and other pulmonary functions.

CONCLUSION: The findings show that occupational exposure to welding hazards in different types of welding may affect oxidative stress and pulmonary function indices.

KEYWORDS: *Welding, Oxidative stress, Biomarkers, Pulmonary function*

INTRODUCTION

There are various techniques for welding used in industries. Among these techniques, electric arc welding is one of the most widely utilized. Shielded metal arc welding (SMAW), gas metal arc welding (GMAW), and tungsten inert gas welding (TIG) are the most common types of this welding [1]. Welders are exposed to different types of hazards, including noise, ultraviolet radiation, gases, and fumes. It has been proven that gases and fumes have copious health effects [2]. The generation of these agents varies depending on the welding technique used, base metals, coated materials, filler metals, fluxes, and electrode

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material [3, 4]. Ozone, nitrogen oxide, carbon dioxide, and carbon monoxide are among the gases that may be released in the welding process [5]. Ozone (O_3) is a gas with strong oxidizing abilities, which may be involved in the production of reactive oxygen species, leading to deoxyribonucleic acid (DNA) mutation. It has also been proven that this gas causes changes in the morphology, physiology, and biochemistry of the lungs, causing asthma. Carbon monoxide is a colorless gas that reduces the affinity of oxygen with red blood cells, leading to asphyxiation. This gas is produced during the incomplete burning of electrodes or flux and when carbon dioxide gas is used as a protective gas. High exposure to oxidant gases, nitric oxide, and nitrogen dioxide can affect lung function and cause pulmonary edema [6-8].

Inhalation exposure to welding pollutants increases lung disorders and decreases lung function. Forced Vital Capacity (FVC) and Forced Expiratory Volume (FEV1) (spirometry indices) are among the most important indices used to evaluate lung function, and the values of these indices change under the influence of various exposures [9, 10]. Oxidative stress can occur in different job situations (such as job stress) and in job encounters with different factors, including chemicals in the welding process [11, 12]. Pollutants in the welding process can increase oxidative stress in the body by reducing intracellular oxygen levels and increasing oxygen free radicals, hydroxyl radicals, superoxide anions, and hydrogen peroxide [13]. Increased oxidative stress among welders has been linked to the generation of reactive oxygen species (ROS) from common metals found in welding contaminants. Biological monitoring is one of the reliable objective methods to effectively identify health risks in the body [14]. Among oxidative stress biomarkers, malondialdehyde (MDA) and total antioxidant capacity (TAC) have been used in most studies as biomarkers indicating oxidant/antioxidant status [15, 16].

Welding is an occupation that demands significant skill and specialized training. Protecting this workforce in related industries is essential to prevent both direct and indirect harm. To implement effective preventive measures, it is crucial to assess the health status of welders by evaluating their pulmonary function and monitoring the potential effects of the exposure on their antioxidant profiles. Considering there are different types of welding in industrial processes, but prominently three types—SMAW, TIG, and CO2 welding—the purpose of this study was to investigate the state of pulmonary function and oxidant/antioxidant profiles in different groups of industrial welders.

MATERIALS AND METHODS

Design and sample

This case-control study was conducted among welding workers in one of the industrial towns in Iran. Data were collected from June 01 to August 05, 2022. The Cochran formula was used to estimate the sample size, and considering the 15% sample loss, the sample size was determined as 92 subjects (52 case, 40 control). The group analyzed in this study included 52 workers, all males, nonsmokers, without any respiratory diseases, performing welding activities in industrial factories (inclusion criteria), who were provided with spirometry tests and blood samples before their working shift, and 40 healthy male employees of the same companies (without exposure to special chemicals). Before providing the samples, all subjects gave their written informed consent to participate in the study.

The demographic questionnaire

The demographic questionnaire included questions about age, marital status, work experience, type of welding, height, and weight (in order to calculate the body mass index [BMI]).

Oxidative stress indices

Levels of oxidative stress indices, including total antioxidant capacity (TAC) and levels of MDA (as a lipid peroxidation index), were measured in participants' serum samples. Blood samples were taken from the median cubital vein in a sitting position (2 ml) and, after collection, were centrifuged at 3000 rpm for 10 minutes (Model: Hettich). The serum was separated and stored at -80 °C until chemical analysis was performed [2].

TAC Biomarker Analysis

The commercial kit provided by ZellBio Company, Germany (ZellBio GmbH, Germany) was used to analyze the TAC biomarker. The test procedure was carried out according to the instructions provided by the company. These kits use the colorimetric method and are based on the reduction of Fe (3+) to Fe (2+) by antioxidants, which are coupled with a suitable chromogen (dye). The result creates a color that can be read at the wavelength of 490 nm (by ELISA reader, Stat Fax 2100).

MDA Biomarker Analysis

The commercial kit provided by ZellBio Company, Germany (ZellBio GmbH, Germany) was used for MDA biomarker analysis. The steps of the test were carried out according to the company's instructions. In this kit, malondialdehyde reacts with thiobarbituric acid (TBA) at high temperature to produce a pink color, which can be read by the colorimetric method at a wavelength of 530-540 nm (by ELISA reader, Stat Fax 2100).

Pulmonary Function Test

Spirometry was performed with the Spirolab II device from MIR, Italy, approved by the American Thoracic Society. After putting on the nose clip, the participants were asked to sit down and put the blowing piece in their mouth. After two or three normal inhalations and exhalations, they took a deep breath and exhaled quickly and forcefully for about six seconds with maximum intensity. This test was performed at least three and at most eight times for each person. Functional indices, including FVC (Liter), FEV1 (Liter), and FEV1/FVC (%), were recorded. FVC (forced vital capacity), FEV1 (expiratory volume in the first second of forced exhalation), and the FEV1/FVC ratio have high sensitivity and specificity in diagnosing pulmonary obstruction [9, 10].

Statistical analysis

Descriptive statistics (frequency, mean, and standard deviation) were used to summarize demographic and organizational data, and $\chi 2$ tests were used to compare demographic variables between groups. Data normality and variance equality were determined using the Kolmogorov–Smirnov and Levene's tests. The differences in biomarkers and spirometry indices between the groups were evaluated by independent t-tests. The relationship between oxidative stress biomarkers and pulmonary function indices was analyzed by Pearson correlation. Statistical analysis was performed using SPSS version 24.0 at a significant level of 0.05.

RESULTS

The demographic information of the study participants is presented in Table 1. Most of the participants (48.91%) were aged ≥40 years. A total of 55.43% of participants had a normal BMI, and approximately 49% of participants had more than 21 years of work experience. Most of the welders were in the SMAW group. None of the demographic variables were significantly different between the case and control groups.

Figure 1 shows the mean and standard deviation of oxidative stress biomarkers and pulmonary function indices in the studied groups. Only the TAC levels were not significantly different between the case and control groups.

Table 2 demonstrates the relationship between oxidative stress biomarkers and pulmonary function indices (using the Pearson Test). FVC demonstrated a remarkable relationship with all other variables. For TAC, the p-value was 0.01, and for FEV1, FEV1/FVC, and MDA, the p-value was 0.05. Also, the MDA biomarker had a significant relationship with all pulmonary function indices.

The correlation coefficients for FVC and MDA

Table 1. Demographic variables in case group (n=52) and control group (n=40).

Variable	Classification	N (%)	Case(%)	Control(%)	P-Value**
Age (years)	≤30	17 (18.47)	8 (15.38)	9 (22.5)	0.65
	31-39	30 (32.60)	17 (32.69)	13 (32.5)	
	≥40	45 (48.91)	27 (51.92)	18 (45.0)	
Marital Status	Single	28 (30.43)	16 (30.76)	12 (30.0)	0.93
	Married	64 (69.56)	36 (69.23)	28 (70.0)	
BMI*	Underweight	7 (7.60)	4 (7.69)	3 (7.5)	0.94
	Normal	51 (55.43)	28 (53.84)	23 (57.5)	
	Pre-obesity	28 (30.43)	17 (32.69)	11 (27.5)	
	Obesity	6 (6.52)	3 (5.76)	3 (7.5)	
Experience (years)	≤10	16 (17.39)	9 (12.7)	7 (12.9)	0.96
	11-20	31 (33.69)	17 (34.9)	14 (19.7)	
	≥21	45 (48.91)	26 (52.4)	19 (67.4)	
Type of welding	SMAW		30(57.69)		
	TIG		8(15.38)		
	CO_2		14(26.92)		

* Body Mass Index, ** χ^2 test

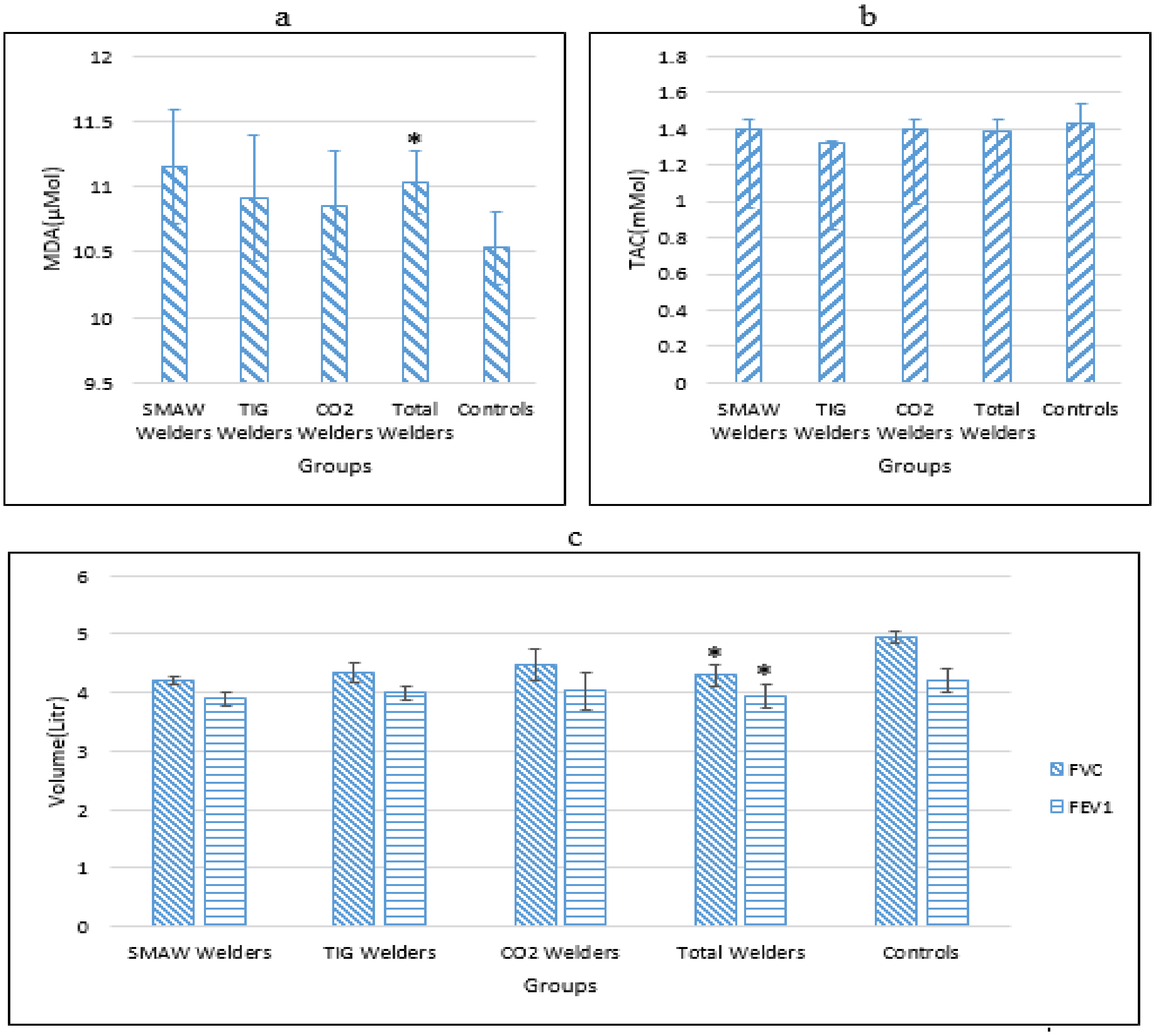

Figure 1. a: Serum Malondialdehyde, (µMol) levels in all group. b: Serum total antioxidant capacity (TAC) levels in all group. c: Force Vital Capacity(FVC) and Forced Expiratory Volume (FEV1) levels in all group. *: Significant in comparison with control.

Table 2. Correlation Coefficient between TAC, MDA, FVC, FEV1 and FEV1/FVC

Variables	Items				
	1	2	3	4	5
1. MDA	1				
2. TAC	-0.176	1			
3. FVC	-0.536**	0.219*	1		
4. FEV1	-0.251*	0.107	0.744**	1	
5. FEV1/FVC	0.429**	- 0.164	-0.577**	- 0.026	1

*: P-Value<0.05; **: P-Value<0.01

measured r = -0.536 and for FVC and TAC, r = 0.476.

DISCUSSION

This study aimed to explore the relationship between oxidative stress biomarkers and pulmonary function indices among welders, comparing case and control groups. The demographic data presented in Table 1 indicate that the majority of participants were aged 40 years or older, with a substantial proportion having more than 21 years of work experience. This suggests that the participants are highly experienced welders, potentially having prolonged exposure to welding fumes and occupational hazards, which could influence both oxidative stress levels and pulmonary function. Notably, there were no significant differences in demographic variables between the case and control groups, which strengthens the validity of subsequent comparisons between these groups as it reduces the likelihood of confounding effects from demographic factors.

Figure 1 illustrates the mean and standard deviation of oxidative stress biomarkers and pulmonary function indices. The results show that the levels of malondialdehyde (MDA), a well-established marker of lipid peroxidation and oxidative stress, were significantly higher in the case group compared to the control group, which is consistent with the results of the study by Mainasara et al. [2]. This suggests that welders in the case group were potentially exposed to higher levels of welding fumes, experiencing greater oxidative damage. Elevated MDA levels have been associated with various adverse health outcomes, including respiratory conditions, which are particularly relevant in occupational settings involving metal fumes and particulate matter, such as welding [17].

Interestingly, the Total Antioxidant Capacity (TAC) levels did not differ significantly between the case and control groups (Figure 1b). This might indicate that the antioxidant defense system in welders was not substantially depleted or that the assay used was not sensitive enough to detect more subtle changes. However, it is also possible that prolonged exposure to oxidative stressors leads to an adaptive response, whereby the body maintains its antioxidant capacity despite increased oxidative stress [18]. Further research with more sensitive markers or larger sample sizes may clarify this finding.

In terms of pulmonary function, both Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1) were significantly lower in the case group compared to the control group (Figure 1c), which is consistent with the results of the studies by Rasoul and Cetintepe [10, 19]. Reduced FVC and FEV1 are commonly observed in individuals exposed to occupational pollutants such as welding fumes, which can lead to respiratory impairment [20]. The observed decline in pulmonary function indices in the case group suggests that welders with higher oxidative stress levels may be at increased risk of developing respiratory issues, potentially due to long-term exposure to harmful particles and gases generated during welding.

Table 2 presents the correlation coefficients between oxidative stress biomarkers (MDA and TAC) and pulmonary function indices (FVC, FEV1, and FEV1/FVC). A strong negative correlation was found between MDA levels and both FVC and FEV1 ($r = -0.536$ and $r = -0.251$, respectively), indicating that higher levels of oxidative stress, reflected by increased MDA levels, are associated with poorer lung function, which is consistent with the study by Moitra et al. [21]. This aligns with previous studies that have demonstrated a link between oxidative stress and impaired pulmonary function in populations exposed to occupational hazards [22, 23].

The strong negative correlation between MDA and FVC ($r = -0.536$, $P < 0.01$) suggests that oxidative stress plays a significant role in reducing lung volume. This could be due to the damage caused by reactive oxygen species (ROS) to lung tissues, leading to inflammation and fibrosis, both of which can restrict lung expansion and reduce vital capacity [24]. The significant correlation between MDA and FEV1 ($r = -0.251$, $P < 0.05$) further supports the notion that oxidative stress contributes to airway obstruction and reduced airflow, both hallmarks of occupational lung diseases such as asthma and chronic obstructive pulmonary disease (COPD) [25].

Interestingly, TAC demonstrated a weak positive correlation with FVC ($r = 0.219$), although this did not reach statistical significance for FEV1. This suggests that higher antioxidant capacity may offer some protective effect for lung function, potentially mitigating the damaging effects of oxidative stress [26]. However, the relatively weak correlation indicates that antioxidant defenses alone may not be sufficient to counteract the extensive oxidative damage caused by prolonged exposure to welding fumes.

The ratio of FEV1 to FVC (FEV1/FVC) demonstrated a significant negative correlation with MDA ($r = -0.577$, $P < 0.01$) and a positive correlation with FVC ($r = 0.429$, $P < 0.01$). This suggests that as oxidative stress increases, the proportion of air that can be forcibly exhaled in one second relative to the total lung volume decreases, which is indicative of restrictive lung disease. The correlation between FEV1/FVC and MDA further highlights the detrimental impact of oxidative stress on pulmonary function and underscores the importance of minimizing oxidative damage in occupational settings [27].

All in all, this study provides evidence for the significant relationship between oxidative stress biomarkers and pulmonary function indices among welders. The findings underscore the need for continued efforts to monitor and mitigate oxidative stress in occupational settings, particularly in industries such as welding where exposure to harmful pollutants is prevalent. By addressing these issues, it may be possible to reduce the incidence of respiratory diseases and improve the overall health and well-being of workers in high-risk occupations.

CONCLUSION

The findings of this study have important implications for the occupational health of welders. The significant associations between oxidative stress biomarkers and reduced pulmonary function suggest that interventions aimed at reducing oxidative stress may help preserve lung function in this population. Such interventions could include improving workplace ventilation, providing personal protective equipment, and promoting the use of antioxidant supplements or dietary measures to boost natural antioxidant defenses. Future research should aim to elucidate the specific mechanisms by which welding fumes induce oxidative stress and contribute to pulmonary dysfunction. Longitudinal studies would be particularly valuable in assessing the long-term effects of occupational exposure on respiratory health and identifying potential biomarkers of early disease. Additionally, studies investigating the effectiveness of various interventions in reducing oxidative stress and improving pulmonary function among welders would provide valuable insights for occupational health practitioners.

CONFLICT OF INTEREST

There is no Conflict of interest.

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