Oxidant-Antioxidant Status and Pulmonary Function in Welding Workers

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Abstract: Oxidant-Antioxidant Status and Pulmonary Function in Welding Workers: Fatma Fidan, et al. Department of Pulmonary Diseases, Turkey—Welding is a process during which fumes, gases, electromagnetic radiation and noise are emitted as by-products. Metal oxide particles are particularly hazardous components of welding fumes. Welding has been found to be associated with respiratory symptoms and our objective in the present study was to study the effects of welding on pulmonary function and serum oxidant-antioxidant status. Fifty-one welding workers and 31 control subjects were recruited. Face to face interviews were conducted using the respiratory illness questionnaire adapted from the American Thoracic Society with the addition of demographic characteristics, work history and working conditions. Additionally physical examinations and spirometric measurements were performed at workplaces. Thiobarbituric acid reactive substances (TBARS), protein carbonyls, protein sulfhydryls (SH) and erythrocyte reduced glutathione (GSH) levels were measured to evaluate oxidant-antioxidant status in 34 welding workers and in 20 control subjects. No statistically significant differences were observed in age, height, weight, body mass index (BMI), smoking status and annual working durations between welding workers and controls. Coughing, sputing and wheezing were significantly higher in welding workers (p<0.05). When adjusted for age, BMI and smoking status in logistic regression, welding work showed a significant risk for chronic bronchitis (OR: 4.78, 95%CI: 1.30–17.54). Forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) and four parameters of forced expiratory flow (FEF: FEF25, FEF50, FEF75, FEF25–75) levels measured in the welding workers were significantly lower than those in the control group (p<0.05). Serum TBARS and protein carbonyl levels were higher in welding workers than those in controls (p<0.001, p<0.05, respectively). On the other hand, total protein SH groups and GSH levels were significantly lower in welders than those in controls (p<0.05, p<0.001, respectively). Pulmonary function tests and oxidant-antioxidant status were found to be negatively affected in welding workers chronically exposed to welding fumes and gases. Preventive measures should be taken to improve the health status of these workers. (J Occup Health 2005; 47: 286–292)

Key words: Welding, TBARS, Protein carbonyls, Protein sulphhydryls, GSH, Pulmonary function test

Welding is a process during which fumes, gases, electromagnetic radiation and noise are emitted as by-products. The fumes are chemically very complex and arise primarily from filler metals, electrode coating or cores. It is obvious that, during the welding process, workers are exposed to all of these agents. Most welding materials are alloy mixtures of metals that contain iron, manganese, silica, chromium, nickel, and others. Fumes generated from stainless steel (SS) electrodes usually contain approximately 20% of chromium with 10% of nickel, whereas fumes from mild steel (MS) welding usually contain more than 80% of iron, with some manganese and nickel with the absence of chromium. The adverse effects of welding on health are due to chemical, physical, and radiation hazards. Common chemical hazards include metal particulates and noxious gases. These toxic gases include ozone, nitrogen oxides, carbon monoxide and carbon dioxide. Physical hazards include electrical energy, heat, noise, and vibration. However, the particulates and gases generated during welding are considered to be the most harmful in comparison with the other by-products of welding. The biological effects of ozone and nitrogen oxides are...
attributed to their ability to cause oxidation and peroxidation of biomolecules, directly and/or via free radical reactions. The sequence of events after lipid peroxidation is loss of functional groups of enzymes, alteration of membrane permeability and cell injury or even trigger of apoptosis processes. Both ozone and nitrogen oxides are found to be capable of depleting antioxidant resources of organisms.

The purpose of this study was to analyze the influence of occupational environment on respiratory systems of welding workers and their oxidant-antioxidant status. Thiobarbituric acid reactive substances (TBARS), protein carbonyls, protein sulfhydryls (SH) and erythrocyte reduced glutathione (GSH) levels were measured to evaluate oxidant-antioxidant status.

**Materials and Methods**

1. Study population
   This study was conducted between January and September, 2004 in Afyon, Turkey. Welding workers (n=51) who had been working for at least 5 yr in welding processes were included. Workers from the automobile electric industry, free of exposure to welding fumes and hazardous dusts were recruited as controls (n=31). Heights and weights of subjects were measured and body mass indices (BMI) were calculated according to the weight (kg) / square of height (m²) formula. According to smoking status, they were grouped as smokers and non-smokers.

1.1. Occupational history
   The work histories of the subjects were assessed through a structured questionnaire including questions on previous and current jobs, job descriptions, working conditions, ventilation conditions of the workplaces, total and daily working times.

1.2. Ascertainment of respiratory effects
   The Medical Ethics Committee of Afyon Kocatepe University approved this study. All participants were informed about the study and their written consent was obtained. Face to face interviews were conducted using the respiratory illness questionnaire adapted from the American Thoracic Society with the addition of demographic characteristics, work history and working conditions. Physical examinations and spirometric measurements were performed at the workplaces. The physical examination of all the subjects was performed by the same pulmonology specialist. Spirometric measurements were obtained by the same physician using a portable spirometer (MIR, Spirobank, Italy) according to the criteria of the American Thoracic Society. Three consecutive measurements were taken and the best value was recorded for forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), FEV₁/FVC ratio, peak expiratory flow (PEF), and four parameters of forced expiratory flow (FEF): FEF₂,₅, FEF₅₀, FEF₇₅ and FEF₂₅₋₇₅.

The symptoms assessed through an interview were cough, sputum, wheezing and dyspnea. Chronic bronchitis was defined as the presence of coughing or sputum on most days of three months or more, for over two years. During physical examination, elongation of expirium, rhonchii in auscultation and wheezing were the pathologic signs in favour of airway disease.

2. Biochemical analysis
   Thirty four of 51 welders and 20 of 31 control subjects agreed to give blood samples, and oxidant-antioxidant markers were measured in the sera of these subjects. Peripheral blood samples were drawn into plain tubes from each subject and were analyzed on the same day. After centrifuging the samples at 1,000 x g for 10 min at +4°C, the serum samples were removed and stored at −20°C for further analysis. To determine lipid peroxidation, thiobarbituric acid reactive substances (TBARS) levels were determined according to a previously described method. Oxidative damage to proteins were assessed by determinations of protein carbonyls and total protein sulfhydryls (SH) levels. Whole blood samples were used for erythrocyte reduced glutathione (GSH) measurements.

3. Statistical analysis
   Student’s t-test, Mann Whitney U and chi-square tests were used where appropriate. A p value less than 0.05 was set as the minimum for statistical significance. To determine the risk of occupation (welding worker) on symptoms and chronic bronchitis, univariate and logistic regression analyses were performed. A model was constructed including age, smoking status and BMI as confounding factors to obtain adjusted odds ratios (OR) for occupation.

**Results**

Table 1 shows general characteristics of the welding workers and controls. All of the participants were male and both groups were similar in age, height, weight and BMI (p>0.05) (Table 1). Smoking was found to be highly prevalent both in controls and the welder group (61.3% and 74.5%, respectively). No statistically significant differences were observed in smoking status (p>0.05). Also no significance was observed in pack-years of smoking (p>0.05) (Table 2).

No statistically significant differences were observed in weekly and annual working durations in both groups (p>0.05); but daily working durations were significantly higher in the control group (p<0.001). The mean daily working duration for welding workers was 4 h. None of the workplaces were found to have a special ventilation system. Of the welders, 48 (94.1%) were working in covered workplaces, whereas 3 (5.9%) were working in semi-covered workplaces. Only 3 workers were using
masks during the welding process. Of the welders, 46
(90.2%) were using protective equipment for the eyes. They reported that they were not using this protective equipment for short duration welding processes, and they were observed to have symptoms of keratoconjunctivitis such as pain and red eyes.

Respiratory symptoms were found to be significantly more prevalent in the welder group than in the controls (Table 4). According to the criteria for chronic bronchitis, 35.3% of the subjects in the welder group and 12.9% of the subjects in the controls were diagnosed as having chronic bronchitis. This difference was statistically significant (p<0.05). Logistic regression analysis adjusted for age, smoking and BMI showed that working in
welding processes revealed a significantly higher risk for cough, sputing, wheezing and chronic bronchitis (Table 4) \((p<0.05)\). Respiratory symptoms were observed to increase in 23.5% of the welders especially in their workplaces and decrease during the weekend. None of the subjects in the control group were found to have worsened respiratory symptoms in their workplaces. This difference was statistically significant \((p<0.05)\).

Although pathologic auscultation findings were detected in 3.2% and 11.8% of the subjects in controls and welders, respectively, no statistical significance was observed \((p>0.05)\). Table 5 shows the observed and percentage predicted spirometric findings in each group. Both measured and predicted percentage values of FEV\(_1\)/FVC, FEF\(_{25}\), FEF\(_{50}\), FEF\(_{75}\), and FEF\(_{25-75}\) levels in the welder group were significantly lower \((p<0.05)\).

Thirty-four of the welders and 20 of the controls agreed to give blood samples. Serum TBARS and protein carbonyl levels were found to be higher in welders than those in controls \((4.3 \pm 2.2 \mu mol/l vs 2.2 \pm 1.0 \mu mol/l, p<0.001, 80.7 \pm 15.6 \mu mol/l vs 70.9 \pm 10.4 \mu mol/l, p<0.05, respectively)\). On the other hand, total protein SH groups and erythrocyte GSH levels were found to be significantly decreased in welders than those in controls \((518.6 \pm 93.2 \mu mol/l vs 584.6 \pm 95.4 \mu mol/l, p<0.05, 1.4 \pm 0.8 \mu mol/gHb vs 3.2 \pm 1.6 \mu mol/gHb, p<0.001, respectively)\) (Table 6).

There were no statistically significant differences in the mean age \((p=0.350)\), height \((p=0.699)\), weight \((p=0.219)\) and BMI \((p=0.299)\) between the 34 welders and 20 control subjects whose oxidant-antioxidant marker levels were measured. Twenty-four (70.6%) welders and 12 (60.0%) control subjects (whose blood samples were studied) were smokers and there were no significant difference between the groups \((p=0.425)\).

No significant correlations were found between the pulmonary functions test parameters and serum oxidant-antioxidant marker levels \((p>0.05)\). Significant differences were found in TBARS, SH and GSH levels between the patients with and without chronic

### Table 5. Spirometric findings of welder and control groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group</th>
<th>% Predicted Value</th>
<th>Observed value (l)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV(_1)</td>
<td>Welder group</td>
<td>95.3 ± 11.9</td>
<td>3.7 ± 0.6</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>100.5 ± 12.8</td>
<td>3.9 ± 0.6</td>
<td></td>
</tr>
<tr>
<td>FVC</td>
<td>Welder group</td>
<td>90.6 ± 12.1</td>
<td>4.1 ± 0.7</td>
<td>0.928</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>89.8 ± 11.3</td>
<td>4.2 ± 0.7</td>
<td></td>
</tr>
<tr>
<td>FEV(_1)/FVC</td>
<td>Welder group</td>
<td>88.5 ± 7.2</td>
<td>88.5 ± 7.2</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>93.5 ± 5.7</td>
<td>93.5 ± 5.7</td>
<td></td>
</tr>
<tr>
<td>PEF</td>
<td>Welder group</td>
<td>77.7 ± 26.4</td>
<td>6.8 ± 1.8</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>86.6 ± 25.2</td>
<td>9.9 ± 11.3</td>
<td></td>
</tr>
<tr>
<td>FEF(_{25})</td>
<td>Welder group</td>
<td>80.7 ± 24.8</td>
<td>6.1 ± 1.5</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>95.0 ± 27.1</td>
<td>7.2 ± 2.2</td>
<td></td>
</tr>
<tr>
<td>FEF(_{50})</td>
<td>Welder group</td>
<td>91.6 ± 22.8</td>
<td>4.6 ± 1.1</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>113.5 ± 29.7</td>
<td>5.7 ± 1.4</td>
<td></td>
</tr>
<tr>
<td>FEF(_{75})</td>
<td>Welder group</td>
<td>109.8 ± 32</td>
<td>2.5 ± 0.9</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>136.2 ± 35.8</td>
<td>3.0 ± 0.8</td>
<td></td>
</tr>
<tr>
<td>FEF(_{25-75})</td>
<td>Welder group</td>
<td>94.2 ± 23.8</td>
<td>4.3 ± 1.1</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>116.4 ± 26.3</td>
<td>5.1 ± 1.2</td>
<td></td>
</tr>
</tbody>
</table>

### Table 6. Levels of TBARS, protein carbonyl, protein sulphhydryl (SH) groups and erythrocyte reduced glutathione (GSH) in control and welder groups

<table>
<thead>
<tr>
<th></th>
<th>Control group (n=20)</th>
<th>Welder group (n=34)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBARS (µmol/l)</td>
<td>2.2 ± 1.0</td>
<td>4.3 ± 2.2</td>
<td>0.000</td>
</tr>
<tr>
<td>Protein Carbonyls (µmol/l)</td>
<td>70.9 ± 10.4</td>
<td>80.7 ± 15.6</td>
<td>0.036</td>
</tr>
<tr>
<td>Protein SH Groups (µmol/l)</td>
<td>584.6 ± 95.4</td>
<td>518.6 ± 93.2</td>
<td>0.021</td>
</tr>
<tr>
<td>Erythrocyte GSH (µmol/g Hb)</td>
<td>3.2 ± 1.6</td>
<td>1.4 ± 0.8</td>
<td>0.000</td>
</tr>
</tbody>
</table>
bronchitis ($p=0.005$, $p=0.000$, $p=0.013$, respectively), on the other hand there were no significant differences in carbonyl levels ($p=0.446$) (Figs. 1, 2).

**Discussion**

Metal oxide particles are particularly hazardous components of welding fumes since they are small enough to deposit in the terminal bronchioles and alveoli, distal to mucociliary cleaning mechanisms\(^{15}\). Welding is often associated with respiratory symptoms and welders have been found to have chronic bronchitis and asthma\(^{16}\).

Beckett *et al.*\(^{17}\) evaluated the respiratory symptoms of a shipyard welder group for a 3-yr period. During the first year of the study, 35% of the welder group reported that they experienced cough, sputting, wheezing, and chest tightness during work hours with improvements on weekends. These symptoms were significantly more frequent among the welder group than controls. We observed the symptoms of cough, sputting and wheezing significantly higher in welders than those in controls ($p<0.05$), but dyspnea was not significant in welders ($p>0.05$). Of the welders 23.5% experienced improvements in their symptoms during the weekend ($p<0.05$). No statistically significant improvements were observed during the weekend in the control group.

In the welder group, 35.3% of the subjects were found to fulfill the criteria for chronic bronchitis ($p<0.05$). Adjusted for age, BMI and smoking status in the logistic regression analysis, working in the welding process showed a significant risk for bronchitis. Cotes *et al.*\(^{18}\) studied 607 shipyard welders and similarly exposed caulker burners. Subjects over 50 yr of age had a 40% prevalence of chronic bronchitis with a relative risk ratio of 2.8 when adjusted for age and smoking status. After a review of published studies of respiratory symptoms of welders, Billings and Howard\(^{19}\) concluded that the association of welding fumes with obstructive airway disease could be as important as that of smoking.

In our study, both measured and predicted percentage values of FEV\(_1\)/FVC, FEF\(_{25}\), FEF\(_{50}\), FEF\(_{75}\), and FEF\(_{25–75}\) were significantly lower in welders ($p<0.05$) than in controls. In welders, FEV\(_1\) and PEF values were found to be decreased 5% and 9%, respectively, but this decrease was not statistically significant ($p>0.05$). Also FVC values were similar in both controls and welders ($p<0.05$). These results indicate an obstructive rather than a restrictive ventilatory defect. Small airways were found to be significantly affected in welders (based on the values of FEF\(_{25}\), FEF\(_{50}\), FEV\(_1\), FEF\(_{25–75}\)) although no statistically significant difference was found with FEV\(_1\) and PEF values, showing central airway activity was decreased in welders compared to controls. However the decrease in the FEV\(_1\)/FVC ratio was statistically significant ($p<0.05$). Wolf *et al.*\(^{20}\), Nakadate *et al.*\(^{21}\) and Stepniewski *et al.*\(^{22}\) also reported affected small airways in welders. Ozdemir *et al.*\(^{22}\) showed decreased values of FVC, FEV\(_1\) and PEF in welders.

Some authors have reported unaffected spirometric parameters after welding\(^{23, 24}\). Wolf *et al.*\(^{20}\) reported that, reduced flow rates in welders could be attributed to smoking habits rather than exposure to fumes during welding. In the study of Meo *et al.*\(^{25}\), welders with an exposure of more than 9 yr showed a significant reduction in FEV\(_1\), FEV\(_1\)/FVC\(_%\), and PEF values. Welders with an exposure of less than 5 yr did not show any significant decrease in these parameters. The apparent disparity in the studies of pulmonary function in welders could be attributed to differences in smoking habits, the welding materials used, the amount of ventilation, and the protective measures taken.

Studies with welders in shipyards, who are more likely to be exposed to greater amounts of fumes due to working in more confined, poorly ventilated areas, showed more negative effects on pulmonary function than welders.
working in well-ventilated places\textsuperscript{26, 27}. Adequate ventilation appears to be a significant factor in the health and lung functions of welders. In our study, we observed that 94\% of the subjects were working in closed, poorly ventilated areas where as the rest, 6\%, were working in semi-closed areas. It is obvious that, improving the ventilation conditions might be effective for preventing the adverse effects of welding on pulmonary function.

There are few publications reporting disturbances of the respiratory tract due to exposure to oxidant gases and fumes generated during welding\textsuperscript{17, 20–22}. Little is reported in the literature on occupational exposure to nitrogen oxides and ozone leading to the impairment of oxidant/antioxidant balance\textsuperscript{28}. Oxidative stress represents the imbalance between oxidants like reactive oxygen species (ROS) and antioxidants\textsuperscript{29}. Malondialdehyde (MDA), which arises from the breakdown of lipid peroxyl radicals, is one of the indicators of oxidative stress\textsuperscript{30}. MDA is also important in that, it can cause further oxidative injury by oxidizing protein molecules\textsuperscript{31, 32}, thus it is both an indicator and effector of oxidative stress. Protein carbonyls arise from the oxidation of amino-acid residues and serve as markers of ROS-mediated protein damage\textsuperscript{33}. In contrast, glutathione (GSH) systems, such as intracellular GSH or the SH group of proteins, such as albumin, function as “sacrificial” antioxidants in extravascular spaces\textsuperscript{34}.

In our study, increased TBARS levels and protein carbonyls, and decreased protein sulphydrys provide relevant estimates of oxidative stress in plasma. We found that welding resulted in an increase of plasma TBARS levels and protein carbonyls, indicating increased lipid and protein oxidation, respectively. Welding also caused decreased plasma protein-SH content and decreased erythrocyte GSH levels, implying decreased potential for oxygen-radical cleansing activity.

Serum levels of metal couldn’t be measured because of technical inadequacy. This is a limitation of our study.

There have been only a few clinical studies about antioxidant status in welders\textsuperscript{5 \textsuperscript{33, 34}}. Stepniewski et al.\textsuperscript{5} reported decreased levels of total antioxidant status (TAS) and decreased catalase (CAT) and superoxide dismutase (SOD) enzyme activities in steel mill welders. On the other hand, Mongiat et al.\textsuperscript{35} reported a normal erythrocyte antioxidant system in welders, but they found increased ceruloplasmin levels in smoking welders and manual metal arc welders, suggesting that the increase could be associated with the severity of the oxidative threat.

It is known from the literature that occupational exposure to nitrogen oxides and ozone leads to the impairment of oxidant-antioxidant balance\textsuperscript{36}. Ozone is a strong oxidant that reacts with body tissues it comes in contact with, particularly the lung\textsuperscript{37}.

No correlations between the pulmonary functions and oxidant-antioxidant balance markers were found in our study. In a previous study it was mentioned that the oxidative-antioxidative balance markers cannot be used as early markers of ventilatory dysfunction\textsuperscript{38}. However, TBARS levels were significantly higher, and SH and GSH levels were significantly lower in subjects with chronic bronchitis than those without. This finding suggests a possible effect of impaired oxidative-antioxidative balance in the pathogenesis of chronic bronchitis.

In conclusion, respiratory symptoms, chronic bronchitis, and central and small airway diseases in welders were found to be much more frequent, compared to the controls. Also, the oxidant-antioxidant system was negatively affected in workers chronically exposed to welding fumes and gases, which are thought to be oxidant pollutants. It is recommended that welders ought to be educated about the outcome of the adverse effects of welding and usage of protective equipment during welding. On the other hand, employers should be encouraged to improve ventilation conditions and provide less hazardous welding materials. We believe that further studies should be addressed to clarify the role of oxidative stress in a broad welders population.

References

1. H Saito, J Ojima and M Taskava: Laboratory measurement of hazardous fumes and gases at a point corresponding to breathing zone of welders during a CO\textsubscript2 arc welding. Indust Health 38, 69–78 (2000)