Two year follow up of pulmonary function values among welders in New Zealand

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Abstract

Objectives—To examine whether welding is a risk factor for an accelerated decline in pulmonary function.

Methods—2 Year follow up of pulmonary function and respiratory symptoms among 54 welders and 38 non-welders in eight New Zealand welding sites.

Results—There were no significant differences in age, height, smoking habits, ethnicity, or total time in industrial work between welders and non-welders. No overall differences were noted in the changes of pulmonary function variables between the two study groups. However, when the comparison was restricted to smokers, welders had a significantly greater (p=0.02) annual decline (88.8 ml) in FEV1 than non-welders, who had a slight non-significant annual increase (34.2 ml). Also, welders without respiratory protection or local exhaust ventilation while welding had a greater annual decline both in forced vital capacity (FVC) and forced expiratory volume in one second (FEV1) than welders with protection (p=0.001 and 0.04, respectively). Among welders a significant association was found between the acute across shift change and the annual decline in FEV1. Chronic bronchitis was more common among welders (24%) than non-welders (5%). Only one welder (2%) but eight non-welders (21%) reported having asthma.

Conclusions—Welders who smoked and welders working without local exhaust ventilation or respiratory protection have an increased risk of accelerated decline in FEV1.

Keywords: pulmonary function; welding fume; follow up study

Exposure to welding fumes is known to be a risk factor for respiratory disorders. Welding fumes may cause acute respiratory effects including airway irritation, acute bronchitis, metal fume fever, and, less commonly, hypersensitivity pneumonitis or occupational asthma. Welders are also known to have a higher risk for chronic respiratory disorders—such as pneumoconiosis, chronic bronchitis, and lung cancer. Several studies have shown a small acute decline in lung function during welding work, although this acute decline is still unclear, although it is possible that repeated acute declines could result in the development of chronic respiratory impairment. Knowledge of the chronic effect of welding fumes on lung function is mainly based on cross sectional studies of current workers. Only a few longitudinal studies have been published, with conflicting results. Chinn et al found an irreversible effect of welding on forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) in a 7 year follow up of welders and caulkers/burners, and they also noted an interaction between the effects of smoking and welding. Beckett et al did not find any effect of welding on the annual decline of lung function in a 3 year follow up.

In 1996 a cross sectional survey was conducted in eight different New Zealand engineering sites and found that an acute decrease in FEV1, relative to work was more prevalent among welders than among non-welders. In that study welders had a mean 2.8% fall from baseline FEV1, after 15 minutes of work compared with a 1.0% increase in non-welders. The purpose of the present survey was to study the same workers 2 years after the previous study and to examine whether welders also had an accelerated chronic decline in lung function.

Subjects and methods

A 2 year follow up visit was performed at the same eight New Zealand engineering sites studied in the first survey in 1996. All sites were known to regularly involve welding as part of their industrial process. Most of the welders studied worked with mild steel or mild steel and stainless steel as a base metal, with either gas tungsten arc welding (TIG) or gas metal arc welding (MIG) techniques.

QUESTIONNAIRE

As in the previous study, the questionnaire included demographic data, current smoking habits, questions about work related respiratory symptoms, and selected questions from the European Community Respiratory Health Survey. Reports of current or recent cough, phlegm, wheeze, chest tightness, and shortness of breath were recorded, along with whether these symptoms were related to work (defined as a symptom reported to be worse at work or improving on rest days or holidays).

Smoking was divided into two categories: smokers included all current smokers during study 1 (it includes four smokers who stopped smoking between the two studies), and non-smokers included non-smokers during the study and ex-smokers who had stopped smoking at least 1 year before the study.

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smokers included both never smokers and long term ex-smokers. Chronic bronchitis was defined as regular phlegm production at any time during the day or night for \( \geq 3 \) months of the year and for \( \geq 2 \) years.

**CURRENT WELDING EXPOSURE**

The current job type and the duration of employment were recorded both in the first and the second survey, but the basic definitions were based on the welding status at the time of study 1. A worker was classified as a welder if he had been an active welder (welding \( \geq 5% \) of the working day) in study 1 and had continued in that job between the two surveys (this includes seven welders who stopped welding between study 1 and study 2 with a mean stopping date of 4 months before study 2). Non-welders were defined as all workers who had never worked as welders and workers who were ex-welders at the time of the study 1 or at that time did only minimal welding (\( \geq 5\% \) of the working day) and had not been active welders between the two surveys.

**PREVIOUS WELDING EXPOSURE**

Similarly, welding history was recorded at both surveys but the basic definitions were based on the welding history at the time of study 1. All workers were asked to describe their previous lifetime exposure in terms of sequential periods spent in differing jobs, and the associated proportion of the day spent welding in each of these posts. The effective exposure in years (per job) was calculated as the product of these two variables, and the cumulative measure (years) was calculated by summing all the individual exposures for each job. This estimate is subsequently referred to as the total exposure index.14

**PULMONARY FUNCTION**

All workers in the study were asked to perform pulmonary function tests with one of the two calibrated portable spirometers (Alpha Spirometer, Vitalograph) used in the first survey. Otherwise the protocol was the same as in study 1.14 Pulmonary function measurements, carried out according to the guidelines set by Quanjer et al.,16 were taken before the shift, 15 minutes after the start of welding work (or at a corresponding time for workers not welding) and again 7 hours into the workshift. All preshift values were recorded before any exposure to welding fumes on the study day and was at least 14 hours since any previous welding work. Forced expiratory volume in one second (FV1), forced vital capacity (FVC) and forced midexpiratory flow \( \left( \text{FEF}_{25-75} \right) \) were measured, with the best value of three forced expiratory manoeuvres in the standing position.

All variables were also converted into the percentage predicted value for each person with the equations integral in the spirometer,18 including adjustment for ethnicity (Polynesian and non-Polynesian).

The two spirometers used in the study 1 differed from each other with a mean difference of 4\% in the FEV1 measurements after adjustment for age, sex, and height. Because only one of these spirometers was used in the second study, the analysis was adjusted for which spirometer was used in the first study. This, for the 23 welders and 21 non-welders who used one spirometer (A) in the first study but the other spirometer (B) in the second study, their pulmonary function measurements for study 1 were adjusted to account for the difference in mean FEV1, measurements between the two spirometers (controlling for age, sex, height, and ethnicity). The other 20 welders and 14 non-welders used the same spirometer (B) in both studies.

**DATA ANALYSIS**

The statistical analysis system (SAS)17 was used for all regression analyses. The mean pulmonary function values were adjusted for age and height as a continuous variable, spirometer, smoking habit in three groups (current, ex-smoker and non-smokers), and ethnicity in two groups (European and non-European—which includes both Maori and other Polynesians) in an analysis of covariance (ANCOVA). This calculates what the mean values would have been if the age, height, smoking, ethnicity, and spirometer distributions were the same in the groups being compared—for example, welders and non-welders.

Continuous variables were compared between groups—for example, welders and non-welders—by estimating the mean (SEM) and the associated unpaired \( t \) test. Categorical variables were compared between groups with the standard \( \chi^2 \) test.

The annual changes in pulmonary function values were calculated from the preshift values for each person as the difference between their pulmonary function values in study 1 and study 2 divided by the time between the two measurements (about 2 years) with the adjusted mean values. Linear regression was used to measure the change in annual decline in pulmonary function values (ml) for a 1\% acute decline in FEV1, measured across the shift in study 1.

All workers in this study gave written informed consent to take part and the study was approved by the Wellington ethics committee.

**Results**

Of the 137 workers studied in 1996, 96 (70\%) participated in this second survey, of whom two were retired, two were on sick leave, one was unemployed, and six had changed job; these 11 workers were visited at home or at their new place of work. Only four women participated in the study; they were all non-welders and were excluded from the analysis. Forty one workers could not be included in the second study (mostly because they could not be contacted), however, those 21 welders and 20 non-welders who did not participate did not differ from those who participated in terms of mean age or pulmonary function values. The response rates were 54/61 (89\%) in male welders and 38/70 (54\%) in male non-welders.
Table 1  Demographic characteristics and welding and smoking history of the welders and non-welders

<table>
<thead>
<tr>
<th></th>
<th>Wilders (n=54)</th>
<th>Non-welders (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Age (y)</td>
<td>40.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Total exposure index</td>
<td>7.9</td>
<td>6.8</td>
</tr>
<tr>
<td>Total time in industry</td>
<td>17.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Work related symptoms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cough</td>
<td>7</td>
<td>13.0</td>
</tr>
<tr>
<td>Phlegm</td>
<td>12</td>
<td>22.2</td>
</tr>
<tr>
<td>Wheezing</td>
<td>6</td>
<td>11.1</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>1</td>
<td>1.9</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>7</td>
<td>13.0</td>
</tr>
<tr>
<td>Any work related symptom</td>
<td>16</td>
<td>29.6</td>
</tr>
<tr>
<td>Respiratory symptoms:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent cough</td>
<td>9</td>
<td>16.7</td>
</tr>
<tr>
<td>Any chest tightness</td>
<td>17</td>
<td>31.5</td>
</tr>
<tr>
<td>Chest tightness just with colds</td>
<td>4</td>
<td>7.4</td>
</tr>
<tr>
<td>Wheezing with or in past 12 months</td>
<td>18</td>
<td>33.3</td>
</tr>
<tr>
<td>Wheezing only with colds</td>
<td>11</td>
<td>20.4</td>
</tr>
<tr>
<td>Shortness of breath grade 1</td>
<td>6</td>
<td>11.1</td>
</tr>
</tbody>
</table>

All data based on study 1, except age in study 2.

Chronic bronchitis was much more common among welders (24%) than among non-welders (5%). Four of the 20 (20%) welders who had never smoked chronic bronchitis, compared with none of the 15 non-welders who had never smoked. Of the work related symptoms only phlegm production and wheezing were more often reported by welders (22% and 11%) than non-welders (13% and 5%), but these differences were not significant. Many of the general respiratory symptoms were more common among non-welders, presumably because of the eight asthmatic workers in that group.

The annual decline in pulmonary function did not differ significantly between welders and non-welders. These were: FVC 102.8 (13.5) in welders and 105.0 (15.8) in non-welders; FEV1 98.4 (13.7) and 98.7 (14.3); and FEF 25-75 80.2 (23.6) and 83.0 (26.7).

The annual decline in pulmonary function did not differ significantly between welders and non-welders (table 3). However, when the analysis was restricted to smokers, welders had a significantly (p=0.02) greater annual decline in FEV1 than non-welders (table 4); the difference in the annual decline in FEF 25-75 also tended to be greater among welders who smoked than non-welders who smoked, but this difference was not significant (p=0.08). The findings were similar after adjusting for pack-years of smoking. Among non-smokers the result was the reverse; non-welders had a steeper annual decline in FEV1, than welders (p=0.05). The high number of asthmatic workers among the non-smoking non-welders did not explain this pattern as excluding them from the analysis did not significantly change the findings; there were also some (n=3) ex-smokers and ex-welders in the group of non-smoking non-welders but excluding them did not change the findings.

At the time of the first survey, 27 (50%) of the 54 welders had used either a personal respiratory or local exhaust ventilation, or both while welding: 20 used a mask, four used an air purifier, and 13 had a local exhaust ventilation. Welders without any personal protection used while welding had a significantly steeper annual decline in FEV1, and FVC than welders with protection (table 5). As the decline was noted both in FVC and FEV1, it was therefore partly related to volume. Welders who smoked and worked without protection had the steepest (144 ml) decline in FEV1, whereas welders with protection who did not smoke had a slight.
annual increase (12 ml) in FEV₁ (not shown in tables).

Welders who showed the most acute decline in FEV₁ across the shift in study 1 also had a greatest annual decline in FEV₁ but not in FVC or FEF₂₅₋₇₅ (table 6).

Table 5 Pulmonary function values in study 1 and study 2, and the annual change separately in welders with and without respiratory protection or local exhaust ventilation in use while welding

<table>
<thead>
<tr>
<th>Protection</th>
<th>No protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean*</td>
</tr>
<tr>
<td>Study 1:</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>27</td>
</tr>
<tr>
<td>FVC (l)</td>
<td>4.61</td>
</tr>
<tr>
<td>FEV₁ (l)</td>
<td>3.74</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅ (l/s)</td>
<td>3.51</td>
</tr>
<tr>
<td>Study 2:</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>26</td>
</tr>
<tr>
<td>FVC (l)</td>
<td>4.68</td>
</tr>
<tr>
<td>FEV₁ (l)</td>
<td>3.78</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅ (l/s)</td>
<td>3.70</td>
</tr>
<tr>
<td>Annual change:</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>26</td>
</tr>
<tr>
<td>FVC (ml)</td>
<td>-123.0</td>
</tr>
<tr>
<td>FEV₁ (ml)</td>
<td>-123.0</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅ (ml/s)</td>
<td>-351.9</td>
</tr>
<tr>
<td>Mean 95% CI</td>
<td>FEF₂₅₋₇₅ (ml/s)</td>
</tr>
<tr>
<td>p Value</td>
<td>0.02</td>
</tr>
<tr>
<td>Annual change welders v non-welders:</td>
<td></td>
</tr>
<tr>
<td>FVC (ml)</td>
<td>-137.9</td>
</tr>
<tr>
<td>FEV₁ (ml)</td>
<td>-123.0</td>
</tr>
<tr>
<td>FEF₂₅₋₇₅ (ml/s)</td>
<td>-351.9</td>
</tr>
<tr>
<td>Mean 95% CI</td>
<td>FEF₂₅₋₇₅ (ml/s)</td>
</tr>
<tr>
<td>p Value</td>
<td>0.05</td>
</tr>
</tbody>
</table>

* Adjusted for age, height, smoking habit (current and non-smokers), spirometer, ethnicity (European and non-European). SE = standard error.

Discussion

In this 2 year follow up no significant overall differences were noted in the annual changes in pulmonary function variables between welders and non-welders. However, when the comparison was restricted to smokers, welders had a significantly steeper annual decline in FEV₁ than non-welders. Chronic bronchitis was more common among welders (24%) than non-welders (5%), and especially notable was the difference in the presence of chronic bronchitis in lifetime non-smokers: 20% in welders and 0% in non-welders. Only one welder (2%) but eight non-welders (21%) reported having asthma.

Our findings should be treated with caution because of the lack of an overall difference between welders and non-welders in annual changes in pulmonary function variables, and because of the number of comparisons that were made. Nevertheless, our findings in smokers are consistent for those of several cross sectional studies by Hunnicutt et al and Özdemir et al found that FEV₁ was reduced relative to the average welding exposure among current and ex-smokers but not among non-smokers. Cross sectional studies by Chinn et al and of one longitudinal study by Cotes et al found significantly impaired pulmonary function among welders who smoked compared with controls who smoked but not among non-smokers. In a 7 year follow up of 488 shipyard workers by Chinn et al welders who smoked had nearly twice the annual decline in FEV₁ (50 ml) than welders who did not smoke (37 ml), and three times more than controls who did not smoke (16 ml).

Thus our findings, together with those from previous studies, strongly suggest that there is a synergistic relation between the effects of smoking and welding exposure, causing airway narrowing of both large and small airways and chronic bronchitis. The mechanism of this interaction is not exactly known, but the basic
pulmonary responses to both smoking and certain occupational exposures—for example, inorganic dust—are similar, both involving polymorphonuclear recruitment and alveolar macrophage activation. Thus, it is plausible that there could be a synergistic effect of smoking and exposures to welding fume.19

In our study, half of the welders did not have available or use any respiratory protection, and only a quarter had local exhaust ventilation, which is recommended. Welders without any protection while welding had a greater annual decline both in FVC and FEV1 than welders with protection. The steepest annual decline in FEV1 was found in welders who smoked and did not have any respiratory protection.

The relation between respiratory protection and pulmonary function values among welders has rarely been reported in previous studies. In the study by Beckett et al,21 all welders had proper preventive measures and they could not find any evidence for chronic irreversible effects on lung function. Similarly, all workers studied by Chinn et al22 in their second follow-up had local exhaust ventilation. They classified welders by regular (100% of the time) and non-regular use of exhaust ventilation, and found that the annual decline in FEV1 was smaller among the regular users. (and between smokers and non-smokers) and could not account for the differences that we have found.

We found a significant association between the acute and chronic effects of exposure to welding fume. Decline in FEV1 across the shift was a significant predictor of annual decline in FEV1. To our knowledge, none of the previous studies on welders have considered this question. However, studies among cotton23 and grain workers24,25 have found that acute responses to occupational exposure, measured as changes in FEV1 across the shift, are a significant determinant of annual change in FEV1. Furthermore, it is biologically plausible that recurrent acute obstructive changes lead to chronic airways obstruction.23

The main limitations of our study are that the number of workers was small, especially in subgroup analysis, and that the follow-up period, 2 years, was short for assessing the effect of exposure to welding on pulmonary function changes. Nevertheless, even in that short period there was a significant difference in annual decline in FEV1 between welders and non-welders who smoked.

As our study was longitudinal all workers could serve as their own controls and we avoided in part some of the typical problems in cross sectional studies including the healthy worker effect. We also attempted to study workers who had left their workplace or who had retired to reduce the healthy worker effect. However, only 11 were surveyed at home or in a new workplace and 41 workers could not be studied, mostly because they had changed work and could not be found. Thus, there was still some dropout from the study population and our findings may therefore still have been affected by the healthy worker effect to some extent.

In our study non-smoking non-welders had an unexpectedly steep decline in FVC and FEV1, steeper than that in smoking non-welders or non-smoking welders. The reasons for these inconsistent findings are unclear, and it was not explained by the number of asthma symptoms or the presence of some ex-smokers and ex-welders in that group; however, the most likely explanation is that it was a chance finding due to the small numbers of workers in this subgroup analysis.

We grouped non-welders and ex-welders together because the ex-welders had stopped welding before study 1 and it was assumed that the effect of welding fumes on decline in lung function does not continue after the end of exposure. There were also some non-welders who had done minimal welding. A similar classification was used for smoking: workers who were ex-smokers during the study 1 were classified as non-smokers because the decline in FEV1 among smokers has been shown to normalise to the same level with never smokers after the end of smoking.24 However, if pulmonary function variables continue to decline after exposure to tobacco or after the end of welding, or if they decline just due to occasional, minimal welding, then our method of categorisation would lead to an underestimation of the true difference between welders and non-welders (and between smokers and non-smokers) and could not account for the differences that we have found.

In conclusion, despite the short follow up period and the few workers in our study, smoking welders and welders welding without local exhaust ventilation or respiratory protection had significantly increased risks for accelerated decline in FEV1. Even though no significant difference was noted among non-smokers, it should be stressed that effective preventive measures should be available for all welders. The use of masks and negative pressure respirators has been found to be unsuccessful because of heat, moisture and discomfort.26 Thus, local exhaust ventilation is the most practical method to avoid exposure to welding fumes, and is highly recommended, as is stopping smoking.

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