Respiratory health of welders in a container yard, Sri Lanka

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Introduction

Welding refers to a production process that joins materials, usually metal or thermoplastics. This is done by melting the work pieces by the use of heat or pressure, or both, and adding a filler material into the molten material thus formed which cools to form a strong joint [1,2].

Many different energy sources can be used for welding, including gas flames, electric arcs, laser, electron beams, friction and ultrasound [2]. Welding fumes generated during the process consist of metal fumes and gases such as carbon monoxide, nitrogen dioxides, ozone and phosgene [3]. Welders are at risk of inhaling the gases and fumes, which may lead to respiratory ill-health.

The different types of welding and their effects on respiratory health have been widely reported [3–11].

Reported respiratory symptoms (RS) include shortness of breath [3,10], chest pain/heaviness [3,10], cough [3–5,11], phlegm [4,5,11], wheeze [11] and chronic bronchitis [5,6,9,10,12]. Impaired respiratory function (RF) has been reported in several studies [5,6,8,9,11,12]. Restrictive impairment has been reported by Luo et al. [5], Rastogi et al. [8] and Buerke et al. [13]. Mixed impairment has been reported by Rastogi et al. [8] and Buerke et al. [13].

The objectives of the study were to determine the prevalence of RS and to assess RF of welders in comparison to a control group (CG).

Methods

A cross-sectional analytical study was conducted in the year 1999 including all the 41 welders (males), irrespective of the duration of service, employed in one of the container yards in Sri Lanka. The welding process used here was arc welding. The CG comprised 41 male office support staff attached to a medical faculty, selected using simple random sampling from a total of 60 who had no past history of exposure to dust or fumes. Selection of this specific category as the CG ensured similar socio-economic background status.

The questionnaire on RS developed by the Medical Research Council [14] modified to suit the local situation (questions on cough and phlegm are in reference to winter
in the original questionnaire and therefore the word ‘winter’ was omitted and the type of smoke was modified in reference to the local context) was used to determine prevalence of chronic RS including cough, phlegm, chronic bronchitis, dyspnoea and asthma and smoking habits and relevant occupational data. The duration was enquired for all relevant symptoms (cough, phlegm, dyspnoea and asthma). Presence of other chest diseases was enquired of in relation to both past and the present. The questionnaire was administered by the authors.

Chronic bronchitis was defined as presence of cough or phlegm, or both, for a duration of ≥3 months, over two or more consecutive years.

The respiratory indices studied were forced vital capacity (FVC), forced expiratory volume in the first second of forced vital capacity (FEV1.0), forced mid–expiratory flow rate (FEF25–75%) and peak expiratory flow rate (PEFR), using an electronic spirometer (Spiroanalyzer SF95) which conformed to the specifications of the American Thoracic Society [15]. Spirometry was conducted by an experienced technician during the morning hours for both groups. It was ensured that the welders did not commence work until spirometry was conducted. A minimum of three readings were taken. The highest reading out of the two which had a variation of <5% was considered as final.

The mean value of each respiratory index was compared with that of the CG as well as with predicted normal values which were computed using the regression models developed by Udupihilla [16] for Sri Lankan Sinhalese. The height was measured to the nearest one-tenth of a centimetre using the standard method.

Student t-test and chi-square test were used to analyse quantitative and qualitative data, respectively. Odds ratio (OR) was determined for each symptom separately which was expressed with its 95% confidence interval (CI).

Informed consent was obtained from all participants and ethical clearance was granted by the Ethical Review Committee of the above Faculty of Medicine.

Comparison of selected relevant variables among welders and controls

Table 1. Comparison of selected relevant variables among welders and controls

<table>
<thead>
<tr>
<th>Variables</th>
<th>Welders</th>
<th>Controls</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years, mean (SE)</td>
<td>37.5 (1.4)</td>
<td>38.1 (1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Height in centimetres, mean (SE)</td>
<td>163.3 (1.2)</td>
<td>161.2 (1.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Educational level, ≥ General Certificate of Education (Ordinary Level)</td>
<td>25 (61%)</td>
<td>30 (73%)</td>
<td>NS</td>
</tr>
<tr>
<td>Duration of service in years, mean (SE)</td>
<td>9.9 (1.01)</td>
<td>12.0 (0.68)</td>
<td>NS</td>
</tr>
<tr>
<td>Hours worked per day, mean (SE)</td>
<td>5.1 (0.40)</td>
<td>8.2 (0.12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Smoking status, smokers</td>
<td>21 (51%)</td>
<td>20 (49%)</td>
<td>NS</td>
</tr>
<tr>
<td>Duration smoked in years, mean (SE)</td>
<td>12.7 (1.9)</td>
<td>17.0 (2.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Number smoked per day, mean (SE)</td>
<td>5 (1.1)</td>
<td>4 (0.6)</td>
<td>NS</td>
</tr>
</tbody>
</table>

SE, standard error.
* Two sample t-test.
* Chi-square test.

Results

The mean age and height of the welders and the CG were 37.5 and 38.1 years, and 163.3 and 161.3 cm, respectively. Mean duration of service for the welders was 9.9 years and for the CG 12 years. Sixty-one per cent (n = 25) of the welders and 73% (n = 30) of the CG had an educational level equal to or above the General Certificate of Education (Ordinary Level). However, none of the above differences were statistically significant. The only significant difference observed was in relation to the mean number of hours worked per day, which was 5.1 h for the welders and 8.2 h for the CG. The number of smokers among welders and CG was 21 (53%) and 20 (50%), respectively (difference not statistically significant). Neither were duration of smoking and number of cigarettes/beedi (local tobacco smoke) smoked per day (Table 1).

Prevalence of all the RS was higher among welders than for the CG, although only chronic bronchitis [welders: 27% (n = 11); controls: 7% (n = 3)] was found to be significantly different (OR = 4.6; 95% CI: 1.1–23.3) (Table 2).

With regard to all the respiratory indices, the welders (FVC: 2.97 l, FEV1.0: 2.6 l, FEF25–75%: 3.4 l/s and PEFR: 339 l/min, respectively) were observed to have higher mean values than in the CG (2.79 l, 2.4 l, 3.38 l/s and 3235 l/min, respectively) (Table 2). However, none of the differences were statistically significant. On comparison of predicted and observed values among welders, all predicted values were higher except for FEF25–75%, for which the observed (3.4 l/s) mean value was higher than the predicted (3.26 l/s). However, this difference was not statistically significant. Among those, predicted FVC (observed: 2.97 l; predicted: 3.35 l) and PEFR (observed: 339 l/min; predicted: 538 l/min) demonstrated a significantly higher difference. With regard to observed and predicted values among CG too, observed (3.38 l/s) FEF25–75% was found to be higher than the
predicted (3.22 l/s) and this difference too was not statistically significant. The predicted values with regard to the other three respiratory indices were observed to be significantly higher than the observed among the CG (Table 3).

**Discussion**

The findings of this study indicate that the welders have a significantly higher prevalence of chronic bronchitis in comparison to the CG. Despite the above, there were no statistically significant differences in RF tests on comparing the groups.

However, with reference to the predicted normal values, both groups demonstrated impaired RF except for FEF<sub>25–75%</sub>. It is noticeable that despite a higher prevalence of all RS, the welders did not show evidence of respiratory impairment in comparison to the CG. Symptoms are subjective and an objective assessment is not feasible. Thus, the higher prevalence of symptoms may be on account of the tendency to report even minor episodes because of the awareness of being exposed to welding fumes and gases.

This is a cross-sectional study which depicts only the existing situation. The observation of similar RF among the two groups may reflect a ‘healthy worker effect’. This has both selection and survivor effects but this can only be proved through longitudinal studies. The inability to discern whether the observed findings are on account of ‘survival of the fittest’ despite adverse effects, or because exposure to welding fumes is devoid of demonstrable adverse effects, is a limitation of this study design.

Both mean duration of service and the average number of hours worked were significantly shorter than that of the controls. Working in the open combined with short duration of exposure per day to welding fumes may be additional factors that contributed towards welders having similar RF as the CG.

FEV<sub>1.0</sub> and PEFR reflect the behaviour of central large airways, which contributes to 90% of total airway obstruction. Even though FEV<sub>1.0</sub> was not impaired with reference to observed and predicted values in this study, the significant decline in PEFR was reflective of the effect on large airways.

It was observed that FEF<sub>25–75%</sub> of both welders and the CG had better functional capacity in comparison to the predicted values. Kilburn et al. [10] too have reported non-reduction of FEF<sub>25–75%</sub> in comparison to the referent group. FEF<sub>25–75%</sub> denotes the effects on the small airways of <2 mm in diameter which has a 10% contribution to the total airway obstruction. The small airways are said to get affected before the large airways and the evidence in this study is to the contrary.

Despite a higher prevalence of RS among welders, only the difference in chronic bronchitis was found to be statistically significant. The total number included in the study was 41 and the power computed for the

### Table 2. Comparison of respiratory symptoms of welders and controls

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Study observed</th>
<th>Control observed</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study observed</td>
<td>Control observed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n = 41 (%)</td>
<td>n = 41 (%)</td>
<td></td>
</tr>
<tr>
<td>Cough ≥ 3 months</td>
<td>6 (15)</td>
<td>1 (2)</td>
<td>6.9 (0.75–195.5)</td>
</tr>
<tr>
<td>Phlegm ≥ 3 months</td>
<td>9 (22)</td>
<td>3 (7)</td>
<td>3.6 (0.79–18.6)</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>17 (42)</td>
<td>9 (22)</td>
<td>2.6 (0.87–7.6)</td>
</tr>
<tr>
<td>Asthma</td>
<td>10 (24)</td>
<td>8 (20)</td>
<td>1.3 (0.41–4.3)</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>11 (27)</td>
<td>3 (7)</td>
<td>4.6 (1.1–23.3)*</td>
</tr>
<tr>
<td>Presence of at least one RS</td>
<td>29 (71)</td>
<td>21 (51)</td>
<td>2.4 (0.85–6.8)</td>
</tr>
</tbody>
</table>

*P = 0.04.

### Table 3. Comparison of respiratory functions of welders with predicted normal and control values

<table>
<thead>
<tr>
<th>Respiratory indicator</th>
<th>Study observed</th>
<th>Study predicted</th>
<th>Control observed</th>
<th>Control predicted</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>SP</td>
<td>C</td>
<td>CP</td>
<td>S/CP&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>n = 41</td>
<td>n = 41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC (l)</td>
<td>2.97 (0.11)</td>
<td>3.35 (0.06)</td>
<td>2.79 (0.07)</td>
<td>3.25 (0.05)</td>
<td>0.23 &lt;0.01</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1.0&lt;/sub&gt; (l)</td>
<td>2.63 (0.09)</td>
<td>2.77 (0.06)</td>
<td>2.44 (0.08)</td>
<td>2.69 (0.05)</td>
<td>0.15 0.17</td>
</tr>
<tr>
<td>FEF&lt;sub&gt;25–75%&lt;/sub&gt; (l/s)</td>
<td>3.40 (0.16)</td>
<td>3.26 (0.07)</td>
<td>3.38 (0.18)</td>
<td>3.22 (0.06)</td>
<td>0.67 0.45</td>
</tr>
<tr>
<td>PEFR (l/min)</td>
<td>338.9 (21.8)</td>
<td>538.2 (6.1)</td>
<td>322.5 (22.2)</td>
<td>527.4 (6.1)</td>
<td>0.79 &lt;0.01</td>
</tr>
</tbody>
</table>

SE, standard error.

<sup>a</sup>Two sample *t*-test.

<sup>b</sup>Paired sample *t*-test.
RS ranged between 53% for chronic bronchitis and 5% for asthma. Thus, the lack of statistical significance may be attributed to the inadequate sample size except for chronic bronchitis. With regard to RF among welders and controls too, the same argument may apply. However, the power computed for comparison of predicted and observed values among both groups was >80% for all indices except FEV\textsubscript{1.0} in welders and FEF\textsubscript{25–75%} in both groups.

Results reported by other studies on RS of welders are inconsistent. A significantly higher prevalence of RS had been reported in three studies [4,6,9–12] while Fogg et al. [7] reported no such difference. A significantly higher prevalence of chronic bronchitis similar to the present study has been reported in two studies [6,10].

Similar inconsistencies also exist in relation to reporting respiratory impairment. Two studies reported no significant change in reference to FEV\textsubscript{1.0} [4,7] and FEF\textsubscript{25–75%} [4] similar to the findings in this study. However, significantly reduced FVC and FEV\textsubscript{1.0} were reported in five studies [6,8–10,12], FEF\textsubscript{25–75%} in three studies [6,8,12] and PEFR in four studies [6,8,11,12] contrary to the findings of the present study.

There were no engineering control measures such as exhaust ventilation available at the worksite and none of the welders were using industrial masks. The non-impairment of RF in comparison to the CG was despite the non-availability of the above measures. However, one cannot ignore the harmful effects of welding fumes and gases reported by other studies. In addition, the respiratory impairment observed in reference to predicted normal values indicates the need to adopt appropriate preventive measures. The non-use of masks may be attributed to lack of awareness and the reluctance in using protective equipment, owing to the discomfort experienced under tropical climatic conditions. These may be circumvented by regular educational programmes.

It is concluded that a significantly higher proportion of welders suffered from chronic bronchitis with non-impairment of lung function in comparison to the CG.

**Acknowledgements**

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**Conflicts of interest**

None declared.

**References**