

# Spirometric evaluation of lung function (maximal voluntary ventilation) in welding workers

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## ABSTRACT

**Objective:** The present study was designed to study the effects of welding fumes on maximal voluntary ventilation (MVV) and to determine its severity in relation to duration of exposure. Additional objective was to reduce the potential health risks of welding workers by providing them with information concerning the hazards of welding fumes.

**Methods:** This study was conducted in the Department of Physiology, Basic Medical Sciences Institute, Jinnah Post Graduate Medical Centre, Karachi, Pakistan in 1999. In this study, the MVV was studied in 50 male control subjects and 50 male arc welding workers and all participants were non-smokers with an age range of 20-60 years. The subjects were matched for age, height, weight and socio-economic status.

Maximal voluntary ventilation test was performed by using an electronic spirometer and results were compared by a paired t-test.

**Results:** Welding workers showed a significant reduction in MVV relative to controls.

**Conclusion:** We conclude that MVV in welding workers is significantly decreased as compared to their matched controls. Stratification of results by years of welding shows a dose-response effect of years of welding on lung function.

Saudi Med J 2003; Vol. 24 (6): 656-659

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Welding is a common and a highly skilled occupational specialty. Welding processes, involve inhalation exposures, which may lead to acute or chronic respiratory disease. The primary source of inhaled particulate material in most welding process is a consumable electrode of filler metal, which is partially vaporized. Metal fume is formed when vaporized metal condenses in air as metal oxide particles. These particles are particularly hazardous component of welding fumes for they are small enough to deposit in the terminal bronchioles and alveoli, distal to mucociliary cleaning mechanisms.<sup>1</sup> Electric arc welding processes produce particles with aerodynamic diameters in the range of 0.1-0.5  $\mu\text{m}$ . These particles are predominantly composed of metals such as iron, nickel, molybdenum, manganese,

chromium and their oxides.<sup>2</sup> Welding has been associated with many respiratory problems, which vary from acute or chronic respiratory symptoms such as, malaise, cough, dyspnea,<sup>3</sup> chronic bronchitis,<sup>4-6</sup> interstitial lung disease,<sup>7,8</sup> pneumonitis,<sup>3</sup> asthma,<sup>9</sup> pneumoconiosis,<sup>10</sup> and lung cancer.<sup>11</sup> Spirometry is an important tool for measuring the extent of impairment and for assessing the response to treatment. When used in conjunction with the clinical and occupational history and chest radiographs, it helps to determine the nature and severity of lung disease. During pre-employment evaluations, it can identify applicants with pre-existing respiratory impairment to assure proper job placement. Periodic re-testing of workers can detect pulmonary disease in its earliest stages, when corrective measures

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Received 23rd November 2002. Accepted for publication in final form 18th February 2003.

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are more likely to be beneficial. Such measures could include improvement in industrial hygiene, job transfer or medical treatment.<sup>12</sup> The parameters of spirometry are important to provide clinical information, including maximal voluntary ventilation (MVV). The MVV was formerly called the maximal breathing capacity (MBC) is the largest volume of gas that can be moved into and out of the lungs in one minute by voluntary effort. The normal MVV is 125-170 litre/min.<sup>13</sup> The MVV depends upon the muscular force, compliance of the thoracic wall and lungs and the airway resistance. Maximal voluntary ventilation is profoundly reduced in patients with emphysema or in airway obstruction. Bronchial constriction in asthma diminishes the forced vital capacity (FVC) and MVV, and causes hyperinflation of the lung.<sup>14</sup> The MVV reflects the function of the entire ventilatory apparatus and pulmonary function test (PFT) used for categorizing dyspnea.<sup>15</sup> Maximal voluntary ventilation is influenced greatly by non-pulmonary factors, such as motivation, sensorium, muscular force and endurance.<sup>16</sup> A reduction in MVV is non-specific, it may be caused by upper or lower airways obstruction, restriction or muscle weakness.<sup>17</sup>

**Methods. Subjects.** The present study was conducted in the Department of Physiology, Basic Medical Sciences Institute, Jinnah Post Graduate Medical Centre Karachi, Pakistan in 1999. In this study 50 apparently healthy male welding workers with a mean age of  $32.4 \pm 10.4$  years (mean  $\pm$  SD), range 21-60 years, were selected from welding shops located in north Karachi, Pakistan, after a personal visit. They were employed as manual metal electric arc welders for at least 8-10 hours a day and worked in a small shops on iron doors and iron window grills. Welders did not use any self-protective measures. These workers were compared to 50, apparently healthy male control subjects selected from shops located in north Karachi, with a mean age of  $32.9 \pm 10.1$  years (mean  $\pm$  SD), range 20-60 years. Welders were individually matched for age, height and weight with controls. The control subjects were of a similar to socio-economic group, assessed by a questionnaire. They were composed primarily of shopkeepers and salesmen. The control subjects had no exposure to welding or any other manufacturing industries and all subjects were non-smokers. All subjects completed a questionnaire, which included anthropometrics data and a consent form.

**Exclusion criteria.** Subjects with gross anemia, abnormalities of the vertebral column or thoracic cage, neuromuscular disease, malignancy, diabetes mellitus, cardiopulmonary disease, drug or cigarette addiction, tobacco chewers and those who had undergone major abdominal or chest surgery were excluded from the study.

**Spirometry.** Maximal voluntary ventilation test was performed on an electronic spirometer (Compact Vitalograph, United Kingdom) at a fixed time (9:00 - 13:00 hours) of the day to minimize diurnal variation.<sup>18</sup>

The apparatus was calibrated daily with one litre calibration syringe and operated within a temperature range of 20-25°C. The maneuver was explained to the subjects and 3 maneuvers were performed after adequate rest. Maneuvers were performed in a standing position without a nose clip and disposable mouthpieces were used for each individual. Tests were conducted according to American Thoracic Society (ATS) recommendations.

**Analysis.** Statistical analysis was conducted using a paired t-test (2-tailed), on initially all matched pairs of subjects, and then in 3 groups divided by their duration of welding exposure. The level of significance was taken as  $p < 0.05$ .

**Results.** Anthropometric and MVV data for welders and their matched controls are shown in **Table 1**. Mean for age, height or weight was not significantly different between groups. Welders had statistically significant reductions in MVV. The mean duration of exposure in the welders was  $7.36 \pm 0.66$  years (mean  $\pm$  SEM), range 1-27 years.

**Duration of exposure <5 years.** There were no significant differences in the means of any anthropometric or MVV data between welders, on the basis of duration of exposure of <5 years, and their matched controls (**Table 2**). The mean duration of exposure in welders was  $3.0 \pm 0.29$  years (mean  $\pm$  SEM), range 1-4 years.

**Duration of exposure 5-9 years.** There were no significant differences between the means of age, height and weight, based on duration of exposure of 5-9 years compared with their matched controls (**Table 3**). However, welders did show a significant reduction in MVV. The mean duration of exposure in welding workers was  $7.25 \pm 0.33$  years (mean  $\pm$  SEM), range 5-8 years.

**Duration of exposure >9 years.** Welders, exposed for >9 years, showed a significant reduction in MVV relative to their matched controls (**Table 4**). There were no significant difference between means of age, height, and weight between the groups. The mean duration of exposure in welding workers was  $11.35 \pm 0.96$  years (mean  $\pm$  SEM), range 10-27 years.

**Discussion.** The assessment of pulmonary function with a spirometer has become common practice in patient settings and industry. Spirometry is now regarded as an integral component of any respiratory medical surveillance program. Pulmonary function test has assumed an essential role in epidemiological studies investigating the incidence, natural history and causality of occupational and environmental lung disease.<sup>12</sup> In the present study, MVV in welding workers is significantly decreased as compared to their matched controls. Stratification of results by years of welding shows a dose response effect of years of welding on MVV. Previously Hunnicutt et al,<sup>19</sup> have reported a significant

Table 1 - Anthropometric and lung function data (MVV) between welders and their matched controls.

Parameters	Control subjects n=50 (mean ± SEM)	Welding workers n=50 (mean ± SEM)	p-value
Age (years)	32.86 ± 1.42	32.36 ± 1.48	NS
Height (cm)	168.92 ± 0.73	169.44 ± 0.75	NS
Weight (kg)	66.22 ± 1.52	65.16 ± 1.83	NS
MVV (litres/min)	114.16 ± 3.67	100.82 ± 3.86	0.007
NS - non significant, MVV - maximal voluntary ventilation			

Table 2 - Anthropometric and lung function (MVV) data for welders, with duration of exposure &lt;5 years, compared with their matched controls.

Parameters	Control Subjects n=18 (mean ± SEM)	Welding workers n=18 (mean ± SEM)	p-value
Age (years)	29.16 ± 2.05	28.67 ± 2.05	NS
Height (cm)	169.56 ± 1.07	170.56 ± 1.78	NS
Weight (kg)	62.83 ± 2.51	61.95 ± 2.80	NS
MVV (litres/min)	119.78 ± 4.30	118.62 ± 5.32	
NS - non significant, MVV - maximal voluntary ventilation			

Table 3 - Anthropometric and lung function (MVV) data for welders with duration of exposure 5-9 years compared with their matched controls.

Parameters	Control Subjects n=12 (mean ± SEM)	Welding workers n=12 (mean ± SEM)	p-value
Age (years)	30.25 ± 2.83	29.92 ± 3.11	NS
Height (cm)	167.08 ± 2.10	167.25 ± 2.11	NS
Weight (kg)	62.92 ± 2.26	60.42 ± 3.07	NS
MVV (litres/min)	118.83 ± 5.57	95.58 ± 7.90	p=0.02
NS - non significant, MVV - maximal voluntary ventilation			

Table 4 - Anthropometric and lung function (MVV) data for welders with a duration of exposure greater than 9 years compared with their matched controls.

Parameters	Control Subjects n=20 (mean ± SEM)	Welding workers n=20 (mean ± SEM)	p-value
Age (years)	37.75 ± 2.18	37.15 ± 3.11	NS
Height (cm)	169.45 ± 0.90	169.75 ± 0.85	NS
Weight (kg)	71.25 ± 2.42	70.90 ± 3.02	NS
MVV (litres/min)	106.30 ± 7.46	78.95 ± 5.19	p=0.04
NS - non significant, MVV - maximal voluntary ventilation			

difference in forced expiratory volume in one second (FEV<sub>1</sub>) between the welders who smoked and the controls that smoked. Welders who smoked had an increased incidence of abnormal pulmonary function test than the controls that smoked. In other words, smoking and welding almost double the percentage of those having abnormal pulmonary function tests. In addition, Kierst et al,<sup>20</sup> showed that a FEV<sub>1</sub> reduced with increasing length of exposure in welding industry. Akbarkhanzadeh,<sup>21</sup> observed the different parameters of pulmonary function test between control and welding works and reported that, in the mean of the FEV<sub>1</sub>, forced expiratory ratio (FEV<sub>1</sub>/FVC%) peak expiratory flow (PEF) and MVV were significantly decreased in welding workers compared with controls. Stern et al,<sup>2</sup> reported that FEV<sub>1</sub>, forced expiratory flow (FEF)<sub>25-75%</sub> and PEF sometimes be reduced in welders. Chinn et al<sup>22</sup> showed that among welders the effect of fumes was the highest in those who admitting not using proper preventive measures and such man experienced a work related deterioration in FEV<sub>1</sub>. Sobaszek et al<sup>23</sup> examined the chronic effects of fumes from stainless steel (SS) welding on the health of welders. Pulmonary function tests were performed at the start and at the end of the work shift. The study of sensitization to harmful respiratory effects of welding was based on the study of the spirometric variations during the shift. In SS welders, they observed a significant decrease in FVC during the shift. Significant across-shift decrements in FEV<sub>1</sub> and FVC were related to the SS welding exposure compared with MS welding. Moreover, the across-shift decreases in FEV<sub>1</sub>, FVC, and peak expiratory flow (PEF) was significantly related to the manual metal arc welding process, compared with metal inert gas techniques. They concluded that welding-related lung function responses are seen in SS compared with MS welders and in those with a longer lifetime welding history. Erkinjuntti-Pekkanen et al<sup>6</sup> reported that, welders who smoked had a significantly greater annual decline (88.8 ml) in FEV<sub>1</sub> than non-welders, who had a slight non-significant annual decrease (34.2 ml). In addition, they showed that, welders without respiratory protection or local exhaust ventilation while welding had a greater annual decline both in FVC and FEV<sub>1</sub> than welders with protection. Among welders, a significant association was found between the acute across shift change and the annual decline in FEV<sub>1</sub>. Welders who smoked and welders working without local exhaust ventilation or respiratory protection have an increased risk of accelerated decline in FEV<sub>1</sub>. Similarly, Erhabor et al<sup>8</sup> reported that the arc welders were found to have characteristically lower lung function parameters than controls. In addition, Kilburn and Warshaw<sup>24</sup> reported significant falls in FVC, FEV<sub>1</sub>, FEF<sub>25-75%</sub> and FEF<sub>75-85%</sub> in 226 welders, although 43 non-smoking welders had significant decreases in expiratory flows only. They proposed that long term welding exposure reduced flows in the smaller airways. Chinn et al<sup>22</sup> showed that FVC, FEV<sub>1</sub>, PEF and FEF (50%) declined over time, where

the decrease was due equally to welding and smoking. However, for FEV<sub>1</sub> specifically, a smoking welder would have an average decline 3 times greater than that of a non-smoking control. It has previously been shown that welders who worked in well ventilated places had no significant decrease in their lung function<sup>12</sup> and that welders working in well ventilated areas showed no obstructive signs or radiological abnormalities, relative to ones working in poorly ventilated areas.<sup>14</sup> Our study also demonstrated a significant decrease in mean values for MVV in welders. Welders with duration of exposure <5 years did not show a significant decrease in MVV, though welders with greater duration of exposure showed a significant reduction. In general, the present study shows a strong association, with a dose response effect, between welding years and decreased MVV. This trend suggests gradually accumulating lung pathology in welding workers. In addition, the present study confirms the findings of others, which strongly shows that welding fumes adversely affect pulmonary function.

It is worthwhile recommended, that welding workers, employers and health officials must work together to adopt technical preventive measures, such as ventilated work areas, wearing appropriate apparel, such as masks, safety goggles and so forth, and using less hazardous welding agents. These measures will help to prevent lung damage. It is also suggested that welding workers must undergo pre-employment and periodic medical surveillance tests. These measures will help identify susceptible workers so they can take preventive measures as well as medication.

**Acknowledgment.** I am thankful to Prof. Dr. M. Abdul Azeem, Department of Physiology, University of Karachi, Dr. Akbar Khoja, Basic Medical Sciences Institute, Jinnah Post Graduate Medical Centre, Karachi, and Dr. M. M. Faisal Subhan, Department of Biological and Biomedical Sciences, Aga Khan, University Hospital, Karachi, Pakistan for their critical review of the manuscript. I would like to extend my thanks to Miss Nada A. Aziz A. Salam, for her secretarial help.

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