Pulmonary Function in Commercial Glass Blowers*

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This study examined the pulmonary function of 87 male commercial glass factory workers. Statistical analysis of the data indicated that workers with full-time glass blowing job descriptions had significantly higher percent predicted values for FVC, FEV, and significantly higher maximal inspiratory and expiratory muscle pressures than their cohorts with minimal or nonglass blowing job descriptions. The results of this study indicate that persons using their respiratory muscles as full-time blowers to manufacture commercial blown glass products have significantly greater lung function values than part-time blowers or their nonglass blowing co-workers. (Chest 1990; 98:871-74)

Glass blowing is an old, respected art that produces glass objects for commercial or artistic use by artisans manually blowing molten glass. Commercial glass blowing efficiency and productivity is increased when glass workers form groups called shops. The shops consist of four to six skilled individuals, each with a precise, specific job in the production of the final glass product. The glass-making process begins when a gatherer collects molten glass at 1,300-1,500°C on the end of a long hollow metal blowpipe (150 to 162 cm length, mouthpiece: 0.3 cm inner diameter, 2.5 to 4.4 cm outer diameter) and delivers the first puff of air through the pipe to expand the molten glass. The blowpipe is then handed to the master glass blower who continues to expand and shape the glass by means of positive pressure produced by careful, controlled oral expiration. The oral pressures generated are low and sustained in such a fashion so as to produce a steady expansion of the rapidly cooling glass (oral communication).

There has been no systematic study of the pulmonary function in American commercial glass blower. Braun and Tsiatis in 1979 reported that glass artisans from diverse backgrounds and expertise had an increased frequency of wheezing and lower lung volumes, although obstructive lung disease could not be documented. The literature indicates that European commercial glass blowers may suffer complications associated with glass blowing.

Literature on pulmonary function in commercial glass blowers is sparse and primarily examines workers in a variety of European factories. Results of these European studies are contradictory on the association of glass blowing with occupational disease.

Since the previous literature has shown such equivocal results, we examined spirometry and respiratory muscle pressures in American glass blowers and their nonglass blowing cohorts to determine the extent of pulmonary dysfunction, if any, in employed glass factory workers. Comparison was made between the worker categories within the glass shop groupings to determine if chronic glass blowing was associated with abnormal pulmonary function.

We studied glass factory workers in four operating glass factories and found that American commercial glass workers were not suffering from an increased prevalence of pulmonary dysfunction, and those regularly blowing glass have larger lung volumes and muscle pressure than their nonglass blowing colleagues.

Materials and Methods

Subjects

Letters of inquiry were sent to all 50 commercial glass factories in the United States listed as having glass blowing operations. The letters requested the management to allow their factory workers to participate in a study measuring the respiratory function and muscle strength in their workers. Three factories in West Virginia and one in Pennsylvania agreed to join the study. In some factories, a preliminary visit was made to explain the project in more detail. Prestudy questionnaires were sent to each factory to compile a preliminary subject information list before on-site testing was done. All participants in the study were volunteers. The study was approved by the Marshall University Institutional Review Board on Human Research.

Subjects in the study were limited to male, white, full-time currently employed commercial glass factory workers. Only employees working in the immediate area of molten glass were included in the study (glass blowers, glass pressers, furnace workers, gatherers, glass transporters). Subjects were maintained in the study regardless of their smoking histories and/or respiratory symptoms.

Testing

Testing lasted 15 to 20 minutes per individual and was conducted at each factory during the subject's actual work shift. Workers participated in the study during scheduled shift breaks or were
replaced in the glass shop by a substitute worker provided especially for that purpose by the factory management. The initial meeting with subjects included an introduction to the investigators and an explanation of the study. The subjects were asked to sign a consent form for the study. All subjects were informed of the results of their tests in writing approximately one month after the factory visit. An interview was conducted by medical personnel to gather information on the subject's health, social, occupational, and medical history prior to any testing. After the questionnaire and interview were completed, blood pressure, pulse, height, and weight were measured.

Negative and positive pressure gauges attached to a stainless steel tube were used to measure maximal inspiratory and expiratory pressures. A mouthpiece of sterilized rubber tubing (31.5 mm internal diameter; 44.5 cm outer diameter) was attached to one end of the cylinder. The outer end of the cylinder was closed except for a small opening (2 mm inner diameter) which prevented the facial muscles from producing significant pressures. Prior to performing the test, each subject was instructed how to perform the maneuver and fitted with a nose clip. Testing was done in the standing position. The Pmax was measured as the most negative pressure generated during a maximal inspiration from residual volume to total lung capacity, the best of three trials was included in the study. The Pmax was measured as the most positive pressure generated during a maximal expiration from total lung capacity with the best of three trials included in the study. The pressures measured were maintained for at least one second.

Following muscle pressure measurement, each subject performed three forced vital capacity maneuvers and finally one maximal voluntary ventilation for 12 seconds, all done in the standing position and with a nose clip in place. The spirometry was recorded on a 13.5 liter, water seal spirometer (Collins) which was calibrated prior to testing at each factory. All records were manually scored for FVC, FEV1, MEF, and MVV. Volumes were converted to BTPS at the current barometric and ambient temperature in the glass factory.

Data Analysis

Based on the amount of time each worker reported they blew glass orally, the workers were divided into three categories: nonglass blowers: those subjects who did no oral glass blowing but worked in the same environment and in close proximity to the glass blowers (glass pressers, furnace workers, glass transporters); part-time glass blowers: those subjects who did oral glass blowing less than 50 percent of their time at work (gatherers); and full-time glass blowers: those subjects who did oral glass blowing for greater than 50 percent of their time at work (glass blowers).

Spirometric data were hand calculated and the best trial of the three was used for the study. The best trial was also used for inspiratory and expiratory muscle pressure. Actual values were then converted to percent predicted values. Means and standard error of the mean were calculated for all measured factors. Statistical analysis was done using ANOVA. A Newman-Keuls posteriori test was used to examine differences between the means of the three glass blower groups for ANOVA tests with F values significant at p<0.05.

### Results

#### Worker Profile

A total of 87 workers from four commercial glass factories were studied during their regular work shift on location in the factory. The workers studied had spent a total of 20.1 ± 1.2 years (mean ± SEM) with a range of three to 50 years employed in the commercial glass industry with 11.5 ± 0.8 of those years spent in their current job position. They ranged in age from 20 to 60 years with a mean age of 41.5 ± 1.2 years (Table 1). Forty-nine percent of the workers were in the middle age group of 35 to 55 years of age, while 16 percent were older than 55 years, and 35 percent were younger than 35 years of age. Eighty-three percent reported themselves to be in good health with only 13 percent identifying themselves as having respiratory problems. Seventy-eight percent of the workers reported a history of smoking cigarettes (27.5 ± 2.9 pack years, N = 64) or pipes (N = 4). At the time of the study, only 47 percent of all workers were currently smoking. Twenty-two percent of the workers reported never having smoked.

Prior to data analysis, the workers were divided by the authors into three glass blowing worker categories based on each worker's description of their current work duties: nonglass blowers (39 percent), part-time glass blowers (30 percent), and full-time glass blowers (31 percent). No significant difference was found between the three worker categories for age, pack-year smoking history, years at current job (Table 1), or health histories.

#### Pulmonary Function

Percent predicted values for both the forced vital capacity (FVC = 6.22, p<0.01) and the forced expiratory volume in one second (FEV1) (FVC = 5.55, p<0.01) were significantly greater by approximately 10 percent in the full-time glass blowers as compared to nonglass blowers and part-time glass blowers (Table 2). No significant difference was found between the three glass worker categories for FEV1/FVC, mid-expiratory flow rate, or maximal voluntary ventilation (Table 2).

#### Muscle Pressures

Maximal expiratory (FVC = 6.09, p<0.01) and in-

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### Table 1—Glass Factory Worker Profile*

<table>
<thead>
<tr>
<th></th>
<th>Nonglass Blower (N)</th>
<th>Part-Time Glass Blower (N)</th>
<th>Full-Time Glass Blower (N)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>42.7 ± 2.0 (34)</td>
<td>39.8 ± 2.0 (26)</td>
<td>41.7 ± 2.1 (27)</td>
<td>NS</td>
</tr>
<tr>
<td>Pack years†</td>
<td>29.1 ± 4.6 (22)</td>
<td>23.4 ± 3.4 (21)</td>
<td>28.7 ± 6.7 (21)</td>
<td>NS</td>
</tr>
<tr>
<td>Years at current job</td>
<td>10.9 ± 1.3 (34)</td>
<td>10.6 ± 1.5 (26)</td>
<td>13.2 ± 1.6 (27)</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Mean ± SEM.
†Pack year, one cigarette pack daily for a year.
sporatory (F2,84 = 3.86, p<0.05) muscle pressures were found to be significantly greater in the full-time glass blowers as compared to either the nonglass blower or part-time glass blower categories. Full-time glass blowers were able to generate approximately 30 percent greater positive pressure on expiration and 20 percent greater negative pressure on inspiration than the other two worker groups (Table 2).

**Discussion**

This study demonstrated a significant increase in the respiratory muscle pressure for both inspiration and expiration and percent predicted values for FVC and FEV1 in full-time glass blowers as compared to part-time glass blowers or nonglass blowing factory workers. Similar findings have been noted in a number of studies on wind instrument players and singers in which there were increased values for vital capacity, total lung capacity, residual volumes, or expiratory flow rates.5-7 However, other groups have found no change8-11 or even a decrease in lung volumes in wind instrument players or singers.12 The discrepancy between studies may be due to the type of instrument, duration of daily practice, or length of professional career.

Another occupation associated with special ventilatory efforts is that of diving. The Ama breath-hold divers of Japan often dive to 10 meters below the ocean surface while holding their breath. These occupational skin divers have been noted to have significantly larger vital capacities than nondivers and to have increased maximal expiratory and inspiratory pressures.13 Professional scuba divers, on the other hand, were found not to have a change in lung volumes as they are not trained to hold their breath or make any unusual respiratory efforts while diving.14

An explanation for the increase in Pmax, and Pmax and percent predicted values for FVC and FEV1 may be due to the type of ventilatory exercise training that is imposed on glass blowers by the very nature of their occupation. Chronic exposure to this specialized type of ventilatory maneuver may explain the increased pulmonary function, even in those subjects with a significant smoking history.

Other studies would support the view that ventilatory training increases respiratory muscle strength. Belman and Mittman18 in 1980, reported improvement in ventilatory muscle performance and submaximal exercise endurance after ventilatory muscle training. In another study, subjects showed significant improvement after five weeks of ventilatory training in pressure maximums but no increase in vital capacity or total lung capacity.16 However, there was improvement in maximal voluntary ventilation.

There did not appear to be an increased prevalence of obstructive airway disease in the American glass blowers in this study due either to smoking or to the occupational environment or stresses involved in blowing glass. However, studies of commercial glass blowers have shown an association of glass blowing with gum and tooth disease (erosion, discoloration, enamel fractures),17 cataracts,18 and upper airway infections from common use of the blowpipe.19

In contrast to our study, a 1968 Czechoslovakian study by Navratil and Rejsek14 found that glass blowers had lower values for both forced and quiet vital capacity measurements than did control subjects or wind instrument players. Glass blowers also had higher ratios of residual lung volume to total lung volume suggesting some degree of obstructive airway disease. Another study by Rozniecki et al20 in 1972 showed no clear difference between glass blowing and nonblowing glass factory workers, but showed FEV1 percent was slightly lower in glass blowers (68.6 ± 16.5) than nonblowers (70.1 ± 13.2). Also, smoking history was not considered in the study. Wagner’s study,21 in 1975, noted that neither pulmonary emphysema nor chronic bronchitis were typical occupational diseases in German glass blowers. Rejsek and Navratil22 also report that emphysema was not found in glass blowers. Studies in Italy23 and India24 suggested that there is an increased prevalence of silicosis in workers in glass
factories but did not comment specifically on glass blowers.

A more recent study of 47 American art glass blowers reported but did not document evidence of amateur glass blowers having an increased frequency of wheezing and lower lung volumes correlated with increasing exposure to the craft.1 Exposure to various inorganic glass constituents and long-term low intensity heat were thought to be associated with possible (undocumented) parenchymal change.

It is possible that other pulmonary effects from glass blowing might be found in the retired or laid off workforce; however, our study only examined currently employed glass blowers. In addition, the size of the final blown glass product may influence the extent of pulmonary function alteration. While our study dealt with glass blowers producing glassware and glass vases, glass blowers producing 90 cm long glass globes (workers not examined in this study) might have even greater pulmonary function improvement than reported here.

While the control subjects used in this study were exposed to a similar environment as the glass blowers, there may be a process of self selection in professional glass blowers which cannot be adequately controlled for in this study design. Blowing molten glass may require attributes such as a high level of voluntary control over the respiratory musculature and increases in FVC and respiratory muscle pressures. Individuals without these characteristics may never advance to the level of master glass blower. This process of selection has also been hypothesized to exist in professional wind instrument players.5

This study of 87 commercial glass factory workers from four American factories found no increased prevalence of obstructive lung disease. The results clearly indicate that there is an increase in FEV1, FVC, and respiratory muscle pressures in professional, commercial full-time glass blowers performing a prescribed set of ventilatory maneuvers in the daily production of glass objects when compared to their part-time and nonglass blowing cohorts. This finding is consistent with other studies showing that ventilatory training may improve pulmonary function.

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REFERENCES