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ARTICLES

Respiratory Function in Workers Employed in the Glassblowing Industry

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A group of 80 men employed in the glassblowing industry was studied in order to investigate the effect of this occupational exposure on respiratory function. Eighty nonexposed workers were included in the study as a control group. Glassblowers had a significantly higher prevalence of chronic bronchitis, nasal catarrh, chronic sinusitis, and nasal bleeding than control workers; length of employment in the industry did not affect the prevalence of symptoms. Many of the glassblowers complained of work shift related symptoms. Measurement of lung function among glassblowers showed there were significant increases in the forced vital capacity (FVC) and the maximum flow rates at 50% and 25% of FVC on maximum expiratory flow volume (MEFV) curves (FEF_{50}, FEF_{25}) across the work shift. Glassblowers had significantly larger preshift FVC and forced expiratory volume in 1-second (FEV_1) measurements when compared to controls. Additionally, residual volume (RV) and RV/TLC% for the glassblowers were significantly increased while the diffusing capacity (DLCO) was normal (when compared to predicted values). Our data indicate that employment in the glassblowing industry contributes to the development of chronic respiratory findings.

Key words: glassblowers, respiratory symptoms, lung function values

INTRODUCTION

There are few reports of the health effects of glassblowing. Braun and Tsiatis [1979] studied pulmonary abnormalities among art glassblowers and found that 21% complained of cough and 31% of wheezing. These authors reported that among these workers a significant drop in vital capacity (VC) and in 1-second forced expiratory volume (FEV_1) occurred, the severity of which correlated with their length of exposure to glassblowing. The authors suggested that there may be pulmonary hazards associated with this profession.

A natural comparison that arises in the study of workers in the glassblowing industry is with wind instrument players and singers. These latter groups are subject to unusual sustained airway pressures. The study reported by Navratil and Rejsek

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[1968] measured lung function in wind instrument players and glassblowers. They found that wind instrument players have a uniform technique of blowing and that their mouth pressure depends primarily on the size of the instrument played. By contrast with glassblowers, the mouth pressure was a function of the size of the glass blown. Schneider [1958] found that the highest pressure generated, up to 120 mm Hg, occurred during the blowing of large bottles (average pressures varied from 30–70 mm Hg). Navratil and Rejsek [1968] found that VC and forced vital capacity (FVC) decreased less with age in glassblowers than in wind instrument players, while residual volume (RV), functional residual capacity (FRC), residual volume/total lung capacity ratio (RV/TLC), and N_2 clearance increase was greater. Nevertheless, the same authors found lower VC and FVC and higher RV/TLC ratios among glassblowers than in control subjects. In the same study, ventilatory impairment in glassblowers was often accompanied by findings of chronic bronchitis. By contrast, Rozniecki et al. [1972, 1973] studied lung function in professional glassblowers and suggested that glassblowing has no detrimental effect on respiratory symptoms.

Of considerable interest has been the question of whether increased airway pressures have a detrimental effect on the terminal airways. Rejsek and Navratil [1962] failed to document emphysema in glassblowing workers. Tucker et al. [1971] reported significantly larger VC, RV, TLC, and expiratory flow rates in brass instrument players. Bouhuys [1964, 1968] found that VC was larger than expected for age and height in brass instrument players, but other lung function (e.g., flow rates) results were similar to or better than those of control subjects. Earlier, Heller et al. [1960] found no significant differences between professional singers and subjects who have had no professional vocal training.

Unlike musicians, glassblowers are occupationally exposed to the inhalation of heated air. Moritz et al. [1945] described that the portion of the lung most vulnerable to thermal injury is the central airways where the respiratory bronchioles and alveoli have the shortest and most direct connection to the primary bronchi.

We studied a group of workers employed as glassblowers in order to investigate whether this form of employment affects the lungs.

SUBJECTS AND METHODS

Occupational Exposure

Glass is an amorphous inorganic, usually transparent or translucent substance. It consists of a mixture of silicates and occasionally borates or phosphates formed by fusion of silica or of oxides of boron or phosphorus with a flux and a stabilizer into a mass that cools into a rigid substance without crystallization.

The possible hazards of working in the glassblowing industry are numerous and include the inhalation of aerosols, of various dusts (e.g., silica, sodium carbonate), from certain metals (e.g., lead), gases (e.g., SO_2), and unfavorable temperature conditions in the workroom. Numerous agents, including heavy metals heated to high temperatures, are used in the glassblowing process, which entails some degree of inhalation as well as blowing out. In addition, glassblowers develop increased airway pressures while blowing glass objects.

Subjects

A group of 80 male glassblowers (95% of the total working population) located in one glass making factory in Zagreb, Croatia was studied. They shaped the glass that had been softened by heat by blowing air into the mass of glass through a tube.

The mean age of the workers was 34 years (range: 21–54 years), their mean height was 171 cm (range: 161–185 cm) with a mean duration of employment in the industry of 15 years (range: 5–25 years). Most of the workers (89%) were regular smokers, smoking on the average 20 cigarettes daily (range: 10–40 cigarettes). A group of 80 men employed as clerical office workers, not exposed to any noxious agents (dust or fumes), were studied as a control group for respiratory symptoms and ventilatory capacity. The glass workers were similar to the controls in mean age (32 vs. 34 years), smoking habit prevalence (75% vs. 87%), pack/years (glassblowers 11 ± 7 years; controls 12 ± 8), and mean duration of employment (15 vs. 14 years).

Respiratory Symptoms

Chronic respiratory symptoms were recorded by using a modification of the Medical Research Council Committee questionnaire [1960] with additional questions on occupational asthma [WHO, 1986]. The following definitions were used.

1. Chronic cough/phlegm: cough or phlegm production or both on most days for at least 3 months in the year.
2. Chronic bronchitis: cough and phlegm for a minimum of 3 months in the year and for not less than 2 successive years.
3. Dyspnea grades: grade 1, no dyspnea; grade 2, exertional dyspnea was not observed; grade 3, shortness of breath when walking with other people on level ground; grade 4, shortness of breath when walking at one's own pace on level ground.
4. Occupational asthma: chest tightness, cough, wheezing, shortness of breath, and acute decrease in ventilatory capacity at or following work.
5. Nasal catarrh and chronic sinusitis complaints were abstracted from patient medical records at the workers health center.

The workers were asked additional questions about acute symptoms which develop while at work, such as cough, dyspnea, irritation or dryness of the throat, eye irritation, bleeding, secretion or dryness of the nose, or headache.

Lung Function Studies

Ventilatory capacity was measured by recording maximum expiratory flow volume (MEFV) curves on which FVC, FEV_1, and flow rates at 50% and 25% of the VC (FEF_{50}, FEF_{25}) were determined. The MEFV curves were recorded using a Pneumotach-spirometer, Pneumoscreen (Jaeger, Federal Republic of Germany). The acute effect of blowing the glass on ventilatory capacity was studied by recording MEFV curves on Monday before and after a work shift. In the control workers, ventilatory capacity was measured only once during the work shift. FRC and RV were measured by the closed-circuit helium dilution technique using the spirometer Pulmotest (Gould, Godart, The Netherlands). From the RV and VC, the TLC and the ratio RV/TLC were calculated. Diffusing capacity (DLCO) was measured by the single breath method with a Respirometer (Morgan Ltd., England). FRC, RV, and DLCO were measured once during the work shift in glassblowing workers only. The measured preshift values for FVC, FEV_1, FEF_{50}, and FEF_{25} were compared with the values in the control group and with the expected normal values [Commission des Communautés Européennes (CECA), 1971, for FVC and FEV_1 and Cherniack and Raber, 1972, for FEF_{50} and FEF_{25}]. The measured volumes of RV and TLC were compared with the expected normal values of CECA [1960] and with predicted normal values for DLCO of Cotes [1975]. The spirometers were calibrated on a daily basis. Two physicians familiar with environmental and epidemiological surveys administered the questionnaire and lung function testing throughout the survey.

Statistical Analysis

The results of ventilatory capacity were analyzed using the Student's two-tailed t-test for paired differences (acute ''shift'' effect) and unpaired (chronic effect) differences. The chi-square test or, where appropriate, Fisher's exact test was used to test differences in the prevalence of respiratory symptoms. The value of $p < 0.05$ was considered as significant.

RESULTS

Respiratory Symptoms

Table I shows the prevalence of chronic respiratory symptoms in 80 glassblowers and in the control group. The prevalence of chronic respiratory symptoms was higher in the exposed than in the control workers being significantly different for chronic bronchitis ($p < 0.04$), nasal catarrh ($p < 0.001$), chronic sinusitis ($p < 0.001$), and nasal bleeding ($p < 0.001$). Length of time in the industry did not appear to influence respiratory symptoms. There were similar prevalences for chronic respiratory symptoms when glassblowing workers employed for 10 years or more were compared to those employed for less than 10 years in the industry. For nasal catarrh (<10 years, 47.4%; >10 years, 55.7%), sinusitis (<10 years, 10.5%; >10 years, 34.4%), and nasal bleeding (<10 years, 10.5%; >10 years, 37.7%), differences were noted but these were not statistically significant ($p > 0.05$).

A large number of glassblowers complained of acute symptoms during the work shift. Symptoms of dry throat (95%), dry nose (87%), eye irritation (60%), and epistaxis (38%) were particularly frequent. All these symptoms were noted by the workers shortly after they had begun working in the glassblowing industry. Workers exposed for less than 10 years compared with those with 10 years or more of exposure had, in general, lower prevalences of shift related symptoms, but the differences between these two groups were not statistically significant ($p > 0.05$). Retention of workers in this industry is high because of the specialization and the acquired skills. Workers with the greater exposures were older than those with lesser exposures.

Lung Function Studies

Acute changes in ventilatory capacity across the work shift in glassblowing workers, and ventilatory capacity in control workers as well as expected normal values are presented in Table II. As can be seen, there was an increase in lung function measurements across the work shift in glassblowers which was significant for FVC, FEF_{50}, and FEF_{25} ($p < 0.01$). The across shift changes were largest for FEF_{25} (+7.2%) and FEF_{50} (+5.0%), and least for FVC (+2.1%) and FEV_1 (+0.3%).

A separate analysis of across shift changes by length of employment, <10 years

TABLE I. Prevalence of Chronic Respiratory Symptoms in Glassblowers and in Control Workers

Group	Mean age (years)	Mean exposure (years)	Chronic cough (%)	Chronic phlegm (%)	Chronic bronchitis (%)	Dyspnea (%)	Asthma (%)	Nasal catarrh (%)	Sinusitis (%)	Nasal bleeding (%)
Glass-blowers (N = 80)	34	15	36 (45.0)	34 (42.5)	33 (41.3)	10 (12.5)	0 (0)	43 (53.8)	23 (28.8)	25 (31.3)
			NS[a]	NS	p<0.04	NS	NS	p<0.001	p<0.001	p<0.001
Control (N = 80)	32	14	25 (31.3)	24 (30.0)	20 (25.0)	7 (8.8)	0 (0)	10 (12.5)	3 (3.8)	3 (3.8)

[a]NS, not statistically significant ($p > 0.05$).

TABLE II. Ventilatory Capacity in Glassblowers, in Control Group and Predicted Normal Values*

	FVC			FEV_1			FEF_{50}			FEF_{25}		
	Before shift	Difference before-after shift		Before	Difference before-after shift		Before shift	Difference before-after shift		Before shift	Difference before-after shift	
Group	L(%)	%	p	L(%)	%	p	L/s(%)	%	p	L/s(%)	%	p
Glass-blowers (N = 80)	4.84 ± 0.75 (95.8)	+2.1	<0.01	3.92 ± 0.70 (100.0)	+0.3	NS[a]	5.95 ± 1.67 (102.6)	+5.0	<0.01	2.67 ± 1.01 (89.6)	+7.2	<0.01
Predicted	5.05 ± 0.53[b]			3.92 ± 0.45[b]			5.80 ± 0.28[b]			2.98 ± 0.31[b]		
Control (N = 80)	4.54 ± 0.65[c] (98.5)			3.60 ± 0.55[c] (97.3)			5.46 ± 1.52 (99.3)			2.58 ± 1.18 (97.4)		
Predicted	4.61 ± 0.40			3.70 ± 0.60			5.50 ± 0.50			2.65 ± 0.60[b]		

*The data are presented as mean ± SD. Numbers in parentheses are percentage of predicted values.
[a]NS, not statistically significant ($p > 0.05$).
[b]Difference between glassblowers/control group and predicted values ($p < 0.01$).
[c]Difference between glassblowers and control group ($p < 0.01$).

of exposure (N = 19) and >10 years of exposure (N = 61) is presented in Table III. The data demonstrate that, in general, workers employed for less than 10 years had small decreases in lung function (except for FVC), while those with 10 years or more of employment demonstrated significant increases in lung function tests ($p < 0.01$) except for FEV_1. Analysis of across shift lung function changes by the presence or absence of chronic bronchitis did not reveal any significant difference (FVC: +1.2%, +3.0%; FEV_1: 0%, +0.6%; FEF_{50}: +5.7%, +4.5%; FEF_{25}: +8.0%, +5.6%).

Comparison of preshift lung function values in glassblowing workers with those of control clerical workers (Table II) demonstrated somewhat larger volumes in glassblowers than in controls, being significantly greater for FVC and FEV_1 ($p < 0.01$). However, as can be appreciated when compared with the expected normal values (from prediction equations), glassblowers had preshift measurements of FVC and FEF_{25} which were significantly lower than expected ($p < 0.01$). This anomaly may be due to the smoking effect not measured by the prediction equations. Glassblowers had very high smoking prevalences (as did the control group).

The presence of chronic bronchitis did not influence the level of lung function in glassblowers. There were two (2.5%) subjects who had FEV_1, four (5.0%) subjects who had FEF_{50}, and nine (11.3%) subjects who had FEF_{25} lower than 70% of expected normal values.

The measured values for RV, TLC, RV/TLC, and DLCO along with expected values are presented in Table IV. VC was significantly decreased ($p < 0.05$) while RV and RV/TLC were significantly increased ($p < 0.01$). When these values were analyzed by duration of exposure (<10 years and >10 years), there was no significant difference in lung function tests between the two groups. Among the glassblowers, five subjects (6.3%) had an increase in RV (139%, 136%, 143%, 189%, 199%) and two subjects (2.5%) had a DLCO lower than 80% of expected normal values (77%, 66%).

DISCUSSION

Our data suggest that work in the glassblowing industry contributes significantly to the development of chronic respiratory symptoms such as chronic bronchitis, nasal catarrh, sinusitis, and nasal bleeding. No case of occupational asthma was recorded among the studied glassblowers. Length of employment in the industry did not appear to influence the prevalence of the chronic symptoms. This finding could reflect a healthy worker effect. In our glassblowing workers the prevalence of chronic cough was higher than that reported by Braun and Tsiatis [1979] who found that 21% of "art" glassblowers had "usual cough." Schneider [1958] described the frequent occurrence of chronic bronchitis among glassblowers. Recently, Srivastava et al. [1988] described that in a population of glass bangle workers in India, 23.8% complained of chronic bronchitis compared to 14.9% in the general population. The authors concluded that the risk of chronic bronchitis was significantly increased by the duration of employment in this industry. Rastogi et al. [1988] have described cases of pneumoconiosis of the restrictive-obstructive type in the glass bangle industry, probably due to the inhalation of SiO_2 dust.

Wingren and Axelson [1985, 1987] studied mortality in the glassworks industry and concluded that glassblowers were at the highest risk for health problems other than chronic respiratory disease, such as colon cancer, lung cancer, and cardiovas-

TABLE III. Shift Related Lung Function Changes in Glassblowers in Relation to Duration of Exposure*

Exposure (years)	FVC			FEV_1			FEF_{50}			FEF_{25}		
	Before shift	Difference before-after shift		Before	Difference before-after shift		Before shift	Difference before-after shift		Before shift	Difference before-after shift	
	L	%	p	L	%	p	L/s	%	p	L/s	%	p
<10 (N = 19)	5.22 ± 0.59	+1.5	NS[a]	4.26 ± 0.49	−0.7	NS	6.39 ± 1.54	−2.0	NS	3.12 ± 0.94	−6.1	NS
>10 (N = 61)	4.65 ± 0.97	+3.2	<0.01	3.81 ± 0.73	+0.5	NS	5.82 ± 1.71	+7.2	<0.01	2.53 ± 1.00	+9.9	<0.01

*The data are presented as mean ± SD.
[a]NS, not statistically significant ($p > 0.05$).

TABLE IV. Pre-Work Shift Lung Function in 80 Glassblowers*

Test	Measured	Predicted	Difference measured-predicted	
			%	p
VC (L)	4.84 ± 0.75	5.05 ± 0.53	95.8	<0.05
RV (L)	1.85 ± 0.66	1.52 ± 0.17	121.7	<0.01
TLC (L)	6.69 ± 0.10	6.69 ± 0.77	100.0	NS[a]
RV/TLC%	27.65 ± 7.40	22.69 ± 2.36	123.8	<0.01
DLCO (ml/min/mmHg)	31.48 ± 4.44	31.71 ± 3.18	99.3	NS

*The data are presented as mean ± SD.
[a]NS, not statistically significant ($p > 0.05$).

cular diseases. Carnow [1976] described that professional and amateur glassblowing artists and craftsmen are exposed to many chemical substances as well as to nonphysiological maneuvers in their work. Different noxious agents in the glass and crystal industry and occupational diseases are described by Sartorelli et al. [1972]. These diverse environmental pollutants may explain some of the nonrespiratory health risks of glassblowers.

In this study ventilatory capacity measurements demonstrated primarily acute increases in lung function during the work shift. These were most pronounced for FEF_{50} (+5.0%) and FEF_{25} (+7.2%). Preshift lung function tests revealed larger values in our glassblowers compared with the control group. However, comparison of the measured values in glassblowers with expected normal values for FVC and FEF_{25} showed a decrease. As mentioned earlier these discrepancies may relate to the high prevalence of smoking in the glassblowing cohort (which was matched for smoking with the control workers but not with the predicted population).

Hyperinflation maneuvers such as incentive spirometry have been extensively used in clinical medicine (e.g., postoperatively) to improve lung volumes. The presumed basis for this improvement is the recruitment and inflation of microatelectatic areas of lung. Similar mechanisms may account for the baseline and across shift increases in lung function seen in glassblowers.

Because the maneuvers of glassblowing are similar in many respects to those of wind instrument players, several authors have compared the data of lung function in these two occupational groups. Our data for glassblowers are similar to those of Tucker et al. [1971] who demonstrated significantly increased VC, RV, TLC, and expiratory flow rates in brass instrument players. The RV in our glassblowers was slightly increased (121.7%) with no decrease in DLCO suggesting that these changes did not represent emphysema. A VC larger than expected was also reported by Bouhuys [1964] in wind instrument players. Cugell [1986] suggested the importance of the interaction of chest wall and abdominal muscles in wind instrument players in determining lung volume. These authors found a considerable variation between performers in the timing and magnitude of thoracic and abdominal contribution to exhalation. End-inspiratory lung volumes were much more consistent in the skilled players than in novices. Interstitial or subcutaneous emphysema of the head, neck, and even upper chest and mediastinum has been described by Levine [1986] in wind instrument players. Schorr-Lesnick et al. [1985] studied lung function in singers, wind instrumentalists, and in a control group of string and percussion instrument players and found no significant difference between these groups in maximum voluntary ventilation, FEV_1, FVC, FEF_{25-75}, peak expiratory pressure, and peak inspiratory pressure.

The respiratory effects of glassblowing appear to be unique to this industry, reflecting their work environment and the respiratory maneuvers that these workers perform. On the one hand, they have an excess of respiratory symptoms which probably reflects airway irritation secondary to the inhalation of irritants such as hot gases and vapors. On the other, their lung function parameters appear to be supranormal. This probably reflects the constant maximal inspiratory maneuvers that they perform throughout the work day. Smoking effects, however, must be accounted for separately.

Our study indicates that glassblowers suffer more respiratory symptoms than do control workers and that a unique pattern of lung function changes are found among these workers. Glassblowers, particularly those employed for more than 10 years in the industry, show significant across shift changes in lung function. Increased RV was documented in these workers but with a normal DLCO. It is not clear whether these changes are pathologic or physiologic; however, the lack of progression with a longer work history suggests the latter. While the exact characterization of the respiratory impairment remains to be defined, this investigation suggests that chronic respiratory changes occur in glassblowers as a result of their occupational exposure.

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