

Ventilatory function in brass workers of Gadaladeniya, Sri Lanka

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A cross sectional study was conducted to determine the respiratory hazards of brass workers. The study group was selected randomly. The control group was selected from the general population matched for age by cluster sampling. There was a total of 154 pairs for the final analysis. A questionnaire was administered to determine the prevalence of respiratory symptoms. Forced vital capacity (FVC), forced expiratory volume in the first second (FEV_{10}), forced expiratory flow rate in the mid 50% of the FVC ($FEF_{25\%-75\%}$) and peak expiratory flow rate (PEFR) were measured. Chest radiography was performed on those with 5 or more years of service. Cough, phlegm, chronic bronchitis and dyspnoea were significantly higher among brass workers. The ventilatory capacity was significantly lower in all the indicators except FVC. Smoking had no significant effect and a dose response relationship could not be demonstrated after inclusion of age in the regression model. Five point five per cent had evidence of septal lines while 6.4% had emphysema.

Key words: Brass workers; occupational health hazards; ventilatory capacity.

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INTRODUCTION

Brass consists mainly of 60–70% of copper and 20–30% of zinc. In addition it may contain metals such as lead, tin, iron, manganese, arsenic, etc. which may be added intentionally to improve the quality of the alloy or may be present as impurities.

Manufacture of brass ware is one of the cottage industries in Gadaladeniya, in the District of Kandy, Sri Lanka. The brass workers are mainly clustered around the Gadaladeniya Buddhist temple which is of historical importance. It is an industry which had been handed over from generation to generation. The processes which were totally manual, have now been mechanized over the last two or three decades.

There are several stages involved in the manufacture of brass ware. First the scrap metal is smeltered and poured into the sand casts of various shapes. Once set they are removed from the casts and the adjoining parts are welded together. Then these are fettled and once smoothed designs are engraved and finally these are polished. Fettling and polishing are mechanically performed and engraving is done manually.

Metal fumes are liberated to the working environment during smelting, pouring of the molten metal into the casts and during welding. Brass and silica dust may be released during fettling and polishing. Gases such as ozone, nitrogen oxides,¹ acetylene and phosphine² are also liberated during welding. These pollutants may pose a threat to the health of these workers as there are no control measures such as exhaust ventilation systems installed in this type of cottage industry.

No research has been conducted in the past to determine the health hazards faced by the brass workers. Thus it was felt important that a survey be conducted in order to identify them.

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OBJECTIVES

To determine the following:

- the prevalence of chronic respiratory symptoms;
- the ventilatory capacity among brass workers compared with a control group not engaged in the brass industry;
- the radiological changes in the lungs of brass workers.

METHODOLOGY

General

Ethical clearance was granted by the Ethical and Higher Degrees Committee of the Faculty of Medicine, Peradeniya, Sri Lanka and written informed consent was obtained from each and every subject prior to the commencement of the investigations.

Study design and period

A cross-sectional study was conducted during the period of August 1992 to January 1994.

Sampling

As no data are available from previous surveys a pilot study was conducted to determine the sample size with reference to ventilatory capacity, audiometry, plasma zinc and copper levels (latter three are not included in this article). A minimum sample size of 91 was obtained for ventilatory capacity while this figure for audiometry was 147 which was the maximum sample size calculated. Twenty-three more were added to make a total of 170 assuming a non response rate of 10% and leaving an allowance of 5% for those who may have to be excluded due to the presence of the following conditions: (1) perforated ear drums; (2) history of congenital deafness;³ (3) exposure to sudden explosions;³ (4) history of ear discharge;³ (5) history of ear surgery; (6) history of head injury with loss of consciousness³ (7) history of tuberculosis;⁴ (8) history of major chest surgery;⁴ (9) history of exposure to 'Paraquat'.⁵

Initially a list of the brass workshops that has been registered with the Grama Seva Niladharis (village headmen) of the 12 brass villages, was obtained. Then a survey was conducted with the help of the Family Health Worker (public health midwife) in order to determine the number of workers engaged in the industry in each brass workshop. A list was formulated with 369 names all of whom were males and from this 170 brass workers were selected randomly irrespective of the duration they had been engaged in the industry.

The control group which consisted of males was selected from the general population residing 3.2 KM

(2 miles) away from the border of the cluster of brass villages and who had never engaged in the brass industry. All the brass villages and the control villages came under the same Deputy Director of Health Service area. Twelve villages were selected randomly from a total of 30 control villages and from each of them a cluster sample was chosen to match the individual age of the brass workers to the exact year (age was taken as completed years).

If either partner of the matched pair did not respond or was found to have a condition mentioned under exclusion criteria both partners were excluded from further analysis.

STUDY INSTRUMENTS

Questionnaire

All those selected for the study were subjected to an interviewer administered questionnaire to obtain personal information, detail occupational history, prevalence of respiratory symptoms, symptoms related to copper, zinc and lead toxicity, hearing and the use of protective gear. Only the symptoms related to the respiratory tract will be discussed in this paper. The following respiratory symptoms⁶ in addition to wheezing were included:

Chronic cough or phlegm: presence of cough or phlegm or both over a duration of three months or more during a period of one year.

Chronic bronchitis: presence of cough or phlegm or both over a duration of three months or more a year for two or more consecutive years.

Dyspnoea on exertion: shortness of breath when walking at ordinary pace on the level.

Wheeze: Shortness of breath associated with noisy breathing.

Spirometry

Spirometry was conducted, in the field, using the Vitalograph which conformed to the international standards.⁷ Forced Vital Capacity in litres (FVC), Forced Expiratory Volume in the First second of the Vital capacity in litres (FEV_{1.0}), Forced Expiratory Flow Rate in the mid 50% of the Vital Capacity in litres per second (FEF_{25%-75%}) were measured. Peak Expiratory Flow Rate in litres per minute (PEFR) was measured using the mini Wright peak flow meter. The procedure was explained, including a demonstration to all by an experienced technician. They had several practice blows until they mastered the technique. Three tracings were obtained from each subject and the highest reading for each test was taken for the final analysis regardless of the curve in which it occurred.

The readings were converted to values of body temperature and pressure saturated with water vapour (BTPS).

Clinical examination

A clinical examination of the respiratory and cardiovascular systems was performed. Height was measured to the nearest 0.1 cm.

Radiology

A full size chest X ray was taken from the brass workers who had been engaged in the industry for five or more years. The chest radiographs were assessed for presence of tuberculosis, bronchiectasis, emphysema, pneumoconiosis and malignancy by two independent radiologists. Only the radiographs that were agreed upon by both were considered for further analysis.

Statistical tests. Student's *t*-test and ANCOVA were used to analyze continuous data while Chi square and McNemar's tests were used to analyze categorical data. Contribution of each relevant variable on ventilatory capacity was determined through multiple linear regression. A probability of less than 0.05 was considered as significant.

RESULTS

One or other of eight pairs did not respond and a further eight pairs had members with conditions mentioned under the exclusion criteria. Therefore a total of 154 pairs were taken for the final analysis.

General. The mean age was the same in the two groups. The brass workers were significantly shorter than the control group. There was no significant difference in the number of smokers or the amount smoked denoted as pack years in the two groups (Table 1). The socio-economic status in terms of average monthly income and the level of education did not differ significantly. Thirty-three per cent of the subjects in the control group were unemployed while 20% were engaged in small scale business and 12% were farmers. The balance 33% were engaged in a variety of skilled, semi-skilled and unskilled occupations.

Chronic respiratory symptoms. Cough and phlegm of 3 months duration, chronic bronchitis and dyspnoea on exertion were significantly more among brass workers. Prevalence of wheeze was very low and did not differ significantly in the two groups (Table 2).

Clinical examination. None had evidence of any cardiovascular or respiratory abnormalities.

Ventilatory capacity. FVC, FEV_{1.0} and FEF_{25%-75%} conformed to a normal distribution while PEFR did so with an exponential transformation of 2.

On comparison of the ventilatory capacity after controlling for the difference in height by using ANCOVA all the four indices were found to be lower among the brass workers. The differences observed were significant except in FVC (Table 3).

Multiple linear regression was used to determine the association between ventilatory capacity and height, exposure and smoking status in the two groups. Exposure was related significantly with all except FVC

Table 1. Description of certain relevant variables

Variable	Group	Total No.	Mean	Range	SE	Prob.
Age (yrs)	S	154	29.9	16-66	0.79	1.0
	C	154	29.9	16-66	0.79	
Height (cms)	S	154	163.2	148-177	0.49	0.02
	C	154	164.7	150-187	0.47	
Smoking (pack-yrs)	S	71	8.55	0.2-37.0	0.97	0.18
	C	76	11.35	0.4-72.0	1.80	

SE = standard error; Prob = probability; statistical test = student's *t*-test; S = study; C = control.

Table 2. Chronic respiratory symptoms

Symptom	Study (%)	Control (%)	OR (CI)	Prob.
Cough: 3months	16 (10.4)	2 (1.3)	8.0 (1.8-34.8)	0.001
Phlegm: 3months	27 (17.5)	9 (5.8)	3.6 (1.5-8.3)	0.003
Chronic bronchitis	27 (17.5)	5 (3.2)	8.3 (2.5-27.6)	0.000
Dyspnoea	54 (35.1)	36 (23.4)	1.9 (1.1-03.4)	0.020
Wheeze	2 (1.3)	4 (2.6)	0.5 (0.1-02.7)	0.690

OR = odds ratio; CI = 95% confidence interval; Prob. = probability; Total in each group = 154; statistical test = Mc Nemar's Test.

(Table 4). Height and smoking were significantly related with ventilatory capacity in all the indices. However when age was included having categorized into five groups using dummy variables (16–20, 21–25, 26–30, 31–35, > 35 years) the effect of smoking became insignificant.

When the ventilatory capacity of the brass workers alone was regressed with height and service in exposed years (calculated taking into account the number of hours worked per day, number of days worked per week and the total number of years worked, the mean value being 3.5 years) the service was found to be significantly associated with ventilatory capacity in FVC and FEV (Table 5). However, when age was included as mentioned above in five year interval groups, the effect of service became insignificant. FEF_{25%–75%}, though was found to have a marginally significant association with service, the probability being 0.10.

The observed values of both groups were compared individually with the respective predicted normal values reported by Udupihilla.⁸ Both brass workers as well as the control group were found to have a significantly lower ventilatory capacity with respect to all the indices (Table 3).

Radiology. There were 115 brass workers who were eligible for radiography out of which five did not

participate. There was disagreement between the two radiologists with regard to one radiograph and therefore the total excluded from the analysis was six (5.2%).

None had evidence of tuberculosis, bronchiectasis, malignancy or pneumoconiosis. However, six (5.5%) had evidence of septal lines which may be suggestive of early parenchymal reaction to the presence of dust⁹ and seven (6.4%) had emphysema.

DISCUSSION

A cross-sectional study does not reveal the temporal relationship between exposure and outcome. However, it is considered the most appropriate when faced with time and financial constraints.

Brass workers had a significantly higher prevalence of chronic respiratory symptoms in comparison to the control group. This confirms what is described by Hayhurst.¹⁰ Selecting the control group from the general population incorporates the inherent selection bias of 'healthy worker effect'¹¹ into the study. Despite this the brass workers were affected more than the control group. This holds true with the ventilatory capacity too which again was significantly affected in brass workers.

Although smoking and duration of service were significantly associated with the decline in ventilatory

Table 3. Comparison of observed ventilatory capacity with the predicted normal values

Indicator	Mean				Probability		
	S	PRS	C	PRC	S/C	S/PRS	C/PRC
FVC (litres)	3.12	3.49	3.15	3.55	0.756	0.000	0.000
FEV (litres)	2.67	2.99	2.87	3.04	0.042	0.000	0.002
FEF (litres/sec)	3.12	3.56	3.55	3.81	0.000	0.000	0.007
PEFR [√] (litres/min)	496.9	549.5	532.8	557.8	0.000	0.000	0.000

S = study; PRS = predicted study; C = control; PRC = predicted control.
Statistical tests: (1) S/C = ANCOVA; (2) S/PRS & C/PRC = Student's *t*-test.

Table 4. Ventilatory capacity by height, exposure and smoking status in the two groups

Indicator		Height (cms)	Exposure Pre/Abs	Smoking (pack-years)	Intercept	R ²
FVC litres	RC	+0.036	+0.009	-0.017	-2.730	17%
	SE	0.006	0.071	0.003	0.966	
	PROB	0.000	0.904	0.000	0.005	
FEV litres	RC	+0.030	-0.168	-0.020	-1.990	18%
	SE	0.006	0.071	0.003	0.960	
	PROB	0.000	0.018	0.000	0.039	
FEF litres/sec	RC	+0.038	-0.666	-0.029	-2.340	17%
	SE	0.011	0.128	0.006	1.750	
	PROB	0.000	0.000	0.000	0.182	
PEFR [√] litres/min	RC	+47.80	-181.0	-35.40	-281.4	11%
	SE	26.20	91.2	20.10	336.8	
	PROB	0.001	0.000	0.002	000.5	

Pre = present; Abs = absent; RC = regression coefficient; SE = standard error; PROB = probability; statistical test = multiple linear regression.

Table 5. Ventilatory capacity by height and service among brass workers

Indicator		Height (cms)	Service (exposed years)	Intercept	R ²
FVC litres	RC	+0.04	-0.27	-2.82	18%
	SE	0.01	0.12	1.08	
	PROB	0.00	0.02	0.01	
FEV litres	RC	+0.03	-0.24	-2.24	13%
	SE	0.01	0.12	1.09	
	PROB	0.00	0.04	0.04	
FEF litres/sec	RC	+0.03	-0.30	-1.90	4%
	SE	0.01	0.22	2.07	
	PROB	0.02	0.17	0.35	
PEFR √ litres/min	RC	+48.2	-150.2	-350.5	4%
	SE	30.9	128.8	395.4	
	PROB	0.02	0.2	0.4	

RC = regression coefficient; SE = standard error; PROB = probability; statistical test = multiple linear regression.

capacity initially, when age which is a covariate was included in the regression model both no longer became significant. This may be attributed to the small mean values observed for both pack years smoked (Table 1) and the duration of service. Further both these variables are known to be correlated with age thus leading to masking of the individual effects.

Most brass workers did not work through out the week which is a feature of these small scale industries. The fact that in FEF, a marginally significant dose response was observed even with the addition of age in the regression model may prove to be of some importance as it denotes small airway function which is the first to get affected as a result of exposure to respiratory pollutants.

It is difficult to isolate one main causative factor, as there are several respiratory pollutants that the brass workers are exposed to as each person engages in multiple tasks with in the industry. The effects observed may be as a result of combination of all these.

It was remarkable that none suffered from silicosis although a few had early radiological changes in relation to dust exposure.⁹ The sand used for the purpose of preparation of moulds was rather moist which prevents the release of silica dust into the environment. This is an observation made by McLaughlin⁹ too. Fetting is another process in which inhalation of silica dust could occur and fettlers among foundry men are at a higher risk of developing this condition.¹² Brass workers here in Sri Lanka do not work in confined spaces. The work shops are either completely open or covered with a wire meshed wall. This may be an additional reason that very few presented with specific radiological changes. Further, silicosis is a rare condition in Sri Lanka¹³ and whether a genetic factor has any significant role to play is still to be explored.

Hayhurst¹⁰ describes that tuberculosis was common among brass founders although none in the present

series did show evidence of it. According to McLaughlin,⁹ tuberculosis as a complication of pneumoconiosis among foundry workers is declining although lung cancer is increasing. He attributes this to the presence of mineral oil, tar and pitch incorporated in the moulding sand. During the survey period there were two deaths due to cancer of the lung among brass workers who were not included in the study. However, none in the present series presented with opacities suggestive of malignancy. It may be worth to follow up these brass workers prospectively in order to determine whether the incidence of malignancy in fact is higher among this occupational group.

In view of the above observations it is imperative that preventive measures need to be adopted in order to decrease the effects described. The use of an industrial mask is the minimum that could be recommended although the ideal may be the installation of exhaust ventilation. However, due to the limited financial resources available for investment in these cottage industries, the latter may not be a feasible option.

CONCLUSIONS

The brass workers were observed to be at a significantly higher risk of developing respiratory symptoms in addition to a decline in ventilatory capacity. This may be as a result of a combination of exposures attributable to the work environment. It is imperative that preventive measures be adopted in order to minimize the above mentioned hazards.

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REFERENCES

1. Beaumont JJ, Weiss N. Lung cancer among welders. *J Occup Med* 1981; 25: 839-844.
2. Evrard M. Acetylene. In: *Encyclopaedia of Occupational Health and Safety. Third Edition.* Geneva, Switzerland: ILO 1983: 40-41.
3. Sataloff RT. The 4000 Hz. audiometer dip. *Ear Nose Throat J* 1980; 59: 251-257.
4. Medical Research Council. *Questionnaire on Respiratory Symptoms and Instructions to Interviewers.* London: Medical Research Council, 1986.
5. World Health Organisation. *Paraquat and Diquat.* Geneva, Switzerland: WHO, 1984; (Environmental Health Criteria 39).

6. Zuskin E, Skuric Z. Respiratory function in tea workers. *Br J Ind Med* 1984; 41: 88–93
7. American Thoracic Society — standardization of spirometry — 1987 update. *Am Rev Respir Dis* 1987; 136: 1285–1296.
8. Udupihilla M. Respiratory function tests: reference norms for the Sinhalese. *Ceylon Med J* 1995; 40: 53–58.
9. McLaughlin AIG. Pneumoconiosis in foundry workers. *Br J Tuberc Dis Chest* 1957; L1(4): 297–309
10. Hayhurst ER. Occupational brass poisoning: brass founder's
ague. *Am J Med Sci* 1913; 145: 723–739
11. Choi BCK. Definition, sources, magnitude, effect modifiers and strategies of reduction of the healthy worker effect. *J Occup Med* 1992; 34: 979–988.
12. McCallum. Respiratory disease in foundrymen. *Br J Ind Med* 1972; 29: 341–344.
13. Uragoda CG. Occupational hazards among granite workers in Ceylon. *J Trop Med Hyg* 1968; 71: 267–270.