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Respiratory Diseases in Agate Grinding Workers in Iran

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Abstract

Background: Agate is a hard silica stone with bands of various colors, which is used in jewelry. The agate grinding workers are exposed to silica dust.

Objective: To determine the prevalence of respiratory diseases in agate grinding workers and the associated factors.

Methods: In this cross-sectional study, 170 agate grinding workers from Mashhad, north-eastern Iran, were examined. Medical and occupational history for respiratory illnesses was taken using respiratory questionnaire of the national program of silicosis control, lung examination, spirometry and chest radiography. Chest x-rays were interpreted according to the International Labor Office (ILO) classification system, 2000.

Results: The mean±SD of age and work duration of the participants were 31.2±10.1 and 13±8.2 years, respectively. The prevalence of silicosis among agate workers was 12.9% (95% CI: 7.9%–18.0%); 18 workers had simple and 4 had complicated silicosis. There was a significant ($p<0.05$) relationship between contracting silicosis and exposure duration. 20 (11.7%) workers had symptoms consistent with chronic bronchitis and 8 (4.7%) showed asthma and asthma-like symptoms. The most frequent disorder observed in spirometry was the restrictive pattern ($n=43$, 30%). In the agate grinders, clinical and spirometry findings did not match with radiological findings.

Conclusion: Agate grinding workers are at increased risk for respiratory diseases, specifically for silicosis and chronic bronchitis. The disease is related to silica dust exposure, poor ventilation and inappropriate personal protection.

Keywords: Silicon dioxide; Silicosis; Respiratory disorders; Dust; Spirometry; Environmental pollution

Introduction

Long-term exposure to respirable dust containing silica leads to silicosis, increased susceptibility to tuberculosis and developing lung cancer.¹ Silicosis is the most common type of pneumoconiosis in the world, the complete

elimination of which until 2030 is one of the goals of the World Health Organization (WHO) and the International Labour Office (ILO).² Agate is a semiprecious stone with great value among Iranian people. It is used for production of a lot of accessories, jewelry, and artifacts. Previous studies have shown a high incidence of silicosis

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among agate workers.^{3,4} Almost three million workers are exposed to silica who are mainly working in mines and industries such as stone cutting, silica milling, slate pencil, and agate.⁵ The highest prevalence of silicosis was in the slate pencil industry (54.4%) followed by agate industries (38%).⁵

Agate processing is done by slicing the stone, cutting with a machine, then grinding and curving in to a pre-defined design. Grinding produces the highest amount of dust in the above-mentioned process.³ Agate industries, which are mostly unorganized and located in southern neighborhoods of Mashhad, northeastern Iran, are the main centers of grinding of this stone in Iran. In these workplaces, agate stones are ground by electric abrasive wheels to give them favorite size and shape. This process generates a large amount of freshly fractured agate dust 2–5 μm in diameter, which contains more than 90% free silica.⁶ Previous records of environmental assessments of agate grinding units showed a mean concentration of the respirable dust of 6.5 mg/m^3 in these workshops,^{4,13} which is larger than the national exposure limits⁷.

Because of the small size of these enterprises, lack of suitable ventilation and low socioeconomic status of the workers (Fig 1), the rate of silica dust production and exposure is high. To the best of our knowledge, a comprehensive report has not yet been published on agate-related respiratory diseases in Iran. We, therefore, conducted this study to determine the prevalence of respiratory diseases and its related associated factors among agate grinding workers in Mashhad, northeastern Iran.

Materials and Methods

The study population consisted of all agate grinding workers in Mashhad. Occupational hygiene experts in health centers could identify 70 workshops and 187 agate grind-



Figure 1: An agate grinding workshop in Mashhad

ing workers, all of whom were referred to an occupational medicine center for chest radiography, physical examination and spirometry. Seventeen workers refused to participate in the study leaving 170 workers to be evaluated. For data collection, the respiratory questionnaire of the national program of silicosis control (confirmed by the Iranian Ministry of Health) was used. It includes demographic information, job history, smoking habits, respiratory signs and symptoms, and history of tuberculosis.⁸ The physical examinations were done by an occupational medicine specialist. Chest x-rays were taken and read by a radiologist and a trained occupational medicine specialist in chest x-ray analysis based on ILO standards. Spirometry (Poney FX, Italy) was done by a trained health expert. For analyzing spirometry tests, forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC percent and forced expiratory flow 25%–75% (FEF_{25-75}) indices were used.

The classification of respiratory diseases was made using the standard diagnostic criteria. Diagnosis of silicosis and its severity were based on the ILO classification for



For more information on work-related respiratory symptoms and airway disease in hairdressers see www.theijoem.com/ijoem/index.php/ijoem/article/view/224

pneumoconiosis and made by a radiologist and an occupational medicine specialist.⁹ Chronic bronchitis was defined according to the Medical Research Council criteria in those with chronic cough and sputum production for a minimum of three months a year for two successive years.¹⁰

The diagnosis of asthma was made in those with self-reported asthma (diagnosed by a physician in the past), or subjects who had asthma-like symptoms (*ie*, simultaneous episodes of dyspnea and wheezing in the past 12 months or time of medical exams).¹¹ SPSS® for Windows® ver 16 was used to analyze the data. Univariate analysis was done using independent-sample *Student's t* test for continuous variables and χ^2 test for categorical variables. Non-parametric statistical tests were used for analyzing data with non-normal distribution. A p value <0.05 was considered statistically significant.

Results

A total of 170 subjects working in the agate industries was assessed. All the participants were male and their job was agate grinding. The median age was 28 (IQR 12) years; their median exposure duration was 10 (IQR 13) years. Table 1 shows the demographic information of the studied workers. Agate grinders usually work for almost

Table 1: Demographic information in agate grinding workers

Description	n (%)
Age	
18–30	102 (60.0)
31–40	40 (23.5)
41–50	20 (11.8)
>50	8 (4.7)
Exposure duration (yrs)	
≤10	90 (52.9)
11–20	58 (34.2)
>20	22 (12.9)
Smoking habits	
Non-smoker	136 (80.0)
Smokers/ex-smokers	34 (20.0)

10 hours a day with low level of physical exertion. Only 10% of workers were using cotton surgical face masks; no one used wet methods. There was no appropriate ventilation in agate grinding units studied; only a very few units had hand-making ventilations designed by the workers themselves to control the dust.

The most common clinical findings were exertional dyspnea (31.8%), cough (21.2%), and sputum production (13.1%). In radiologic evaluations, 28 (16.4%) of 170 workers had abnormal chest x-rays, 22 (12.9%; 95% CI: 7.9%–18.0%) of whom had silicosis and 6 (3.5%) had other problems not related to silicosis (*eg*, lung emphysema, cardiomegaly, hilar calcification, and bronchiectasis). Silicosis mainly occurred in workers aged >40 years and those with exposure duration >25 years.

Of 170 workers, 27 (15.9%) either did not agree to participate in spirometry or could not perform the test acceptably (according to the American Thoracic Society [ATS] criteria), leaving 143 spirometry

For more information on spirometric parameters in workers of a tile and ceramic industry in Yazd, Iran see www.theijoem.com/ijoem/index.php/ijoem/article/view/217



Table 2: Prevalence of respiratory diseases in the studied agate grinding workers

Disease Condition	n (%; 95% CI)
Silicosis	
Simple	18 (10.6; 5.9–15.3)
Complicated	4 (2.4; 0.1–4.7)
Previously diagnosed chronic bronchitis	20 (11.8; 6.9–16.6)
Asthma and asthma-like symptoms	8 (4.7; 1.5–7.9)
History of tuberculosis	2 (1.2; 0.0–2.8)

results for analyses. The most prevalent respiratory diseases diagnosed in agate grinding workers are presented in Table 2. Sixty-six (38.8%) workers had functional abnormalities on spirometry. The most common abnormality observed was restrictive (24.3%) followed by obstructive (5.8%) patterns. Almost 30% of those with silicosis had normal spirometry; on the other hand, almost 25% of workers without silicosis had abnormal spirometry.

Multiple logistic regression analysis revealed that only exposure duration was a significant independent predictor for developing silicosis ($r^2=0.715$; OR: 1.48; 95% CI: 1.25–1.75).

Non-Silicosis Subjects

The 148 workers without radiological silicosis had a median age of 28 (IQR 10) and a median exposure duration of 10 (IQR 8) years. Twenty-six (17.6%) subjects were smoker and 6 (4.1%) were under treatment because of chronic respiratory disease. Spirometry results were available for 143 workers (Table 3). Forty-four (30.8%) workers had abnormal spirometry—34 (77%) had mild restrictive pattern, 8 (18%) had obstructive, and 2 (5%) had mixed pattern.

Of non-silicosis subjects, 20 (13.5%) had dyspnea, 45 (30.4%) had sputum production, 15 (10.1%) suffered from cough, 12 (8.1%) had chest tightness, and 5 (3.4%) had wheezing.

Silicosis Subjects

Of 22 workers with radiological silicosis, 18 (82%) had opacities smaller than 10 mm in diameter and 4 (18%) had larger opacities interpreted as progressive massive fibrosis (PMF). All the workers with silicosis underwent spirometry test (Table 3). Of those with silicosis, 9 (41%) had restrictive pattern, 3 (14%) had obstructive pattern, 3 (14%) had mixed and 7 (32%) had normal spirometry. In this group, the median age

TAKE-HOME MESSAGE

- Agate is a hard silica stone with bands of various colors, which is used in jewelry.
- The agate grinding workers are exposed to silica dust.
- Long-term exposure to respirable dust containing silica leads to silicosis, increased susceptibility to tuberculosis and developing lung cancer.
- Silicosis is the most common type of pneumoconiosis in the world.
- Because both exposure to agate dust and getting silicosis present with restrictive pattern, it can be inferred that exposure to agate dust would cause spirometry disorders before radiologic changes.
- Workers in agate grinding industries are at increased risk for respiratory diseases, specifically for silicosis and chronic bronchitis.

was 46 (IQR 13) and the median exposure duration was 30 (IQR 11) years. Of workers with silicosis 15 (68%) had dyspnea, 8 (36%) had sputum production, 8 (36%) had cough, 3 (14%) suffered from chest tightness, and one had wheezing. In this group, 5 (23%) were smokers and 6 (27%) had intense respiratory symptoms and were receiving drugs. Only 2 (9%) workers had the history of tuberculosis in recent years that were treated.

There was no significant ($p=0.749$) dif-

Table 3: Spirometric variables in workers with and without silicosis. Figures are mean±SD.

Variable (% predicted)	Workers without silicosis (n=22)	Workers with silicosis (n=121)	p value
FEV ₁	82.4±9.9	72.9±7.6	0.003
FVC	80.6±9.5	71.1±11.9	0.004
FEV ₁ /FVC	82.5±7.6	77.2±10.5	0.04
FEF ₂₅₋₇₅	80.7±19.9	57.3±12.3	<0.001

For more information on silica exposure and serum angiotensin converting enzyme activity see www.theijoem.com/ijoem/index.php/ijoem/article/view/5



ference between the prevalence of smoking between workers with and without silicosis. Median age and exposure duration, as well as the mean spirometry parameters were significantly different between workers with and without silicosis (Table 3). Up to March 2011, three patients with silicosis died of respiratory failure and two were in critical conditions.

Discussion

The present study provides evidence of respiratory disease in agate grinding workers exposed to respirable crystalline silica at levels in excess of the Occupational Safety and Health Administration (OSHA) permissible exposure limit during the course of their work. For the most part, exposures occurred in small and unorganized units without adequate environmental control and respiratory protection.

Our study showed that the prevalence of the silicosis was 12.9%. Silicosis mainly occurred in workers over 40 years and those with exposure duration >25 years, which can be considered “long-term exposure” with moderate amount of silica dust in the agate industries. Multiple regression analysis showed that exposure duration was the only independent predictor for developing silicosis, so that 71.5% of variance in developing silicosis could be explained by the duration of exposure.

Prevalence of silicosis was high compared to the report of Aghilinezhad, *et al*, that found a prevalence of 10% in stone mill industries in Malayer,¹² but lower than a report from Gujarat, India, that showed 39.8% of male and 34.2% of female agate grinders had silicosis¹³. A study done by Rastogi and his colleagues on 342 workers in agate industries showed that 18.4% of subjects had silicosis.¹⁴ In another study conducted in India, the prevalence of silicosis in 123 clinically suspected patients working in an agate grinding industry

was 69.1%. The incidence of the disease in workers exposed >10 years was 4.8 times than that in those with lesser exposure.¹⁵

Although those workers suffering from silicosis had worked for a median of 30 years, there were young workers with silicosis who had exposure duration <10 years and aged <35 years. Therefore, as expected, the exposure dose, ventilation condition of the workplace, institution of dust control measures, and individual susceptibility can be effective in getting the illness and prognosis. In our study, the low prevalence of silicosis compared to other studies, might be attributed to short work duration of the study participants, their low cumulative exposures, and the nature of the respirable silica dust encountered.

In our study, the most common clinical findings were exertional dyspnea (31.8%), cough (21.2%), and sputum production (13.1%). This prevalence rates are similar to those reported in a cross-sectional study on stone mill workers where 53.3% of subjects had dyspnea, 36.7% had cough, and 30% had sputum production.¹⁶ Tjoe-Nij, *et al*, also reported that 10% of the studied workers suffered from chronic cough and sputum.¹⁷

Only 1.1% of studied agate grinder workers had history of tuberculosis. It is much lower than that reported in a study from India where the prevalence of tuberculosis amongst male and female agate grinders were 37.4% and 40.3%, respectively,¹³ and lower than another study from India where the prevalence was 15.5%.¹⁴ Nonetheless, in the current study, tuberculosis was evaluated by patient self-expression only and not through specific tests. Therefore, the prevalence could be underestimated.

Overall, 11.7% of participants had findings of chronic bronchitis. These findings are similar to those reported by other investigators.^{17,18} Similar findings were also observed among South African gold miners and Canadian hard rock miners.^{19,20}

For more information on pulmonary problems among quarry workers in Ebonyi State, Nigeri see www.theijoem.com/ijoem/index.php/ijoem/article/view/152



The findings are in contrary to those reported by Rastogi that found the prevalence of chronic bronchitis in agate workers was lower than the control group (2.6% vs 6.7%).¹⁴

Almost 5% of studied workers had either history of asthma in the past or asthma-like symptoms at the time of examination. Although increase in the risk of work-related wheeze and asthma has been reported for workers exposed to silica and other dusts, occupational exposure to silica has so far not been shown as a significant cause of asthma.^{18,21} In our study, the prevalence of asthma in agate workers was lower than that in general population—10% in urban population based on Iranian national survey.²²

Because both exposure to agate dust and getting silicosis present with restrictive pattern, it can be inferred that exposure to agate dust would cause spirometry disorders before radiologic changes. In a study conducted in 2001 in Kermanshah, western Iran, 16.7% of stone millers suffered from obstructive diseases in spirometry (mild to severe).¹⁶ In a study conducted in India, more than half of the agate grinders had pulmonary function abnormalities.¹³

Only 6 (27%) of 22 workers with silicosis were under treatment because of respiratory symptoms. Therefore, we concluded that in agate grinding workers, spirometry findings and clinical symptoms did not match with radiological findings of silicosis and progressed independently. These findings match with previous studies that suggest that loss of pulmonary function can occur with exposure to silica dust and this effect is independent of silicosis.²³

The current study had some limitations. The study design was cross-sectional, that might result in underestimation of disease prevalence due to healthy worker effect. Indeed, because of the vast extension of small workplaces in Mashhad and the domestic nature of these industries, it

was not possible to identify all the workers exposed to agate. A number of agate workers had died because of severe respiratory diseases; some of them were not able to participate in this study for unsuitable health status.

Some of agate industries were in household areas, creating the condition that other residents like women and children being indirectly exposed to the dust. In the current study, possible work-related respiratory diseases of women or children were not evaluated.

In conclusion, we found that workers in agate grinding industries are at increased risk for respiratory diseases, specifically for silicosis and chronic bronchitis. The disease conditions are related to the silica dust exposure, poor ventilation and inappropriate personal protection at the workplace. To alleviate the condition, establishment of methods to eliminate or reduce dust exposure, such as using wet grinding and institution of a properly executed respiratory protection program in agate grinding workshops are recommended. Furthermore, training of workers in potential adverse health effects of silica dust exposure would prevent respiratory diseases in long-term.

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