doi • 10.5578/tt.67990
Tuberk Toraks 2019;67(1):39-46
Geliş Tarihi/Received: 04.02.2019 • Kabul Ediliş Tarihi/Accepted: 18.03.2019

KLİNİK ÇALIŞMA
RESEARCH ARTICLE

Predictive risk factors for development of silicosis in Turkish ceramic workers

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Cite this arcticle as: *Karataş M, Gündüzöz M, Özakıncı OG, Karkurt Ö, Başer N. Predictive risk factors for development of silicosis in Turkish ceramic workers. Tuberk Toraks 2019;67(1):39-46.*

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SUMMARY

Predictive risk factors for development of silicosis in Turkish ceramic workers

Introduction: *Silicosis is still one of the the most common occupational disease in the world. The ceramic industry is one of the main sectors where silicosis patients are increasingly reported. The aim of this study was to evaluate the differences in demographic characteristics, radiological findings and pulmonary function test results of the ceramic workers with silicosis and those did not develop the disease.*

Materials and Methods: *A total of 626 workers, 459 with silicosis and 167 without silicosis, working in the ceramics industry those admitted to Ankara Occupational and Environmental Diseases Hospital between 2009 and 2018 were included in the study. The cases were evaluated retrospectively.*

Results: *The median age and duration of work of the workers with silicosis were significantly higher (p< 0.001) compared to workers without silicosis. The risk of silicosis was found to be 22.5 times higher in 50 years or older age. Working 11-20 years and more than 20 years increased the risk of silicosis by 3.1 fold and 3.9 fold respectively. Smoking more than 10 package-years was*

found to increase the risk of silicosis 2 fold. The workers who had worked in clay processing, sanding, glazing or smelting were found to have 5.2-fold, 3.8-fold 2.5 and 2.4 fold higher silicosis risk, respectively.

Conclusion: *In this study, it has been shown that older age, longer duration of work, smoking, working in clay processing, sanding, glazing or smelting sections increase the risk of silicosis in ceramic workers.*

Key words: *Silicosis; ceramic workers; ILO; lung function*

ÖZET

Türk seramik çalışanlarında silikozis gelişiminde prediktif risk faktörleri

Giriş: *Silikozis halen dünyada en yaygın meslek hastalıklarından biridir. Seramik endüstrisi, silikozis hastalarının giderek daha fazla rapor edildiği ana sektörlerden biridir. Bu çalışmanın amacı, silikozis tanılı seramik çalışanları ile silikozis tanısı olmayan olguların demografik özellikleri, radyolojik bulguları ve solunum fonksiyon testi sonuçları arasındaki farklılıkları değerlendirmektir.*

Materyal ve Metod: *2009-2018 tarihleri arasında Ankara Mesleki ve Çevresel Hastalıklar Hastanesine başvuran ve seramik endüstrisinde çalışan 459'u silikozis tanılı toplam 626 olgu çalışmaya dahil edildi. Olgular retrospektif olarak değerlendirildi.*

Bulgular: *Yaş ve çalışma süresi, beklendiği üzere silikozis grubunda silikozis olmayan gruba göre istatistiksel olarak anlamlı bulundu ($p< 0.001$). Elli yaş ve üzerinde olmanın silikozis riskini 22.5 kat artırdığı tespit edildi. 11-20 yıl arasında çalışmış olmanın silikozis olma riskini 3.1 kat, > 20 yıldan uzun çalışma süresinin silikozis riskini 3.9 kat artırdığı tespit edildi. On paket/yıl'dan daha uzun süre sigara içmiş olmanın silikozis riskini iki kat artırdığı tespit edildi. Çamur hazırlama bölümünün riski 5.2 kat, zımparalama bölümünün riski 3.8 kat, sırlama bölümünün 2.5 kat ve dökümhane bölümünün 2.4 kat artırdığı tespit edildi.*

Sonuç: *Bu çalışmada ileri yaş, uzun çalışma süresi, sigara kullanımı ile fırınlama, zımparalama, çamur hazırlama, kalıp ve kalite bölümlerinde çalışmanın seramik endüstrisi için silikozis gelişiminde riskli olduğu gösterilmiştir.*

Anahtar kelimeler: *Silikozis; seramik işçisi; ILO; akciğer fonksiyonu*

INTRODUCTION

Occupational exposure to silica and related health problems are still one of the most important public health issues in developing countries (1,2). In India, it is estimated that 11.5 million workers have been exposed to silica dust and silicosis and tuberculosis prevalence in these workers is reported to be quite high (3). In China, more than half a million silicosis patients and 24.000 deaths related with silicosis have been reported between the years 1991-1995 (4). Although it is a preventable disease, the relatively high prevalence of silicosis in countries with rapid population growth is associated with high unemployment rates, unregistered employment and lack of sustained close inspection of the workplaces (5). Despite the regulations and strategies for the control of exposure, new silicosis cases continue to emerge due to, partially, exposure to silica from non-traditional sources, newly defined working sectors or well known sectors (1). It is difficult to determine exact rate of silicosis in our country because of the lack of specific surveillance systems. The only data about the prevalence of silicosis is the number of occupational diseases announced by Social Insurance Agency (SIA) annually. The data comprise only the insured workers and consists of those who are entitled to compensation due to occupational disease. In 2016's SIA statistical yearbooks, 118 out of 597 occupational diseases were reported to be silicosis patients (6). Despite the advances in occupational health and safety, silicosis remains to be one of the most common occupational disease in Turkey.

As the employment in coal mining industry has declined recently, cases of silicosis began to be reported from sectors such as sandblasting, stone breaking, construction, mining, cement and glass production. The ceramics industry is also one of the sectors where silicosis cases commonly reported (7). It has been shown that exposure levels for crystalline silica have exceeded and were associated with high exposure levels almost in all ceramic process steps such as raw material preparation, mixing, molding, casting and retouching (8).

The aim of this study was to evaluate the differences in socio demographic characteristics, radiological findings and other effective factors such as smoking duration of work between ceramic workers with silicosis is and those did not develop the disease.

MATERIALS and METHODS

A total of 626 workers, 459 with silicosis and 167 without silicosis (control group), working in the ceramics industry those admitted to Ankara

Occupational and Environmental Diseases Hospital between 2009 and 2017 were included in the study. The present study has been approved by the local ethics committee of Keçiören Educational and Research Hospital, Ankara, Turkey. Demographic characteristics, smoking history, detailed work anamnesis, work characteristics, exposure factors, exposure times and physical examination findings was obtained from our hospital's digital archive system retrospectively and analyzed. A standard spirometer measurement was done with a dry-seal- spirometer (Zan 100, nSpire Health Inc., Oberthulba, Germany) and pulmonary function tests was applied according to the American Thoracic Society (ATS) standards (9). Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), FEV_1/FVC ratio and maximum mid expiratory current (MEF) measurements were recorded.

Posteroanterior (PA) chest X-Rays were taken in the radiology department of our hospital. A short exposure time with high voltage technique was used (Trophy UFXRAY, 500 mA, TM). PA chest X-Rays were evaluated and graded by two certified readers according to the International Labour Organization (ILO)-2000 classification of pneumoconiosis. Radiographic abnormalities of the pneumoconiosis were classified into three profusion categories, regarding the concentration of small opacities in affected zones of the lung. Also 9 subcategories were determined as 1 (1/0; 1/1; 1/2), 2 (2/1, 2/2, 2/3) or 3 (3/2; 3/3; 3/+) according to the ILO classification (10). Patients with profusion categories 1/0 and higher is considered to be silicosis. The shape and size were evaluated by comparing standard radiographs. The predominant shape and size were classified as p, q, r, s, t, u. Large opacities were defined by A, B, C. A GE HISpeed scanner (General Electric Medical Systems, Milwaukee, HI spit NXI, Milwaukee, Wisconsin, USA) was used for the high resolution computed tomography (HRCT). Slices in 1 mm size at 1.5 s intervals which increased by 10 mm, image reconstruction with a 512 × 512 px matrix with the use of a high-resolution algorithm, and 1000 Hounsfield unit (HU) width were used.

We made the statistical analysis of data by SPSS (Version 21.0) (SPSS Inc, Chicago, IL, USA) package program. Coherence to normal distribution analysis was made by using Kolmogorov-Smirnov test. Values were presented as mean ± SD or median (min-max). The presence of a statistically significant difference between the groups in terms of continuous variables was examined with ANOVA for parametric and Kruskal-Wallis test for non-parametric variables. For the significant ($p< 0.05$) analytes, Student's t test for parametric and Mann-Whitney U test for non-parametric variables were performed; Spearman's correlation analysis was also performed.

RESULTS

A total of 626 people working in the ceramic sector were included in the study. After clinical and radiological evaluations, 459 patient whom were 1/0 and over according to ILO classification were diagnosed as silicosis. 167 people were regarded as control group. The demographic characteristics of study group are presented in Table 1.

The median age of the silicosis group and control group were 40 years (23-60) and 36 years (24-59), respectively ($p< 0.001$). The median duration of work of silicosis and control group were 14 years (1-36) and 10 years (1-32), respectively ($p< 0.001$). Age and duration of work were statistically significant between two group. There was a significant difference by means of smoking among silicosis group 10 (0-42) packet-year and control group 8 (0-30) packet-year. Overall silicosis group had more symptoms and dyspnea was statistically significantly higher in this group. The workers had worked in ten different departments and mostly in smelting (31.6%) and glazing (18.7%). The departments where the silicosis patients had worked longer were smelting 15 years (2-36), clay processing 15 years (3-27) and maintenance 15 years (1-15). Significant differences were found between silicosis group and control group by means of duration of work at smelting ($p< 0.001$). 61.3% ($n= 451$) of the workers had worked more than ten years. There was a significant difference between two groups by means of ten years work ($p< 0.001$); 68.9% of the silicosis group and 40.7% of the control group had worked for more than ten years. The comparison of SFT findings between silicosis and control groups is summarized in Table 2. Accordingly, all the values, except for FEV_1/FVC, were found to be statistically significantly lower in silicosis group.

Chest X-Ray findings showed that, all zones were involved in 74.7% of the silicosis patients, while the lesions were located in the upper zone in 25.3% of

Table 1. Characteristics of ceramic workers with and without silicosis

	All workers	With silicosis	Without silicosis	p
Number	626	459	167	
*Age, median (range)	39 (23-60)	40 (23-60)	36 (24-59)	< 0.001
BMI (kg /m^2), mean ± SD	25.6 ± 3.4	25.52 ± 3.45	26.07 ± 3.73	0.402
***Duration of work,** median (range)	12 (1-36)	14 (1-36)	10 (1-32)	< 0.001
0-10 years, n (%)	242 (38.7)	143 (31.2)	99 (59.3)	
11-20 years, n (%)	295 (47.1)	240 (52.3)	55 (32.9)	
> 20 years, n (%)	89 (14.2)	76 (16.6)	13 (7.8)	
Smoking status, n (%)				
*Amount of smoking, pack/year	10 (0-42)	10 (0-42)	8 (0-30)	< 0.001
Never smoked	160 (25.6)	108 (23.5)	52 (31.1)	0.054
Smoker	466 (74.4)	351 (76.5)	115 (68.9)	0.054
Ex-smoker	33 (5.3)	32 (7.0)	1 (0.6)	0.002
Presence of symptoms, n (%)	397 (63.4)	308 (67.1)	89 (53.3)	0.002
Cough	181 (28.9)	139 (30.3)	42 (25.1)	0.212
Sputum	171 (27.3)	132 (28.8)	39 (23.4)	0.183
Dyspnea	285 (45.5)	224 (48.8)	61 (36.5)	0.006
Chest pain	113 (18.1)	85 (18.5)	28 (16.8)	0.614
Wheezing	92 (14.7)	71 (15.5)	21 (12.6)	0.366
Working departments, n (%)				
Glazing	117 (18.7)	92 (78.6)	25 (21.4)	0.153
Firing	29 (4.6)	16 (55.2)	13 (44.8)	0.024
Maintenance	16 (2.6)	11 (68.8)	5 (31.3)	0.675
Sanding	65 (10.4)	55 (84.6)	10 (15.4)	0.03
Smelting	198 (31.6)	153 (77.3)	45 (22.7)	0.129
Clay processing	51 (8.1)	45 (88.2)	6 (11.8)	0.012
Machine operator	22 (3.5)	18 (81.8)	4 (18.2)	0.359
Molding	29 (4.6)	12 (41.4)	17 (58.6)	< 0.001
Quality	50 (8)	28 (56)	22 (44.0)	0.004
Others	49 (7.8)	29 (59.2)	20 (40.8)	0.021

* Data are given as median (minimum-maximum), SD: Standart deviation.

silicosis group. High-resolution CT evaluations revealed that all patients had nodular pattern, (n= 90) 19.6% had bullae or emphysema, (n= 74) 16.1% had interlobular septal thickening. Most of the nodular lesions were bilateral and subpleural. According to the radiographic ILO classification 74.9% (n= 344) of the silicosis patients had profusion category 1 with mostly p/p parenchymal opacity.

Regression analysis (model 1) of risk factors showed that workers over 50 years had 22.5-fold higher risk of silicosis. The duration of work was analyzed in a three ten years period in Table 5. Regardless of any other risk factor, 11-20 years duration of work increased the risk of silicosis by 3.0 fold, while more than 20 years duration of work increased the risk of silicosis by 4.1 fold. Smoking more than 10 package- years increased the risk of silicosis two fold. When the ceramic processes considered the silicosis risk was 5.2-fold higher for clay procession, 3.8-fold higher for sanding, 2.5 fold higher for glazing and 2.4 fold higher for smelting. Multivariate analyses (model 2) revealed that duration of work

Table 2. Results of pulmonary function tests in those with and without silicosis

	With Silicosis (n= 459)	Without Silicosis (n= 167)	p
Pulmonary function tests			
FVC, (L)	4.5 ± 0.8	4.8 ± 0.8	< 0.001
$FVC_{\%}$	97.4 ± 14.5	102.1 ± 13.4	< 0.001
FEV_1, (L)	3.6 ± 0.7	3.9 ± 0.7	< 0.001
*$FEV_{1\ \%}$	97 (33-146)	100 (47-141)	0.003
*FEV_1/FVC	82 (54-99)	82 (54-98)	0.565
*PEF, (L/s)	7.72 (2-14)	8.56 (2-13)	< 0.001
$PEF_{\%}$	84.1 ± 21.3	90.3 ± 19.3	0.001
$MEF_{25-75\%}$, (L/s)	3.7 ± 1.1	3.9 ± 1.2	0.007
$MEF_{25-75\%}$	85.2 ± 25.3	88.2 ± 24.6	0.213
*$MEF_{75\%}$, (L/s)	6.79 (1.35-13.57)	7.74 (1.92-12.43)	< 0.001
*$MEF_{75\%}$	87 (17-193)	96 (26-151)	0.001
$MEF_{50\%}$, (L/s)	4.5 ± 1.4	4.8 ± 1.5	0.024
$MEF_{50\%}$	89.9 ± 28.5	93.7 ± 27.1	0.137
*$MEF_{25\%}$, (L/s)	1.62 (0.35-4.81)	1.67 (0.14-4.06)	0.068
*$MEF_{25\%}$	74 (18-191)	75 (20-189)	0.412
DLCO, (mL/min/mmHg)	11 ± 2.4	12.4 ± 2.4	< 0.001
$DLCO_{\%}$	103.8 ± 20.7	114.1 ± 21.1	< 0.001

* Data are given as median (minimum-maximum).
FEV: Forced expired volume, FVC: Forced vital capacity, PEF: Peak expiratory flow, MEF: Maximal expiratory flow, DLCO: Diffusion capacity of the lung to carbon monoxide, L: Litre; L/s: Litre/second.

Table 3. Evaluation of chest pasteroanterior (PA) graphy according to the ILO classification in silicosis patients (n= 459)

Zone of lung	n (%)
Upper	116 (25.3)
Intermediate	16 (3.5)
Lower	16 (3.5)
Upper-intermediate	4 (0.9)
All zone	343 (74.7)
Large opacity	
A	16 (3.5)
B	7 (1.5)
C	4 (0.9)
Profusion category	
Category 1 (1/0, 1/1, 1/2)	344 (74.9)
Category 2 (2/1, 2/2, 2/3)	83 (18.1)
Category 3 (3/2, 3/3)	32 (7)

ILO: International Labour Organization.

Table 4. High-resolution computed tomography (HRCT) findings in silicosis patients (n= 459)

HRCT findings	n (%)
Ground glass	43 (9.4)
Hilar LAP	19 (4.1)
Mediastinal LAP	38 (8.3)
Peribronchial thickening	4 (0.9)
Air cyst	2 (0.4)
Bullae-emphysema	90 (19.6)
Atelectasis	5 (1.1)
Reticulonodular infiltration	32 (7)
Calcified nodule	25 (5.4)
Linear density increment	12 (2.6)
Interlobular septal thickening	74 (16.1)
Bronchiectasis	35 (7.6)
Category 3 (3/2, 3/3)	32 (7)

LAP: Lymphadenopathy.

Table 5. Multiple logistic regression analysis of risk factors for silicosis

	Model 1			Model 2		
Risk factors	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Age, years						
21-30	Ref.	-	-	-	-	-
31-40	2.3	1.3-4.2	0.005	-	-	-
41-50	6.3	3.3-12.3	< 0.001	-	-	-
> 50	22.5	2.8-180.5	0.003	-	-	-
Duration of work, years						
≤ 10	Ref.	-	-	Ref.	-	-
11-20	3	2.1-4.6	< 0.001	2.9	1.9-4.4	< 0.001
> 20	4.1	2.1-7.7	< 0.001	3.4	1.7-6.8	< 0.001
Working department						
Others	Ref.	-	-	Ref.	-	-
Glazing	2.5	1.2-5.2	0.011	4.2	1.7-10.1	0.002
Firing	0.9	0.3-2.2	0.729	1.8	0.6-5.5	0.281
Maintenance	1.5	0.5-5.0	0.496	2.7	0.7-10.2	0.157
Sanding	3.8	1.6-9.2	0.003	6.3	2.3-17.8	< 0.001
Smelting	2.4	1.2-4.5	0.011	3.8	1.7-8.9	0.002
Clay processing	5.2	1.9-14.4	0.002	8.5	2.7-27.1	< 0.001
Machine operator	3.1	0.9-10.6	0.071	5.4	1.4-21.1	0.015
Molding	0.5	0.2-1.2	0.131	0.7	0.2-2.1	0.532
Quality	0.9	0.4-2.0	0.749	1.6	0.6-4.2	0.348
Smoking						
≤ 10 packet/year	Ref.	-	-	Ref.	-	-
> 10 packet/year	2	1.4-3.0	< 0.001	1.8	1.2-2.7	0.005

Ref: Reference.

over 20 years increased the risk of silicosis by 3.4 fold, smoking more than 10 package- years increased the risk of silicosis by 1.8 fold, working in clay processing increased the risk of silicosis by 8.5 fold when smoking, duration of work and working department analyzed together in Table 5.

DISCUSSION

The results obtained from epidemiological studies show that the rates of silicosis is still high in developing countries although the different radiological screening methods have been used. The workers in ceramics industry face to relatively high risk for silicosis. Our study showed that duration of exposure, as an indicator of cumulative exposure to silica dust, had strongly influenced the development of the disease. Besides, smoking and work department were found to increase the risk of silicosis. Current study is one of the most extensive one performed among ceramic workers with silicosis.

Sun et al. emphasized the effect of age and the duration of exposure on the development of silicosis (11). In this study, it was shown that the risk of silicosis was significantly higher in workers 50 years of age or older and with working duration 10 years or more. The median age and duration of work of patients was found to be 61.5 and 19 years, respectively in a study conducted in the ceramic industry in Taiwan and it was reported that older age and working more than 20 years increased the risk of silicosis 1.07 fold and 2.4 fold, respectively (12). In a Swiss study, the mean duration of work of silicosis patients, including ceramic workers, was found to be more than 40 years. However, it was emphasized that some of the patients were seasonal workers and had not been exposed to

silica intensively (13). The variances of occupational health and safety practices between developed and developing countries should be concerned. The risk of inflammation is higher in workers those exposed to more silica due to longer duration of work and as the exposure lasts pulmonary diseases such as pneumoconiosis and fibrosis might occur (7,14).

It has been reported that smoking increases the rate of silicosis among the patients those exposed to similar amounts of silica (15-18). Smoking has been shown to increase the deposition of foreign particles in lung tissue by disrupting the clearance mechanisms and lead to silicosis (19). In our study the mean of cigarette pack-years was significantly higher in silicosis group compared to control group. The rate of smokers either in silicosis group or in control group (76.5% and 68.9%, respectively), were higher in this study compared to other studies in the literature. The smoking rates were similar to ours in a study of ceramics workers from Turkey, however, the authors did not find significant differences by means of smoking among silicosis group and control group (20).The sum of rates of smokers and ever smokers were approximately 79.7% of the study population in our study. Thus, it is important to consider smoking history as well as silica dust exposure when determining etiology of respiratory diseases. It should be kept in mind that it is important to quit smoking for employees who have exposure stories.

The amount of respirable silica dust varies in different ceramic processes. The department with the highest number of employees in our study was the smelting and working in clay processing, sanding, glazing or smelting seem to increase the risk of silicosis in ceramic workers.

In a study of ceramic workers PFT abnormality was found to be 79% in men and 81%, in women (21). In another study, the silica exposed group had lower FEV_1/FVC compared to unexposed group after controlling for effect of smoking (22). In our study, FVC, FEV_1, PEF, $MEF_{25-75\%}$ and diffusion capacities were significantly lower in the silicosis group compared to the control group. There was no significant difference in FEV_1/FVC value.

Recent studies have found an association between cumulative silica exposure and development of COPD (23). However, it seems not possible to ascertain this relationship in groups where smoking rates are high as in our study.

The most important limitation of our work was its retrospective design and the workplace environment inhalable silica dust measurements could not be achieved due to the fact that the study group were from different factories. Although, a weak marker for cumulative silica exposure, we used duration of work as a measure of exposure. Also the varieties in airborne particle concentrations among departments could not be assessed. Another limitation was that work histories were based on each workers own declarations, which might cause employees to express their symptoms at a lesser degree because of the loss of work.

CONCLUSION

Silicosis is still a major health problem in developing countries with rapid economic growth indicators such as Turkey. Prevention should be the main goal since it has no curative treatment and it causes significant health and labor losses in later years of life. The provision of legal and regulatory inspections is the most important step in ensuring that occupational health and safety practices are included in the primary protection and in their implementation. In this study, it was shown that workers in ceramics industry with older age, longer duration of work, smoking, working in departments such as was clay procession, sanding, glazing and smelting have higher risk of silicosis . For this reason, periodic examinations and early detection of disease and protection of the patient, cessation of smoking and careful application of the personal environment and personal protective measures in certain areas are important.

ACKNOWLEDGEMENTS

We thanks to our hospital staff for helping to collect data about patient.

CONFLICT of INTEREST

The authors reported no conflict of interest related to this article.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: MK, MG, ÖK

Analysis/Interpretation: MK, OGÖ, NB

Data Acquisition: MK, MG, NB

Writting: MK, OGÖ, ÖK

Critical Revision: MK, MG, OGÖ

Final Approval: MK, MG, OGÖ

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