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Clustering in a Small Business. Diagnosis of Pneumoconiosis: Heads or Tails?

Küçük Ölçekli bir İşletmede Kümelenme. Pnömokonyoz Tanısı: Yazı mı Tura mı?

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Abstract

Occupational diseases and accidents are lagging indicators of occupational health and safety (OHS), and clustering in certain areas suggests that OHS policies have failed in this regard. A cluster of pneumoconiosis cases employed at a refractory concrete factory was noted among those admitted to an occupational disease clinic, with 12 of the total 22 blue-collar workers (54.5%) employed by the small-scale enterprise (SSE) being followed up with a diagnosis of pneumoconiosis. The first case in the SSE was detected in 2017 and regular health audits were initiated following workplace inspections. The median exposure time was 8.5 years, with a range of 4–22 years. During follow-up, one-third of the cases progressed (median 3.5 years). To summarize, the probability of a blue-collar worker in the SSE developing pneumoconiosis is greater than the chance of a coin landing on either heads or tails when they first start their job. Workers in developing countries in particular are more prone to problems related to OHS, particularly in SSEs.

Keywords: *Clustering, occupational disease, occupational health and safety, pneumoconiosis, small scale enterprise.*

Öz

Meslek hastalıkları ve iş kazaları, iş sağlığı ve güvenliğinin (İSG) ardıl göstergeleridir. Belli alanlardaki kümelenmeler, İSG politikalarının bu noktalarda başarısız olduğunu göstermektedir. Meslek hastalıkları polikliniğine başvuran pnömokonyoz olguları arasında aynı refrakter beton fabrikasında bir kümelenme tespit edildi. Bu küçük ölçekli işletmede (KÖİ) çalışan toplam 22 mavi yakalı çalışanın 12'si (%54,5) pnömokonyoz tanısıyla takip ediliyordu. Bu KÖİ'de ilk olgu 2017 yılında tespit edilmiş ve iş yeri denetimlerinin ardından düzenli sağlık gözetimi başlatılmıştı. Maruz kalım süresi 4-22 yıl arasında değişmekle birlikte ortalama 8,5 yıldı. İzlemde (ortalama 3,5 yıl) her 3 olgudan 2'sinde progresyon saptandı. Özetle, bu işletmedeki mavi yakalı çalışanların pnömokonyoz olma olasılığı, işe başladıkları gün havaya attıkları paranın yazı ya da tura gelme olasılığından daha yüksekti. Özellikle gelişmekte olan ülkelerde KÖİ'lerde İSG açısından daha ciddi sorunlar yaşanmaktadır.

Anahtar Kelimeler: *Kümelenme, meslek hastalığı, iş sağlığı ve güvenliği, pnömokonyoz, küçük işletme.*

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The majority of the global workforce is employed in small-scale enterprises (SSEs), being companies with fewer than 50 employees. Such enterprises employ an average of 40% of the workforce in industrialized OECD (Organization for Economic Cooperation and Development) countries, and 60% in developing countries (1). For various reasons, however, these businesses often face significant challenges in the assurance of occupational health. Although the hazards present in smaller workplace environments are similar to those in larger businesses, the risk of exposure is often significantly higher in SSEs (1,2). Various studies have reported a greater frequency of occupational disease in SSEs (3). Occupational diseases serve as lagging indicators of occupational health and safety (OHS), highlighting a need for comprehensive retrospective analyses. This case series presented here examines the clustering of pneumoconiosis cases within a single SSE.

CASES

This report delineates the characteristics of 12 pneumoconiosis cases, all of whom were employed in the same refractory concrete factory. After obtaining informed consent from the patients for their inclusion in the study, their current and past working conditions were meticulously detailed during their admission, and an in-depth retrospective review of their clinical follow-ups was carried out based on hospital records. Approval for the study was obtained from the Necmettin Erbakan University Non-Pharmaceutical and Non-Medical-Device Research Ethics Committee (No:2023/4406). Chest X-ray assessments were conducted according to the guidelines published by the International Labor Organization (ILO) International Classification of Radiographs of Pneumoconiosis (2022), by a certified specialist. High-resolution computed tomography (HRCT) images of the cases were retrieved from the hospital's radiology archive, and progression was categorized based on the reports of experienced radiologists. Pulmonary function tests (PFT) and carbon monoxide diffusion capacity (DLCO) measurements were performed in our facility using a ZAN 100 spirometer device (Oberthulba, Germany) and following the current guidelines (4). Descriptive statistics of the cases were presented, ratios were compared with Pearson's Chi-square and Fisher's exact tests, and a Mann-Whitney-U test was used to compare the means of the two groups. A significance level of $p<0.05$ was defined.

Workplace Features

According to patient statements, 34 people are employed by the SSE, including 12 administrative staff, eight maintenance and repair workers (MRWs), and 14 manufacturing workers (MWs). The company makes use of such raw materials as quartz, magnesite and bauxite in the production of heat-resistant bricks and concrete, known also as fire bricks. The production facility is equipped with crushers, sieves, mills and filling-packaging machinery, and all associated tasks are performed by the MWs on a rotational basis. Dust control was not managed through wet work. The MWs spend the entire working day (8 hours/day) in the production area, while the MRWs spend only a portion of the working day (4–5 hours/day) in this area while engaged in repair and assembly work, while the rest of the day (3–4 hours/day) is spent in the mechanical maintenance workshop performing metal cutting, assembly and welding works. It was noted that in 2017, after the identification of the first case of silicosis in the workplace (case no.12), the health monitoring of all employees was initiated, and OHS services were procured from a private joint health and safety center, and 11 further cases of pneumoconiosis were subsequently identified. It was understood that following the workplace inspections, local exhaust ventilation systems were established at several points in the facility and dust masks were provided to the employees.

Of the 22 blue-collar workers in the plant, 12 were diagnosed with pneumoconiosis and were under follow-up. The mean age of the pneumoconiosis cases was 46.5 (±6.69), the mean age at diagnosis was 42.75 (±7.03), and the median exposure time (period from employment to diagnosis) was 8.5 (4–22) years. One-quarter of the cases had no respiratory complaints, and breathing sounds were normal on physical examination in two-thirds of the cases. The affected workers included eight MWs and four MRWs (Table 1).

During the median follow-up period of 3.5 years (2–6) post-diagnosis, radiological progression was observed in eight (66.7%) of the cases, seven of whom were MWs. Large opacities were observed in three cases and Ax opacity in one case. Follow-up HRCT images of some of the pneumoconiosis cases are presented in Figure 1. A file containing HRCT imaging of all cases over time is presented as supplementary material (Figure 3).

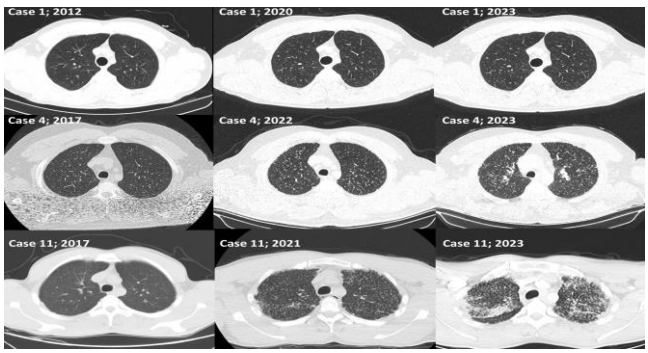

Figure 1: *HRCT images of some pneumoconiosis cases in the follow-up*

Table 1: Characteristics of the pneumoconiosis cases

Case no	Age, sex	Comorbidite	Smoking history	Task	Dust/smoke exposure at previous job history	Exposure time before diagnosis	Respiratory symptom	Physical examination	Any change in job/task status
1	44, male	Yes, Hypertension	Ex-smoker, 20 pack years	MW	Never	4 years	Exertional dyspnea	Rhonchi	Had changed as gardener, 2014
2	58, male	Yes, Hypertension	No	MW	Never	11 years	None	Normal	Had changed as administrative staff, 1994
4	48, male	No	Ex-smoker, 14 pack years	MRW	Yes; 19 years, welding fume	12 years	Exertional dyspnea	Normal	No change
5	46, male	Yes, lumbar discopathy	Ex-smoker, 1 pack years	MW	Yes; 6 years, brick manufacturing	8 years	Exertional dyspnea	Normal	No change
6	49, male	No	Ex-smoker, 20 pack years	MRW	Yes; 12 years, welding fume	12 years	Exertional dyspnea	Normal	No change
7	52, male	No	Smoker, 15 pack years	MRW	Yes; 5 years, welding fume	10 years	Exertional dyspnea and wheeze	Normal	No change
8	39, male	Yes, sacroiliitis	Smoker, 20 pack years	MW	Never	4 years	None	Normal	No change
9	33, male	Yes, celiac	No	MW	Never	6 years	Exertional dyspnea	Normal	No change
10	51, male	No	Smoker, 28 pack years	MRW	Never	22 years	None	Normal	No change
11	50, male	Yes, Hypertension and diabetes	Ex-smoker, 20 pack years	MW	Yes; 20 years, brick manufacturing	8 years	Exertional dyspnea	Rhonchi	Retired, 2023
12	40, male	Yes, Asthma	Ex-smoker, 15 pack years	MW	Never	9 years	Exertional dyspnea, wheeze and cough	Rhonchi	No change

Note: Age, smoking exposure, symptoms and physical examination findings are the data of current (2023) applications.
MW: manufacturing worker; MRW: maintenance and repair worker

Table 2: Radiologic and functional examinations of the pneumoconiosis cases

Case no	Follow-up time after diagnosis	Radiological findings			Current pulmonary functional evaluation				
		ILO radiology at diagnosis	ILO radiology currently	HRCT follow-up findings	FEV1 % predicted	FVC % predicted	FEV1/FVC ratio	DLCO	DLCO/VA
1	5 years	p/p 1/0	p/p 1/2	Progression	53	60	73.2	68	121
2	4 years	p/p 1/2	p/p 1/2	Stable	88	82	85.6	98	128
4	2 years	p/p 1/1	p/p 1/1	Stable	109	103	85.0	113	108
5	6 years	q/p 2/2	r/q 3/2, B	Progression	63	74	69.5	85	128
6	3 years	p/s 1/0	p/q 2/1	Progression	94	100	77.4	-	-
7	2 years	p/s 1/2	p/p 1/2	Stable	83	91	73.2	124	127
8	5 years	p/s 1/0	p/p 2/1	Progression	104	101	85.6	86	112
9	3 years	p/s 1/0	q/q 2/3, Ax	Progression	100	103	81.7	128	109
10	2 years	p/p 0/1	p/p 0/1	Stable	85	100	69.6	-	-
11	4 years	p/q 1/1	q/q 3/2	Progression	87	89	80.1	-	-
12	3 years	p/q 1/1	q/q 3/3, B	Progression	67	86	65.4	-	-

FEV1: Forced expiratory volume in the first second. FVC: Forced vital capacity; DLCO: Diffusing capacity of the lung for carbon monoxide (% of predicted); DLCO/VA: Diffusing capacity per litre alveolar volume (% of predicted)

After the cessation of exposure of three MWs, two (66.7%) showed progression, while the other five MWs (100%) whose exposure continued demonstrated progression (p=0.37). Case 10 was included in the group with continued exposure as he had just retired. Conversely, all MRWs had continued exposure, and progression was observed in one (25%) (Table 2). The exposure time was significantly shorter in MWs than in MRWs (p=0.010, means 7.25 years ±2.43 and 14 years ±5.42, respectively) (Table 3).

Table 3: Comparison of the features of pneumoconiosis cases according to tasks

	Total N=12 (100 %)	MWs N=8 (66.7 %)	MRWs N=4 (33.3 %)	p value
HRCT follow-up findings				
• Progression	8 (66.7)	7 (87.5)	1 (25.0)	0.067
• Stable	4 (33.3)	1 (12.5)	3 (75.0)	
ILO opacity at diagnosis				
• < 1.5 mm (p or s)	8 (66.7)	4 (50.0)	4 (100.0)	0.208
• > 1.5 mm (q,r,t,u)	4 (33.3)	4 (50.0)	0 (0.0)	
ILO profusion at diagnosis				
• Category 1	10 (83.3)	6 (75.0)	4 (100.0)	0.325
• Category 2	1 (8.3)	1 (12.5)	0 (0.0)	
• Category 3	1 (8.3)	1 (12.5)	0 (0.0)	
ILO opacity currently				
• < 1.5 mm (p or s)	6 (50.0)	3 (37.5)	3 (75.0)	0.545
• > 1.5 mm (q,r,t,u)	6 (50.0)	5 (62.5)	1 (25.0)	
ILO large opacity currently				
• No	9 (75.0)	5 (62.5)	4 (100.0)	0.491
• Yes	3 (25.0)	3 (37.5)	0 (0.0)	
ILO profusion currently				
• Category 1	5 (41.7)	2 (25.0)	3 (75.0)	0.070
• Category 2	3 (25.0)	2 (25.0)	1 (25.0)	
• Category 3	4 (33.3)	4 (50.0)	0 (0.0)	
Age of diagnosis of pneumoconiosis¥	44 (30-54)	39.5 (30-54)	47.5 (46-50)	0.060
Exposure time before diagnosis (years)¥	8.50 (4-22)	8 (4-11)	12 (10-22)	0.010
Cigarette exposure (pack/year)¥	14.5 (0-28)	7.5 (0-20)	17.5 (14-28)	0.141
Pulmonary functional assessment¥				
• FEV1 % [a]	87 (53-109)	87 (53- 104)	89.5 (83-109)	0.450
• FVC % [a]	91 (60-103)	86 (60-103)	100 (91-103)	0.154
• FEV1/FVC[a]	77.4 (65.4- 85.6)	80.1 (65.4-85.6)	75.3 (69.6-85)	0.776
• DLCO % [b]	98 (68-128)	86 (68-128)	118.5 (113-124)	0.245
• DLCO/VA % [b]	121 (108-128)	121 (109-128)	117.5 (108-127)	0.434

¥The median and min-max values of the variables are presented in the table

[a] Values of 11 cases with current PFT are included

[b] Values of 7 cases with current diffusion test are included

***MWs:** manufacturing workers; **MRWs:** maintenance and repair workers; **FEV1:** Forced expiratory volume in the first second; **FVC:** Forced vital capacity. **DLCO:** Diffusing capacity of the lung for carbon monoxide; **DLCO/VA:** Diffusing capacity per litre alveolar volume*

All cases applied to the social insurance institution, and four (case no 4,8,10,11) were granted permanent partial disability compensation. Case 12 had retired after being granted permanent total disability, and had recurrent hospitalizations with a diagnosis of pneumothorax, and is currently under follow-up at the lung transplant center to which he was referred. Long-term chest X-ray images of Case 12 are presented in Figure 2.

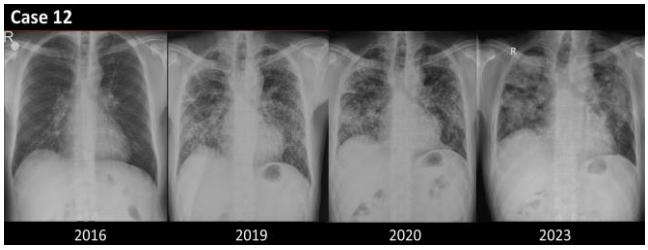

***Figure 2:** Chest x-ray images of Case 12. Rapid progression is observed over approximately seven years*

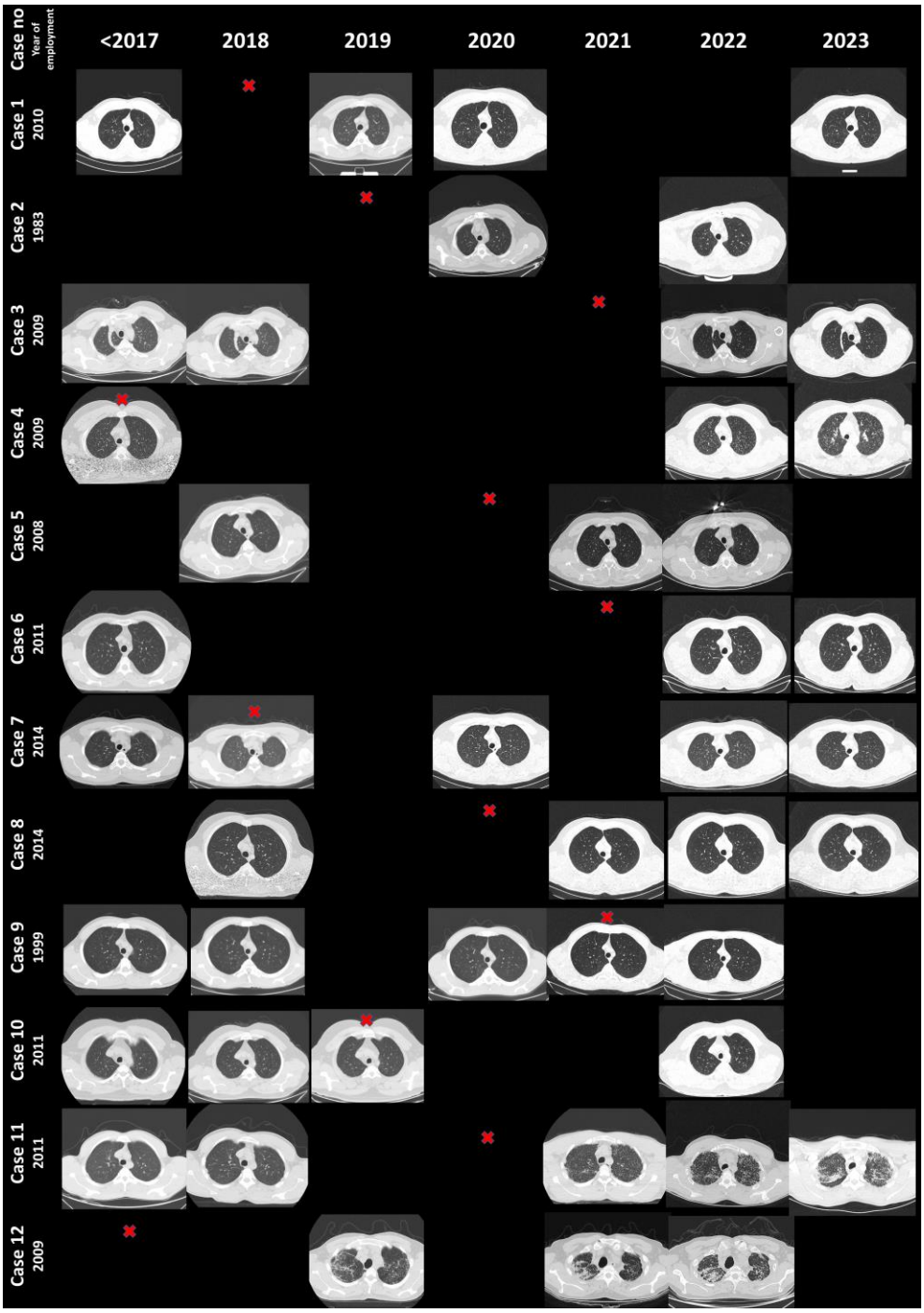

Figure 3: HRCT images of pneumoconiosis cases in the follow-up x = Years of the diagnosis. Note: Due to the problem in the archive system, some external center radiology examinations could not be reached

DISCUSSION

This case series tells a real-life story of how the health of workers in a small business could not be protected, with more than half of the blue-collar workers in this small business being diagnosed with pneumoconiosis. The maintenance of OHS in SSEs can be challenging due to the limited human, financial and technological resources (1,2), and the need to enhance the knowledge and skills of employers, who play a key role in OHS, has been frequently emphasized. In a qualitative study, an inspector was reported to state that owner-managers in SSEs have only limited awareness of the risks associated with their business, citing the frequently used phrase, "As long as nothing happens, it's all good" (5).

The risk of pneumoconiosis in the refractory brick production sector is well known, for example, Vien et al. reported a prevalence of 10% in a medium-sized enterprise (6). Silicosis can rapidly develop due to the increased oxidative stress, and pro-inflammatory and pro-fibrotic response associated especially with the inhalation of high-density freshly crushed silica (7). Gravimetric dust measurements have shown that respirable dust concentrations

increase intensively especially in such processes as quartz crushing, chopping/mixing and weighing/filling operations (6,8). The exposure intensities of the MWs were similar in the present study, as all these processes took place in the same production area, and all tasks were done on a rotational basis. It was observed that pneumoconiosis developed and progressed much faster in MWs than in MRWs, who spent only half of the working day in the dusty production department. It clarifies the dose-response relationship. Undesirable consequences can develop more rapidly with increased frequency or intensity of exposure (6).

The other substances to which MRWs are exposed, such as metal dust and welding fumes, should not be overlooked in this generalization. In welder's pneumoconiosis, which has a reported prevalence of 0.8–8% (9,10), no progressive massive fibrosis develops, and regression is experienced by almost one-third of the cases after the cessation of exposure (10,11). That said, the MRWs in the present study were also exposed to silica, which has proven fibrogenic effects (7), in addition to welding fumes, and their exposure did not cease, leading to progression in one of the four MRWs, while the findings were stable in the other three.

In the follow-up of the MWs, progression was observed in all five (100%) of the cases with continued exposure, and in two of the three (66.7%) whose exposure was terminated. Similarly, León-Jiménez et al. (12) reported progression in 56% of 106 silicosis patients at a mean follow-up of 4.01±2.1 years after exposure cessation, while Kimura et al. (13) described progression in 207 retired coal miners with pneumoconiosis, specifically 62% in the first decade and 29% in the second decade.

Most cases in the study recorded normal physical examination and PFT results, with functional abnormalities observed in four cases (cases 9 and 11=obstructive; case 1=restrictive; case 4=mixed). Early-stage pneumoconiosis may present with no PFT abnormalities, while obstructive, restrictive or mixed abnormalities may develop as the disease progresses. Smoking history, a common confounder, is also significant alongside workplace exposure (14).

The prevention and early exposure termination is crucial due to the lack of effective treatment for pneumoconiosis (13). Despite the launch of health audits in this SSE in 2017, exposure could not be prevented, and employees continued to work under almost the same conditions, even after new cases of pneumoconiosis were identified and the significant progression of previous cases. Health audits without preventative actions are meaningless, and the owner's actions, such as the provision of dust masks and local ventilation, were insufficient for effective dust control. The environmental monitoring of workplaces is a dynamic process requiring ongoing risk assessments and improvements (15). Apart from two retired employees, none of the workers have resigned from the company.

The lack of national policies regarding employment protection and occupational rehabilitation may have led workers diagnosed with pneumoconiosis to continue working as an alternative to unemployment.

The present study reports on the follow-up of a pneumoconiosis cluster with similar exposures due to their employment in the same workplace. Although statistical significance could not be determined between the task groups other than in the exposure time due to the limited number of cases, differences in the subgroups were well-defined. The exposure times in this workplace were the only ones included in the analyses, as five cases with defined dust/fume exposure in previous jobs lacked pre-employment medical records, which is a limitation that should be considered.

CONCLUSION

Difficulties are experienced related to the monitoring of health in SSEs. Further studies of this subject are required, especially in developing countries, due to their potential contribution to the development of primary and secondary prevention and rehabilitation policies.

CONFLICTS OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

Concept - M.D.A.; Planning and Design - M.D.A.; Supervision - M.D.A.; Funding - M.D.A.; Materials - M.D.A.; Data Collection and/or Processing - M.D.A.; Analysis and/or Interpretation - M.D.A.; Literature Review - M.D.A.; Writing - M.D.A.; Critical Review - M.D.A.

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