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COAL WORKERS' PNEUMOCONIOSIS: A COMPARATIVE ANALYSIS OF LIGNITE AND HARD COAL MINE WORKERS

Kömür İşçisi Pnömokonyozu: Linyit ve taşkömürü madeni işçilerinin karşılaştırılmalı analizi

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Abstract

Physical and chemical properties of coal and its relationship with coal workers' pneumoconiosis (CWP) have been studied previously. However definitive conclusions have not been reached, primarily due to the complex nature of coal mine dust. It remains unclear exactly which properties of coal mine dust related to the grade of coal cause differences in the exposure–response relationship. The aim of the study is to identify the coal mine environmental factors, and personal factors affecting the severity of CWP. This study was a retrospective cross-sectional study and included total of 116 coal mine workers diagnosed as CWP in a tertiary hospital between January 1, 2014, and December 31, 2021. Of the cases, 77 (66.4%) worked in a hard coal mine and 39 (33.6%) worked in a lignite mine, and mean age was 60.2 ± 11.5 years. There was a significantly higher prevalence of concomitant pulmonary disease in hard coal mine workers compared to lignite mine workers (p= 0.005). In addition, the prevalence of progressive massive fibrosis (PMF) was higher in hard coal mine workers compared to lignite mine workers, and a statistically significant difference was found (p= 0.004). The value of FEV1 and FEV1/FVC were significantly lower in hard coal mine workers than in lignite mine workers (p= 0.005, p= 0.002). As a conclusion, concomitant lung disease, presence of PMF and impairment in lung functions, which are important causes of mortality and morbidity for CWP, were found to be more common in hard coal mine workers than in lignite mine workers. Therefore, taking into account the type of coal mine while making protective arrangements to prevent pneumoconiosis in coal mines may contribute to reduce the burden of CWP.

Keywords: Pneumoconiosis, coal workers' pneumoconiosis, hard coal mine, lignite mine.

Özet

Kömürün fiziksel ve kimyasal özellikleri ile kömür işçisi pnömokonyozu (KİP) gelişimi arasındaki ilişki daha önce incelenmiştir. Ancak, özelikle kömür madeni tozunun karmaşık yapısı nedeniyle kesin sonuçlara ulaşılamamıştır. Kömürün derecesi ile ilgili olarak kömür madeni tozunun hangi özelliklerinin doz-cevap ilişkisinde farklılıklara neden olduğuna dair bilgi halen belirsizliğini korumaktadır. Bu çalışmada KİP ağırlığını etkileyen, kömür madeni ortam özelliklerini ve kişisel faktörleri belirlemek amaçlanmıştır. Çalışma retrospektif kesitsel bir çalışma olup 1 Ocak 2014 ile 31 Aralık 2021 tarihleri arasında üçüncü basamak bir sağlık kuruluşunda KİP tanısı alan toplam 116 kömür madeni işçisi çalışmaya dahil edilmiştir. Olguların 77'si (%66,4) taşkömürü madeninde, 39'u (%33,6) linyit madeninde çalışmakta olup yaş ortalaması 60.2 ± 11.5 idi. Taşkömürü madeni işçilerinde linyit madeni işçilerine kıyasla eşlik eden akciğer hastalığı önemli ölçüde daha yüksek saptandı (p= 0.005). Taşkömürü madeni işçilerinde linyit madeni işçilerine kıyasla progresif masif fibrozis (PMF) prevelansı yüksek olup istatistiksel olarak anlamlı fark saptandı (p= 0.004). FEV1 ve FEV1/FVC değerleri taşkömürü madeni işçilerinde linyit madeni işçilerine göre daha düşüktü (p= 0.005, p= 0.002). Sonuç olarak KİP için önemli mortalite ve morbidite nedenlerinden olan, eşlik eden akciğer hastalığı, PMF varlığı ve akciğer fonksiyonlarında bozukluk taşkömürü madeni işçilerinde linyit madeni işçilerine göre daha fazla saptanmıştır. Bu nedenle, kömür madenlerinde pnömokonyozu önlemeye yönelik koruyucu düzenlemeler yapılırken, kömür madeni türünin de dikkate alınması, KİP yükünün azaltılmasına katkı sağlayabilir.

Anahtar kelimeler: Pnömokonyoz, kömür işçisi pnömokonyozu, taşkömürü madeni, linyit madeni.

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Introduction

Coal workers' pneumoconiosis (CWP), a reticulonodular interstitial lung disease that can lead to progressive massive fibrosis (PMF), is the most common occupational disease associated with coal mining(1-3). Unfortunately, it still accounts for a significant portion of the burden of occupational diseases in developing countries (4-6). In addition to CWP, the risk of chronic bronchitis, chronic obstructive pulmonary disease (COPD), lung cancer, and gastric carcinoma is increased in those exposed to coal mine dust (7, 8).

Many substances exist in the atmosphere of the coal mine, including silica; silicates such as mica and kaolin; trace elements such as nickel, cadmium, iron, and zinc; diesel exhaust particles; and bioaerosols released from water sprays that prevent dusting. The particles in the coal mine are collectively referred to as coal mine dust (9). CWP, which continues to be a significant occupational disease in Turkey that develops after coal mine dust exposure, is an important respiratory system disease.

Types of coal differ in both their formation time and the amount of carbon in their composition. From the highest to lowest geological age and calorific value, they are classified as anthracite or hard coal, bituminous or oily coal, subbituminous or lignite, and peat (1). As the carbon content of coal decreases with decreasing geological age, the quantity of volatile matter and moisture it contains increases and its calorific value decreases. Coal types with higher calorific value—that is, more combustion capacity—are thought to carry a higher risk of causing CWP because they contain the most surface free radicals (10).

Many studies have been conducted on the properties of coal and its relationship with CWP. Although evidence suggests that both the physical and chemical properties of coal contribute to the development of CWP, definitive conclusions have not been reached, primarily due to the complex nature of coal mine dust, which comprises not only carbon but also other mineral dust produced in the coal bed or the surrounding rock layers. It remains unclear exactly which properties of coal mine dust related to the grade of coal cause differences in the exposure–response relationship (11). In Turkey, no studies have conducted an in-depth evaluation of the development of CWP, coal mine environmental factors, and personal factors. Thus, in this study, we evaluated the clinical findings and occupational characteristics of patients diagnosed with CWP in Occupational Disease Clinic of Ankara Atatürk Sanatorium Training and Research Hospital which is an important pneumoconiosis referral center in Turkey.

Material and Method

This study was a retrospective cross-sectional study, and the population consisted of patients diagnosed with CWP at the Occupational Disease Clinic of Ankara Atatürk Sanatorium Training and Research Hospital between January 1, 2014, and December 31, 2021. The study began after approval was granted by the ethics committee (2012-KAEK-15/2479). The diagnosis of CWP was made by a history of working in a coal mine, radiological findings compatible with pneumoconiosis, and exclusion of other diagnoses. The medical history, pulmonary function test (PFT), and chest X-ray (CXR) results obtained at the time of diagnosis were reviewed by an experienced occupational diseases specialist and used in the analysis. Cases characterized by the presence of round and/or linear opacities less than 1 cm in diameter were classified as simple CWP, and cases with opacities larger than 1 cm in diameter were classified as PMF.

The medical history included the

descriptive characteristics of the participants, past disease information, smoking status, clinical information regarding the current disease, and detailed occupational history including the type of mine and duration of time spent working in the mine. Dust exposure duration was determined as the time period in which miners declared that they have worked in the underground coal mine. Concomitant lung diseases such as chronic obstructive pulmonary disease (COPD), pulmonary tuberculosis and asthma were recorded according to the miners' self-report and confirmed with diagnostic tests at the time of hospital admission. PFTs consisted of forced vital capacity (FVC) percentage, forced expiratory volume in the first second (FEV1) percentage, and FEV1/FVC ratio. The CXRs were reported independently by two readers and classified according to the International Labour Organization (ILO) international classification of radiographs of pneumoconiosis. Small opacities were defined by their profusion, shape, and size. The small opacity profusion was classified into four categories and 12 subcategories based on the evaluation of the standard radiographs. An ILO profusion category of 1/0 and above was considered pneumoconiosis. Small round opacity sizes were indicated with the letters p (0–1.5 mm), q (1.5–3 mm), and r (3–10 mm), and small irregular opacity sizes were indicated with the letters s (0–1.5 mm), t (1.5–3 mm), and u (3–10 mm). PMF was diagnosed for all large parenchymal opacities exceeding 10 mm in long diameter and classified as category A for one large opacity with an elongated diameter of between 10 and 50 mm or several large opacities with a sum of their long dimensions not exceeding 50 mm, category B for one or more opacities with a diameter greater than 50 mm but not exceeding the upper right zone, and category C for one or more opacities with a diameter exceeding the right upper zone equivalent.

Statistics

The obtained data were analyzed in the IBM SPSS Statistics 22.0 program. Categorical data are presented as number (n) and percentage (%), and numerical data are presented as mean and standard deviation. The conformity of the data to the normal distribution was evaluated with the Kolmogorov–Smirnov test. Mann–Whitney U test was used to examine the differences between PFTs, age, exposure duration, and smoking in pneumoconiosis cases working in hard coal and lignite mines. Chi-square and Fisher exact tests were used to compare radiological findings and other categorical data. A p value less than 0.05 was considered statistically significant.

Results

Descriptive Characteristics

A total of 116 CWP cases were included in the study. All of the cases were male, and the mean age was 60.2 ± 11.5 years. The mean dust exposure duration was 20.4 ± 6.7 years. Across the sample, 51 (44%) patients were smokers, 38 (32.7%) patients were ex-smokers, and 27 (23.3%) patients were never-smokers. The mean cigarette smoking exposure was 26.3 ± 17.2 pack-years. Concomitant pulmonary disease was detected in 57 (49.1%) cases. Of the cases, 77 (66.4%) worked in a hard coal mine and 39 (33.6%) worked in a lignite mine. There was a significantly higher prevalence of concomitant pulmonary disease in hard coal miners compared to lignite miners (p= 0.005). The demographic data of the cases working in hard coal and lignite mines are presented comparatively in Table 1.

Radiological Findings

When the radiological findings were evaluated, the dominant small opacity was q in 45 (38.8%) cases, p in 21 (18.1%) cases, t in 19 (16.4%) cases, r in 17 (14.7%) cases, and s in 14 (12.1%) cases. No cases had a predominant small opacity of u. When small opacities were evaluated by size, more than half of the cases (55.2%) were found to have an opacity between 1.5 mm and 3 mm in diameter. When the small opacity profusion scores of the cases were evaluated, category 2 was found in 66 (56.9%) cases, category 1 was found in 39 (33.6%) cases, and category 3 was found in 11 (9.5%) cases. PMF was present in 45 (38.8%) cases, and of these, 25 (55.6%) were classified as category A, 16 (35.6%) were classified as category B, and 4 (8.9%) were classified as category C. There was a significantly higher prevalence of PMF in hard coal miners compared to lignite miners (p= 0.004). The comparison of radiological findings of the CWP cases working in hard coal and lignite mines is shown in Table 2.

PFT Findings

When the PFT findings of the cases were examined, the mean FEV1 was 73.5% ± 21.4%, mean FVC was 76.1% ± 19.9%, and FEV1/FVC was 74.7%. The value of FEV1 and FEV1/FVC were significantly lower in hard coal mine workers than in lignite mine workers (p= 0.005, p= 0.002). The comparison of PFT findings between the two groups is presented in Table 3.

Table 1: Comparison of descriptive characteristics of CWP cases working in hard coal and lignite mines.

	Hard Coal Mine Workers (mean±sd)	Lignite Mine Workers (mean±sd)	p
Age (years)	61.8 (±9.6)	57.0 (±14.1)	0.063#
Dust Exposure Duration (years)	21.6 (±5.6)	18.1 (±8.0)	**0.015#**
Smoking (pack-years)	27.7 (±18.5)	23.2 (±13.4)	0.440#
Smoking Status*			
Never-smoker	16 (%20.8)	11 (%28.2)	
Smoker	31 (%40.3)	20 (%51.3)	0.134‡
Ex-smoker	30 (%39.0)	8 (%20.5)	
Concomitant Pulmonary Disease*	45 (%58.4)	12 (%30.8)	**0.005‡**

** Presented as number (percentage), ‡ chi-square test, #Mann-Whitney U Test*

Table 2: Comparison of radiological findings of CWP cases working in hard coal and lignite mines.

	Hard Coal Mine Workers n (%)	Lignite Mine Workers n (%)	p
Small Opacity by Size			
<1,5 mm	18 (%23.4)	17 (%43.6)	
1,5-3 mm	47 (%61.0)	17 (%43.6)	0.079#
>3 mm	12 (%15.6)	5 (%12.8)	
Dominant Small Opacity			
p	8 (%10.4)	13 (%33.3)	
q	30 (%39.0)	15 (%38.5)	
r	12 (%15.6)	5 (%12.8)	**0.015***
s	10 (%13.0)	4 (%10.3)	
t	17 (%22.1)	2 (%5.1)	
u	0 (%0.0)	0 (%0.0)	

Small Opacity Profusion Score			
Category 1	22 (%28.6)	17 (%43.6)	
Category 2	46 (%59.7)	20 (%51.3)	0.198#
Category 3	9 (%11.7)	2 (%5.1)	
PMF			
Non-exists	40 (%51.9)	31 (%79.5)	**0,004#**
Exists	37 (%48.1)	8 (%20.5)	
PMF by size			
A	20 (%54.1)	5 (%62.5)	
B	14 (%37.8)	2 (%25.0)	0.766*
C	3 (%8.1)	1 (%12.5)	

**Fisher-Exact Test, #chi-square test*

Table 3: Comparison of PFT findings of CWP cases working in hard coal and lignite mines.

	Hard Coal Mine Workers (mean±sd)	Lignite Mine Workers (mean±sd)	p
Small Opacity by Size			
FEV1 (%)	69.59 ± 21.28	81.43 ± 19.61	**0.005***
FVC (%)	73.68 ± 20.06	80.95 ± 18.99	0.066*
FEV1/FVC (%)	72.19 ± 13.23	79.78 ± 9.43	**0.002***

**Mann-Whitney U test*

Discussion

As the quality, hardness, and carbon content of coal increase, it is thought that its particle surface area, electrostatic properties, free radical and silica content, and therefore fibrogenicity also increase. However, differences in the pneumoconiosis characteristics and severity in miners who have worked in mines with distinct coal types are unknown. Therefore, in this study, the relationship between coal mine type and the factors affecting the severity of CWP was evaluated for the first time in Turkey by comparing miners with pneumoconiosis working in lignite mines with those working in hard coal mines. The most important finding of this study was that the presence of PMF alongside a diagnosis of CWP was higher in hard coal mine workers than in lignite mine workers. The second important finding was that FEV1 and FEV1/FVC were lower in hard coal mine workers with a diagnosis of CWP than in lignite mine workers with a diagnosis of CWP. In addition, pulmonary diseases, such as COPD, pulmonary tuberculosis, and asthma, which are important causes of mortality and morbidity in pneumoconiosis patients, were detected more frequently in hard coal mine workers than in lignite mine workers.

Coal types vary widely in their charring process, moisture content, ash and volatile matter content, fixed carbon content, and sulfur and mineral substance content, as well as in their geological, physical, chemical, and thermal properties (1). In 1957, a general classification was developed by the International Coal Board, which was supported by the International Standards Organization. In this classification, coals are divided into two classes—hard (hard coal) and brown (subbituminous and lignite) coals—according to their calorific value, volatile matter content, fixed carbon content, and coking properties. Hard coal has a high heat value due to its high carbon content and carries more free radicals on its surface compared to lignite coal, which indicates more cytotoxicity and pathogenicity (12). In addition, there is a higher percentage of crystalline silica in hard coal. Hard coal reserves in Turkey are found in Zonguldak (Kozlu, Üzülmez, Karadon, Armutçuk) and Amasra. Lignite is classified as a brown coal, a coal type with a low heat value due to its low carbon content and high volatile matter and moisture content. Lignite is a mineral mined throughout the Turkey; it is extracted primarily in the provinces of Ankara, Manisa, Çanakkale, Kahramanmaraş, Kütahya, and Muğla (13). This study was carried out in one of the important referral center for pneumoconiosis patients in Turkey, where patients can apply for treatment both personally and by referral because it is in close proximity to many coal mining centers.

Studies have shown that the severity and risk of CWP development are related to the quantity of inhaled dust and the rank of coal (11, 14, 15). The electrical properties that change in relation to the rank of coal, the relationship between exposure and effect, and the increased incidence of CWP in regions with high coal ranks have been found to be statistically significant (16-18). High-rank coals have a high electrostatic charge during disintegration. High electrical load also causes an increase in the respiratory deposition of the dust and the toxicity of the respirable dust (19). In addition, studies have shown a significant positive correlation between high-rank coal fracturing and the concentration of respirable dust particles in the air (20, 21). These studies conclusively demonstrated that the rates of total dust and respirable dust formation during both the crushing and grinding processes increase with increasing coal rank. In studies investigating the risk of PMF in coal mine workers, it has been reported that PMF increases in direct proportion to age, dust exposure duration, and the coal's carbon content. In this study, similar to the findings in the literature, it was found that PMF, which is an indicator of CWP severity, was more common in patients who worked in a high-rank hard coal mine compared to patients who worked in a lignite mine.

In coal mine workers, there is a decrease in PFTs in direct proportion to their cumulative dust exposure, regardless of the presence of pneumoconiosis. In a 38-year prospective longitudinal study, the risk of an approximately 1-liter reduction in FEV1 when the dust concentration was 0 mg/m^3 was 10% in non-smoking miners and 25% in smokers. When the mean dust concentration increased to 6 mg/m^3, the risk of a decrease in FEV1 rose to 19% in non-smokers and 45% in smokers (22). A recent study by Prasad et al. found that annual FVC loss was approximately 5 times higher and FEV1 loss was approximately 4 times higher in workers with coal dust exposure compared to workers without dust exposure. In addition, a negative correlation between exposure time and respiratory function has been reported (23). However, previous studies have not evaluated the relationship between coal mine type and respiratory function. In this study, FEV1 and FEV1/FVC were found to be significantly lower in hard coal mine workers than in lignite mine workers. Considering that the average working time of hard coal mine workers is longer than that of lignite mine workers, findings support the negative correlation between exposure time and respiratory function reported in previous studies. In addition, as emphasized in numerous studies, in high-grade coal mining, the increase in electrical charge of the respirable dust may cause more dust deposition in the lung tissue and greater loss of respiratory function due to increased toxicity.

Conclusions

In this study, the data of hard coal and lignite mine workers were evaluated comparatively for the first time in the literature. However, because this study was not a field study and was instead based on data obtained from patients admitted to the hospital, the findings may be affected by the characteristics of the study participants. Therefore, the results cannot be generalized and the findings should be interpreted with caution. In addition, due to the retrospective nature of this study, dust measurements in the workplace could not be evaluated. The study findings need to be confirmed in a prospective study on a large study population.

In conclusion, this study provides evidence that hard coal mine workers are at greater risk of PMF and pulmonary function loss, which highlights the importance of developing and implementing methods to diminish CWP burden according to coal mine type.

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