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Six-minute walk test as a tool for functional assessment of patients with pneumoconiosis

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Abstract:

BACKGROUND AND AIM: Pneumoconiosis can impair lung functions and the exercise capacities of patients. The six-minute walk test (6MWT) is a submaximal cardiopulmonary exercise test. In cases of pneumoconiosis, it may serve as a reliable functional tool for medical, social, and legal assessments. Considering this, we aimed to investigate the value of the 6MWT in pneumoconiosis patients experiencing dyspnea despite normal pulmonary function tests (PFTs).

METHODS: This cross-sectional study, conducted from September to December 2015, investigated 85 inpatients with pneumoconiosis who showed symptoms of dyspnea despite having normal results in PFTs. Data on sociodemographic features, occupational history, functional and radiological assessments, and 6MWT results were evaluated. Radiological assessment were performed according to International Labour Organization (ILO) categorization.

RESULTS: All patients were male. The mean age of the patients were 41.65±10.8. The majority had q opacity (51.8%) and were in category 1 (67%). 11 (13.0%) patients had a large opacity, and 6 of these were classified as having A opacity in ILO classification. The mean distance in the 6MWT was 488.54±87.54 meters, with 18 (21.1%) patients developing desaturation of more than 4%. A moderate negative correlation was observed between chest X-ray profusion and walking distance ($p=0.001$, $r=-0.365$). Walking distance was significantly lower in patients with a profusion of 2/1 or higher (452.29±94.36 m vs. 506.35±78.8 m; $p=0.021$). Receiver operating curve analysis indicated a cut-off value of 414 meters for category 2 or worse radiology.

CONCLUSIONS: This study evaluated pneumoconiosis patients with dyspnea and normal PFT results, showing that the 6MWT is moderately correlated with radiological findings. More extensive disease was associated with a lower walking distance. These results suggest the potential role of the 6MWT in the routine evaluation of pneumoconiosis patients. The 6MWT may be a valuable tool in occupational health for monitoring pneumoconiosis patients.

Keywords:

Dyspnea, lung function, pneumoconiosis, pulmonary function test, six-minute walk test

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Introduction

Pneumoconiosis is a chronic progressive interstitial lung disease caused by the inhalation of inorganic dust.^[1] Despite being entirely preventable, it is an irreversible, progressive disease once it develops, with the only treatment option being a lung transplant. The disease poses a significant burden despite its preventable nature, with over 23,000 deaths and 1,288,000 disability-adjusted life years (DALYs) reported by the National Institute for Occupational Safety and Health (NIOSH) and the World Health Organization (WHO).^[2,3]

Dyspnea, particularly exertional dyspnea, is one of the most common symptoms observed in workers exposed to dust. However, its subjective nature and relatively lower correlation with radiologic and pulmonary function tests (PFTs) in the early stages of the disease limit its use in clinical and legal assessments.^[4-6] As the disease progresses, a decline in functional assessment is generally observed, especially marked by increasing symptoms of breathlessness. Exertional dyspnea and exercise intolerance can become more pronounced, even though they do not always correlate with radiological and functional findings.^[6] This discrepancy often results in decreased work capacity. Claims for respiratory disability compensation in silica-exposed workers are frequently contested in legal settings. Therefore, it is important to translate a worker's dyspnea-associated decrease in labor capacity into objective data, especially when radiological and functional measures might appear normal in early stages of the disease.

The diagnosis of pneumoconiosis is primarily based on a history of occupational exposure, coupled with compatible radiological and functional test results.^[7] Additional tests, such as the cardiopulmonary exercise test (CPET), might be offered, depending on the patient's specific circumstances. CPETs are non-invasive tests that evaluate an individual's capacity during dynamic exercise, providing diagnostic and prognostic information.^[8] In Türkiye, CPETs are not routinely used, but they are requested by the social security institution in specific cases.

The six-minute walk Test (6MWT), as a submaximal cardiopulmonary exercise test, may be a test of choice in these situations due to its practical features.^[8] It is widely used in the evaluation of various pulmonary

diseases and also serves as objective data in the evaluation of daily activities and the disability caused by pulmonary issues.^[9] A potential early correlation in pneumoconiosis could serve as a more reliable functional tool for medical, social, and legal assessments. In light of this, we aimed to investigate the value of the 6MWT in pneumoconiosis patients with dyspnea and normal PFTs.

Materials and Methods

Study design

This is a cross-sectional study conducted at Occupational Diseases Hospital. All patients who were admitted to our hospital between September and December 2015 and eventually diagnosed with pneumoconiosis, who had dyspnea despite normal PFT results, were included in the study. Dyspnea was evaluated subjectively and was questioned and graded on the Modified 10-Point Borg Scale at rest. Patients with chest pain, hemodynamic instability, pulmonary hypertension, heart failure, and other chronic diseases were excluded. Additionally, patients who did not have normal forced vital capacity (FVC) or forced expiratory volume in 1 second (FEV₁) levels were excluded. Pneumoconiosis was diagnosed based on the presence of radiological findings compatible with pneumoconiosis, an appropriate history of exposure, and exclusion of other diagnoses leading to similar radiological findings.^[10] Detailed data on sociodemographic features and occupational history were noted.

Pulmonary function assessment: PFTs were performed in accordance with the American Thoracic Society (ATS) criteria.^[11] A standard spirometry measurement was conducted using dry-seal spirometry (Zan 100, nSpire Health Inc., Oberthulba, Germany). The spirometric parameters included the percent of predicted FEV₁, FVC, FEV₁/FVC ratio, maximum expiratory flow at 25–75% (MEF₂₅₋₇₅) and carbon monoxide diffusion capacity (DLco).

International Labour Organization (ILO) classification: Posteroanterior chest X-rays were obtained using a technique with short exposure time and high voltage (Trophy UFXRAY, 500 mA, TM). Chest X-rays were evaluated according to the International Labour Organization (ILO) 2011 standards.^[10] According to the ILO classification, small opacities are described by profusion, affected zones of the lung, shape (rounded or irregular), and size.

Opacities with profusion 1/0, 1/1, and 1/2 have been classified as category 1; those with profusion 2/1, 2/2, and 2/3 as category 2; and those with profusion 3/2, 3/3, and 3/+ as category 3. Shapes are categorized as either rounded or irregular. For small, rounded opacities, sizes are labeled as p, q, and r, and small irregular opacities as s, t, and u based on size.^[10]

Large opacities classified as A, B and C as shown below.

Category A One large opacity having the longest dimension up to about 50 mm, or several large opacities with the sum of their longest dimensions not exceeding about 50 mm.

Category B One large opacity having the longest dimension exceeding 50 mm but not exceeding the equivalent area of the right upper zone, or several large opacities with the sum of their longest dimensions exceeding 50 mm but not exceeding the equivalent area of the right upper zone.

Category C One large opacity which exceeds the equivalent area of the right upper zone, or several large opacities which, when combined, exceed the equivalent area of the right upper zone.^[10]

Six-minute walk test (6MWT): Three nurses were trained about the study method before data collection. The 6MWT, as described in the ATS guideline (2002), involves walking on a 30-meter hospital floor, marked every three meters. At the beginning and end of the test, the patient's vitals, such as heart rate, blood pressure, and respiratory rate, were measured. Oxygen saturation was also noted using a pulse oximeter. In the 6MWT, subjects were asked to walk as far as they could in 6 minutes with standardized encouragement.^[9] Dyspnea was assessed before and after the 6MWT using a visual analog scale, ranging from 'nothing at all' (0) to 'maximal' (10), based on the Modified Borg Scale.^[12] The 6MWT can measure exercise-induced desaturation. A decrease in oxygen saturation (SpO_2) of $\geq 4\%$ suggests significant desaturation and is used to assess the need for oxygen supplementation in patients with chronic lung disease.^[13,14] Both the total walking distance and any observed desaturation were recorded.

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) Statistics for Windows® version 20.0 (IBM Corp., Armonk, NY, USA).

Table 1: Characteristics of the cases

	Feature	
	n	%
Number	85	
Age (mean \pm SD, min-max)	41.65 \pm 10.8 (24–79)	
Smokers	68	80
Smoking (pack-years)	12.9 \pm 10.34 (0–45)	
Exposure time (months) (mean \pm SD, min-max)	167.8 \pm 68.3 (24–384)	
Occupation		
Ceramic Workers	52	61.2
Miners	14	16.5
Dental Technicians	9	10.6
Foundry Workers	5	5.9
Welders	5	5.9
Modified 10-Point Borg Scale (at rest)		
Score (mean \pm SD, min-max)	3.6 \pm 1.9	(1–9)
PFT (Mean \pm SD)		
FEV ₁	96.45 \pm 13.21	
FVC	99.50 \pm 14.38	
FEV ₁ /FVC	80.81 \pm 5.19	
MEF _{25–75}	81.50 \pm 25.83	
DL _{CO} (n=31)	104.1 \pm 22.2	

SD: Standard deviation, PFT: Pulmonary function Test, FEV₁: Forced expiratory volume in 1 second, FVC: Forced vital capacity, MEF_{25–75}: Maximum expiratory flow at 25–75%, DL_{CO}: Carbon monoxide diffusion capacity

Descriptive statistics, including mean, median, range (minimum-maximum), and standard deviation, were computed. The Kolmogorov-Smirnov test was used to assess the distribution of continuous variables. Results for variables with parametric and non-parametric distributions were expressed as mean \pm standard deviation (SD) and median (25th–75th percentile), respectively. Correlations were assessed using Pearson or Spearman tests, as appropriate. A receiver operating characteristic (ROC) curve was generated, and the area under the ROC curve (AUC) was calculated to estimate the cutoff value of the 6MWT. Statistical calculations were performed using the pROC package in R software and PASW Statistics 16 (IBM Corporation, Somers, NY, USA). ROC analysis was undertaken to quantitatively evaluate accuracy, compare accuracy between different tests, and determine the optimal threshold. A p-value of <0.05 was considered statistically significant.

Ethics

Approval for this study was obtained from the institutional review board (2169-201215).

Table 2: ILO classification of radiographs

	n	%
Small opacity		
p	36	42.4
q	44	51.8
r	2	2.4
s	1	1.2
t	1	1.2
u	1	1.2
Category/profusions		
1		
1/0	24	28.2
1/1	21	24.7
1/2	12	14.1
2		
2/1	6	7.1
2/2	11	12.9
2/3	2	2.4
3		
3/3	9	10.6
3/+	–	–
Large opacity		
A	6	7.1
B	4	4.7
C	1	1.2

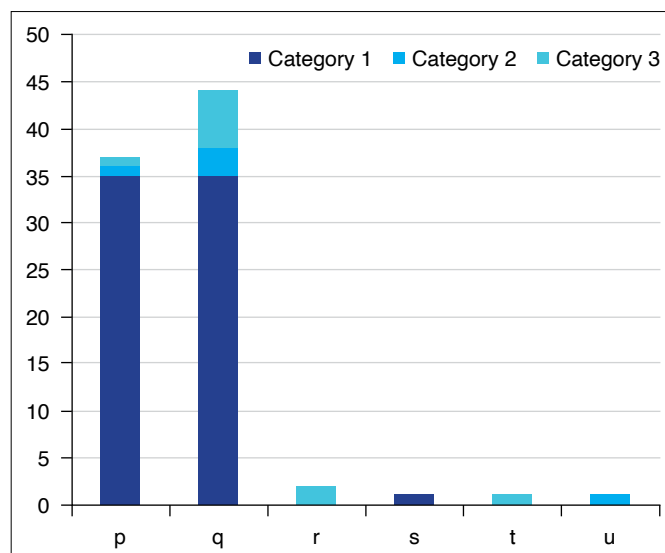
ILO: International Labour Organization

Results

During the study period, 85 patients were diagnosed with pneumoconiosis. All were male. Demographics and specific features of the cases are summarized in Table 1. The mean age was 41.65 ± 10.8 years. The mean time of exposure was 167.8 ± 68.3 months, with a minimum of 24 months and a maximum of 384 months. Additionally, out of the cases, 61.2% (n=52) were employed in the ceramic sector, 16.5% (n=14) were miners, 10.6% (n=9) were dental technicians, and 5.9% (n=5) were foundry workers and welders. Pulmonary function tests were within normal ranges. The mean FEV_1 was $96.45 \pm 13.21\%$, FVC was $99.50 \pm 14.38\%$, the Tiffeneau ratio was 80.81 ± 5.19 , and the mean DLco was $104.1 \pm 22.2\%$ (Table 1).

Table 3: Six-Minute Walk Test results

Parameter	Results
Walking distance (meters, mean \pm SD)	488.54 \pm 87.54
Initial SpO ₂ % (mean \pm SD) (min-max)	96.39 \pm 2.15 (89–100)
SpO ₂ at the end (mean \pm SD) (min-max)	94.33 \pm 3.14 (99–84)
Initial systolic BP (mmHg) (mean \pm SD)	116.99 \pm 12.98
Initial diastolic BP (mmHg) (mean \pm SD)	73.82 \pm 9.3
Systolic BP at the End (mmHg) (mean \pm SD)	122.12 \pm 17.68
Diastolic BP at the End (mmHg) (mean \pm SD)	76.32 \pm 10.71

SpO₂: Pulse oxygen saturation, BP: Blood pressure**Figure 1: International Labour Organization (ILO) classification of radiographs**

Radiological features of the cases are summarized in Table 2 and Figure 1. Most of the patients had q opacity (51.8%) and were category 1 (67%). Eleven patients (13.0%) exhibited large opacities, and six of them were A opacity.

The results of the 6MWT are presented in Table 3. The mean distance was 488.54 ± 87.54 meters. Eighteen patients (21.1%) developed desaturation of more than 4%. A correlation analysis between chest x-ray profusion and PFT parameters (FVC, FEV_1 , DLco) was performed, but no correlation was found between radiological findings and functional parameters. There was a moderate negative correlation between profusion on chest X-ray and walking distance ($p=0.001$ $r=-0.365$). Walking distance was significantly lower in patients with profusion of 2/1 or higher (452.29 ± 94.36 m vs. 506.35 ± 78.8 m; $p=0.021$). Receiver operating curve analysis yielded a cutoff value of 414 meters for category 2 or worse radiology. Walking distance was significantly lower in patients with profusion of 2/1 or higher (452.29 ± 94.36 meters vs. 506.35 ± 78.8 meters; $p=0.021$). Receiver operating curve (ROC) analysis yielded

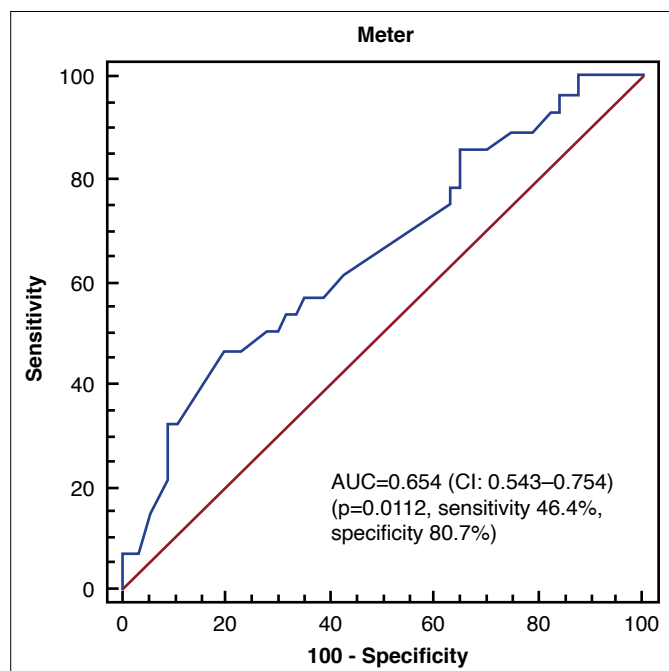


Figure 2: Receiver operating curve analysis of walking distance for category 2 or worse radiology

a cutoff value of 414 meters for category 2 or worse radiology. The area under the curve was 0.654 (CI: 0.543–0.754) ($p=0.0112$, sensitivity 46.4%, specificity 80.7%) [Fig. 2].

Discussion

Pneumoconiosis, which presents with dyspnea, especially exertional dyspnea, is the most common occupational disease globally, particularly in developing countries.^[1] Routinely, a simple spirometric examination is used to monitor functional capacity assessment. In our study, the 6MWT walking distance was significantly lower, and ROC analysis yielded a cutoff value of 414 meters for profusion of 2/1 or higher in patients who had dyspnea with normal PFTs.

Pneumoconiosis may present with or complicate exertional dyspnea. A simple spirometric examination is performed at rest. Evaluating the functional status of these patients during exercise, including increased metabolic requirements during work and assessment of cardiovascular-pulmonary activity, will yield more realistic results. Cardiopulmonary exercise tests provide highly valuable information by showing cardiopulmonary capacity.^[15] The 6MWT is a submaximal exercise test used to determine exercise tolerance in various cardiopulmonary diseases. The merits of this test are its ease of adminis-

tration, better tolerance, and more accurate reflection of daily living activities.^[16] In a study comparing physical activity between interstitial lung disease (ILD) patients and healthy individuals, it was shown that ILD patients had significantly lower walking distances in the 6MWT and were more likely to be physically inactive.^[17] Baughman et al.^[18] used the 6MWT to assess patients with sarcoidosis and found that the 6MWT is a useful test, whereas PFTs and radiological findings do not correlate well in sarcoidosis.^[19] Similar results were observed in asbestosis-related lung disease, concluding that the 6MWT is a useful tool for determining peak exercise capacity and physical activity when maximal CPETs cannot be performed.^[20]

The 6MWT is now recommended for diagnostic and follow-up measures in the national guidelines of Germany.^[21] Noh^[22] stated that although radiology and simple spirometry are used in the Coal Worker's Pneumoconiosis (CWP) disability evaluation assessment system in Korea, the 6MWT is highly correlated with respiratory complaints. Distortions in the test appear even in cases where radiological findings cannot be demonstrated by chest X-ray. This result indicates that cardiopulmonary functions are affected in early-stage CWP cases.

In general, a correlation between 6MWT distance and PFTs is known.^[23,24] However, this data from obstructive and interstitial lung diseases (ILDs) was not well projected and shown in pneumoconiosis. A possible cutoff value is absent. As increased profusion correlates better with 6MWT distance rather than PFT results, it can be concluded that functional status, in terms of exercise capacity, is better determined with the 6MWT.

The level of impact (impairment and dysfunction) is important in evaluating incapacity for work (disability and invalidity). The more specific and sensitive the criteria used to assess the functional disorder – i.e., the impairment caused by the disease – the more accurately the result will reflect the level of impairment. In our country, occupational disease hospitals and clinics are also legally responsible for evaluating and reporting patients with pneumoconiosis in terms of disability and invalidity. National guidelines indicate radiological and PFTs for all patients; however, they suggest performing CPET only in selected cases. Blanco et al.^[25] found abnormal 6MWT results in many patients with silicosis, especially those with complicated silicosis B and C. The presence of complicated silicosis B and C, moderate or

severe emphysema, altered pulmonary function tests (FEV₁, FVC%, DLco), and desaturation during the test and night-time oximetry recording contribute to poorer results in the test. This study shows that the 6MWT can be a reliable alternative to CPET and should be routine in the evaluation of pneumoconiosis, with its simple rationale, easy application, and supporting scientific data. Receiver operating curve analysis has yielded a cutoff value of 414 meters for category 2 or worse radiology. The area under the curve was 0.654 (CI 0.543–0.754) (p=0.0112, sensitivity 46.4%, specificity 80.7%).

The major limitation of this study was that it was a cross-sectional study. Since the Borg Scale is a subjective test, it is limited in demonstrating dyspnea for the patients.

Conclusion

In this report, we evaluated patients with pneumoconiosis who had dyspnea despite normal PFT results and found that the 6MWT is moderately correlated with radiological findings. Extensive disease was associated with a lower walking distance. This result highlights the potential role of the 6MWT in the routine and disability evaluation assessment systems in patients with pneumoconiosis.

Conflicts of interest

There are no conflicts of interest.

Ethics Committee Approval

The study was approved by the Keçiören Training and Research Hospital Clinical Research Ethics Committee (No: 2169-201215, Date: 23/09/2020).

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Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept – T.N.Ö., N.Ş.A., A.C.B., İ.O.A., M.K.; Design – T.N.Ö., N.Ş.A., A.C.B., İ.O.A., M.K.; Supervision – T.N.Ö., N.Ş.A., A.C.B.; Funding – T.N.Ö., N.Ş.A.; Materials – T.N.Ö., N.Ş.A.; Data collection &/or processing – T.N.Ö., N.Ş.A., İ.O.A., M.K.; Analysis and/or interpretation – A.C.B., N.Ş.A.; Literature search – A.C.B., N.Ş.A., İ.O.A.; Writing – T.N.Ö., N.Ş.A., A.C.B., İ.O.A., M.K.; Critical review – T.N.Ö., N.Ş.A., A.C.B., İ.O.A., M.K.

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