

## Original Article

# Six-minute walk test among silicosis patients: Its correlation with abnormal radiographic findings on chest radiograph and high resolution computed tomography scan

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## ABSTRACT

**Objectives:** Silicosis is one of the oldest chronic lung diseases that leads to relentless fibrotic changes in the lungs with a resultant fall in lung functions. This study was conducted to assess exercise capacity utilizing a six-minute walk test (6-MWT) among patients detected to have “simple” and “complicated” forms of silicosis. A further correlation between 6-MWT parameters and abnormal chest imaging findings was also done.

**Material and Methods:** Silicosis diagnosis among study subjects was based on the history of exposure to occupational silica dust along with suggestive radiological findings of pneumoconiosis assessed by the trained experts. Study subjects performed the 6-MWT as per standard protocol. Chest radiological and “high resolution computed tomographic” (HRCT) abnormalities were also analyzed in each subject and compared with their 6-MWT components (distance walked in meters and oxygen desaturation occurrence, if any).

**Results:** One hundred twelve study subjects (males 106 and females 6; mean age 44.05±10.84 years) constituted the final study population. The six-minute walk distance (6-MWD), fall in SpO<sub>2</sub> and BORG dyspnea scale in patients with grade “0” on chest X-ray was 362.79 ± 34.2 meter, 1.28 ± 0.91% and 0.96 ± 0.59, respectively and these parameters gradually converted with increasing International Labour Organization silicosis grading with 94.21 ± 29.4 meter, 7.11 ± 1.61% and 4.50 ± 0.93, respectively in grade “C.” A gradual change in 6-MWT parameters was also evident when compared with HRCT scan grading abnormalities.

**Conclusion:** Results of this study shows abnormally reduced lung function parameters among subjects with silicosis and it also correlates with degree of the profusion of nodules seen radiologically both on chest radiograph and HRCT.

**Keywords:** Silicosis, 6-minute walk test, Chest radiology, HRCT scan

## INTRODUCTION

Silicosis is an age-old pneumoconiosis that occurs following inhalation, retention, and subsequent pulmonary reaction to crystalline form of silica.<sup>1</sup> The “Chronic silicosis” is the most common type of silicosis that occurs following low silica dust exposure for more than 10 years. The “acute silicosis” develops following high silica concentrations exposure, usually over a period of weeks or months; on the other hand, the “accelerated silicosis” mostly develops about 5 to 10 years of high dust exposure to silica.<sup>2</sup> As per the recent International Labour Organization (ILO), guidelines, the standard method of silicosis diagnosis is X-ray chest studies and occupational history of exposure to the crystalline form of silica.<sup>3</sup>

Pulmonary function tests are not considered the standard diagnosis modality for this disease, however, these are commonly utilized for longitudinal studies among workers having silicosis.<sup>4,5</sup> The lung volumes measured on spirometry and “diffusing capacity for carbon monoxide” (DLCO) values are reduced among silicosis patients according to the extent of underlying pulmonary fibrosis.<sup>6</sup> Six-minute walk test (6-MWT) is a commonly utilized tool to assess exercise capacity that essentially measures the distance walked by an individual over 6 minutes.<sup>7</sup> This is cost-effective, easy to be performed by subjects, and indicates the functional assessment of patients therefore accepted as a useful and reproducible test specially for the “chronic respiratory disorders.”<sup>8,9</sup> This test helps to determine supplemental oxygen requirements among

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chronic pulmonary illnesses such as “chronic obstructive airway disease,” “idiopathic pulmonary fibrosis,” etc. It also serves as an important prognostic tool to predict morbidity and mortality in such conditions. This is now an important assessment parameter for lung transplantation too.<sup>10,11</sup>

This study was an attempt to analyze the 6-MWT performance among subjects with silicosis and further to explore the correlation if any, between its parameters with radiologic and computed tomographic examination abnormalities.

## MATERIAL AND METHODS

### Study population

The study subjects were patients with radiologically proven silicosis attending the occupational health clinic of our institution over the last three years. Those having occupational exposure to silica dust in various forms were included in this study. Those with other comorbidity contraindicating 6-MWT and those with associated active pulmonary tuberculosis were ruled out by appropriate investigations and excluded from the study. All patients were evaluated by in-depth clinical history with a specific focus on occupational exposure to silica dust in detail. This study was conducted following due approval by the institutional ethical committee.

### Six-minute walk test (6-MWT) and chest imaging

The diagnosis of silicosis constituted a true occupation history of silica dust exposure along with suggestive chest radiographic findings. The trained pulmonologist and experienced radiologist separately examined the chest radiographs of the study participant. The radiological assessment essentially included a standard chest roentgenogram and a high-resolution computed tomographic (HRCT) scan of the thorax. The pulmonary function tests performed by these patients were spirometry and 6-MWT.

In 6-MWT, the distance walked by a patient in meters on a flat surface over a period of 6 minutes time was recorded. This test is commonly used these days to assess medical intervention response in cardiac as well as pulmonary diseases. The most important measurement in the 6-MWT is the number of meters that the patient walks, however, modification in oxygen saturation provides additional information regarding disease progression and treatment response more precisely.<sup>7</sup>

The test was conducted on a long, evenly flat, and straight hard surface corridor in an indoor setup. The walking course length was 30 meters and the corridor was marked at every 3 meters length distance. The pre- as well as post-walk “Borg dyspnea and fatigue levels” were recorded. SpO<sub>2</sub> and pulse rate were measured by a digital oximeter. The distance walked by the subjects was measured and recorded separately for each

individual. Patients with baseline SpO<sub>2</sub> below 88%, those with an inability to perform the test, and requiring supplemental oxygen during the test were excluded from the final analysis.

Using standard radiographs, differing types (“shape and size”) and severity (“profusion”) of abnormalities were identified and recorded in individual patient record sheets. The study subjects were classified into four categories (0, 1, 2, 3) on the basis of small opacities and three categories (A, B, C) of large opacities as per standard criteria.<sup>12</sup> All eligible patients were subjected to an HRCT scan thorax to assess the nature, extent and details of radiographic abnormalities. The standard criteria were used to describe radiographic lesions and recorded separately for each patient.

### Statistical analysis

SPSS software, version 20 (Chicago IL, USA) was utilized to analyze the study data. The quantitative data were presented by mean and standard deviation while qualitative data were presented in the percentage. Kruskal Wallis “H” test, followed by post hoc if required, was utilized to test the difference of the mean between more than two groups. A p-value of <0.05 was considered to be statistically significant.

## RESULTS

One hundred twelve patients were found eligible as per the protocol and constituted the final study population. They were mainly between the third and fifth decades, with males constituting the most (male 94.6%, female 5.4%). More than one-third of subjects (37.5%; n = 42) were non-smokers, whereas 32.1% (n = 36) were ex-smokers, and 30.4% (n = 34) were current smokers. Most of these patients were engaged with stone cutting work (35.71%) followed by stone grinding (16.1%), well digging (15.17%), stone drilling (14.28%), stone slabs breaking (8.9%), stone fine cutting with chisel & hammer (0.89%), supervisory work at stone powder factory (0.89%) and stone powder packaging (0.89%).

The mean values among 6-MWT indicators, such as 6-Minute Walk Distance (6-MWD), fall in SpO<sub>2</sub> and Borg Rating of Perceived Exertion (BORG) rating changes, were 243.89 ± 108.94 (range 60–410) meter; 3.67 ± 2.64% (range 0%–10%) and 2.28 ± 1.57 (range 0.5–5.5) respectively [Table 1].

Chest X-ray grading was according to ILO categories in which distribution of study participants for small opacities was as follows: 28 (25%) in category “0”; 22 (19.69%) in category “1”; 22 (19.64%) category “2,” and 28 (25%) in category “3.” Large opacities were seen only in 28 patients; of them, type “A” opacity was seen in 10 (8.9%) patients, while type “B” and type “C” opacities were seen in 6 (5.3%) and 12 (10.7%) patients, respectively. As per the abnormal HRCT findings, the computed tomography (CT) grading pattern among the

**Table 1:** 6-Minute Walk Test (6-MWT) findings in patients with silicosis

Variable	Range	Mean value	SD
Distance covered (meter)	60–410	243.89	108.94
BORG rating before test (0–10)	0.0–2.0	0.32	0.48
BORG rating after test (0–10)	0.5–7.0	2.72	2.03
Change in BORG rating	0.5–5.5	2.28	1.57
SpO <sub>2</sub> before test (%)	89–99.0	95.37	9.42
SpO <sub>2</sub> after test (%)	81–96	91.49	8.34
Degree of O <sub>2</sub> desaturation (%)	0.0–10.0	3.67	2.64

BORG: Borg rating of perceived exertion, SD: Standard deviation.

study subjects was as follows: 12 (10.71%) in category “0”; 16 (14.28%) in category “I”; 28 (25%) in category “II”; 24 (21.42%) in category “III,” and 32 (28.57%) in category “IV.” The emphysema findings were also notable in 32 (28.57%) individuals with different gradings on HRCT [Tables 2 and 3].

The 6-MWD, fall in SpO<sub>2</sub> and BORG dyspnea scale while performing 6-MWT in patients having grade “0” on chest X-ray was 362.79 ± 34.2 meters, 1.28 ± 0.91% and 0.96 ± 0.59 respectively and these values changed a lot with increasing ILO silicosis grading to an extent of 94.21 ± 29.4 meter, 7.11 ± 1.61% and 4.50 ± 0.93 in those individuals having ILO grading “C” with a clear difference in 6-MWD by 268 m, fall in SpO<sub>2</sub> by 5.83% and BORG dyspnea scale by 3.54; statistically these changes were highly significant (p < 0.01) [Table 4].

The 6-MWD, fall in SpO<sub>2</sub>, and BORG dyspnea scale while performing 6-MWT in patients having grade “0” on HRCT

**Table 2:** Chest X-ray finding in study subjects

Chest X-ray finding	Grade	No.	%
Small opacities	0	28	28%
	1	22	22%
	2	22	22%
	3	28	28%
	Total	100	100%
Large opacities	A	10	35.71
	B	6	21.42
	C	12	42.85
	Total	28	100%
Pleural thickening		21	18.75%

**Table 3:** HRCT finding in study subjects

HRCT finding	Grade	No.	%
HRCT grading	0	12	10.71%
	1	16	14.28%
	2	28	25%
	3	24	21.42%
	4	32	28.57%
	Total	112	100%
Emphysematous changes	1	14	43.75%
	2	7	21.87%
	3	6	18.75%
	4	5	15.62%
	Total	32	100%

HRCT: High resolution computed tomographic.

**Table 4:** 6-Minute Walk Test (6-MWT) parameters in relation to the radiographic profusion in patients with silicosis

Parameters	Chest X-ray ILO grading					p value
	0	1	2	3	C	
Distance covered (meter)	362.79 ± 34.21	297.0 ± 90.84	216.64 ± 69.13	165.86 ± 69.47	94.21 ± 29.45	<0.01
O <sub>2</sub> desaturation (%)	1.28 ± 0.91	2.01 ± 1.61	4.18 ± 2.31	5.50 ± 2.02	7.11 ± 1.61	<0.01
Change in BORG rating (0–10)	0.96 ± 0.59	1.31 ± 1.10	2.86 ± 1.53	3.01 ± 1.27	4.50 ± 0.93	<0.01

BORG: Borg rating of perceived exertion, ILO: International labour organization.

**Table 5:** 6-MWT parameters in relation to the tomographic categories

6-MWT parameters	HRCT grading					p value
	0	I	II	III	IV	
Distance covered (meter)	370.33 ± 32.94	367.63 ± 38.0	293.8 ± 60.39	182.0 ± 66.55	131.20 ± 65.51	<0.01
O <sub>2</sub> desaturation (%)	1.01 ± 1.09	1.37 ± 0.74	2.07 ± 1.32	4.45 ± 2.29	6.60 ± 1.56	<0.01
Change in BORG rating (0-10)	0.75 ± 0.61	1.06 ± 0.62	1.46 ± 1.08	2.63 ± 1.16	3.97 ± 1.27	<0.01

BORG: Borg rating of perceived exertion, HRCT: High resolution computed tomographic.

**Table 6:** Spearson's correlation coefficients for the correlations between 6-minute walk test and results of the scores obtained with high-resolution computed tomography and chest X-ray.

		HRCT grading	Chest X-ray grading
Change in BORG rating	r value	.783	.745
	p value	.000	.000
O <sub>2</sub> desaturation	r value	.843	.793
	p value	.000	.000
Distance	r value	-.841	-.840
	p value	.000	.000

BORG: Borg rating of perceived exertion, HRCT: High resolution computed tomographic.

chest was  $370.33 \pm 32.91$  m,  $1 \pm 1.09\%$  and  $0.75 \pm 0.61$ , respectively and this also drastically fall with increasing HRCT silicosis grading to  $131.00 \pm 65.51$  m,  $6.60 \pm 1.56\%$  and  $3.97 \pm 1.27$  in those with grade IV of HRCT abnormality with a change in 6-MWD to 239.33 m, fall in SpO<sub>2</sub> to 5.60% and BORG dyspnea scale to 3.22. Changes in these parameters were statistically significant ( $p < 0.01$ ). Parameters of 6-MWT significantly changed from patients having "progressive massive fibrosis" (PMF) to those with "simple silicosis" as per the ILO from grade 0 to III and IV ( $p$  value  $< 0.01$ ) [Table 5].

This study also analyzed correlations between 6-MWT and different scores observed with abnormal findings on high-resolution computed tomography and chest skiagram. Distance covered during 6-MWT by patient was found to be inversely proportionate to the chest X-ray grading ( $r = -0.82$ ) ( $p < 0.000$ ) as well as HRCT chest grading ( $r = -0.87$ ) ( $p < 0.001$ ) while O<sub>2</sub> desaturation and change in BORG rating were directly proportionate to chest X-ray ( $r = 0.78$ ;  $p < 0.000$  and  $r = 0.71$ ;  $p < 0.000$ , respectively) as well as HRCT chest grading abnormality according to the profusion ( $r = 0.93$ ;  $p < 0.000$  and  $r = 0.7$ ;  $p < 0.000$ ) [Table 6].

## DISCUSSION

The "simple silicosis" (category 0, 1, 2) was not observed to produce significant impairment in pulmonary functions in this study; however, this was evident among those having advanced simple silicosis (category 3). At the end of 6-MWT, Izabela Cozza *et al.*<sup>13</sup> noticed a significant rise in "BORG rating perceived exertion scale" (Borg scale) as well as a drop in SpO<sub>2</sub> by 5% ( $n = 18$ , 28%;  $p < 0.01$ ), however, 6-MWT was not correlated with larger opacities in radiological images. In a series of 83 coal workers' pneumoconiosis, a good correlation of the 6-MWT to lung function was found by Noh,<sup>14</sup> but its significant correlation with abnormal radiological grading in silicosis was lacking ( $p$ -value = 0.706). These observations are

different from our study and may be explained by the variable selection criteria of study subjects. Deepak *et al.*<sup>15</sup> observed a gradual decrease in distance walked with increased dyspnea rating and fall in SpO<sub>2</sub> when compared to abnormal radiographic grading on ILO classification. A mean difference of 188 meters in 6-MWD was seen among patients with grade "C" i.e., "pulmonary massive fibrosis." Blanco Pérez *et al.*<sup>16</sup> also observed abnormal 6-MWT in patients having complicated silicosis with grade "B" or "C" abnormality, and this was also associated with an increase in desaturation and a decrease in distance of walking during the test. Karhate Andaloussi *et al.*<sup>17</sup> also observed abnormal 6-MWT among 147 patients with silicosis with a statistically significant correlation between dyspnea, quality of life, anxiety level, and distance walked. The overall observations in most studies are similar to those with the present study and reflects compromised lung functions and poor functional reserve in patients having extensive radiological lesions.

There is scanty literature addressing the relationship between the profusion of parenchymal opacities detected on "HRCT" and 6-MWT. While correlating the HRCT abnormalities of silicosis patients with 6-MWT, we observed significant changes in 6-MWT parameters among patients having "pulmonary massive fibrosis" (PMF) to "simple silicosis" with HRCT grade 0, I, II, and III. Further, increased profusion on HRCT was significantly associated with increased dyspnea rating with a fall in SpO<sub>2</sub> that reflects the increased degree of parenchymal destruction to be associated with increased grading on HRCT.

There is a paucity of data in radiology on a description of the computed tomography abnormalities in silicosis patients.<sup>18</sup> Computed tomography is definitely superior to standard chest radiographs as far as early detection of pulmonary nodules and interstitial changes in silicosis patients is concerned. Thin CT slices in the "trans-axial plane" decrease the superimposition of parenchymal structures and permits more clearer visualization of the distribution and severity of parenchymal abnormalities.<sup>19</sup>

The main strength of this study lies in conducting 6-MWT among fairly good number of silicosis patients and correlating 6-MWT parameters with various grades of HRCT abnormality first time in literature. However, there were a few limitations also that include a lack of inclusion of patients with baseline SpO<sub>2</sub>  $< 88\%$  with supplement oxygen to perform 6-MWT, which could have further increased the sample size. We also could not compare 6-MWT parameters among smokers versus nonsmokers.

This is to be noted that restriction in 6-MWT may also occur due to other co-founding factors like muscular strength, nutritional status of a patient, and ability to comprehend

instructions etc. and this part was also not addressed in this study. But despite such limitations, this study suggests that compromised lung function in the form of decreased exercise capacity, decreased oxygen saturation, and increased BORG rating, dyspnea score, etc. correlates well with the extent of radiological abnormalities.

## CONCLUSION

6-MWT is a simple and non-invasive investigation, this can be used as a complementary test to evaluate disease severity and monitor disease progression in patients having silicosis at frequent intervals during follow-up visits. It could also be utilized as a prognostic factor to predict functional status, quality of life and need for hospitalization and rehabilitation among such patients.

## Ethical approval

The research/study is approved by the Institutional Ethics Committee at Jawahar Lal Nehru Medical College, Ajmer, number S.No. 268/education III/MCA/2018/ column no. 70, dated 06<sup>th</sup> February 2018.

## Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

## Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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