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Abstract

Purpose: Prevalence and severity of respiratory disorders are very high among coal miners as continuous exposure of workers in such environment leads to accumulation of dust in the lungs. This study was designed to assess the prevalence of lung function impairment and to find whether there is any correlation between dust exposure duration and lung function indices.

Materials and Methods: Two hundred thirty (230) underground coal dust exposed workers and one hundred thirty (130) age matched nonexposed workers were recruited from an underground mine of West Bengal, India. Spirometry test was performed for lung function test and also basic information on personnel dust exposure, smoking and respiratory morbidity were collected. Student's t test, Pearson's correlation coefficient (*r*), uncorrected Pearson's Chi square and Fischer's exact tests were performed for statistical analysis.

Results: Lung function indices were significantly (p<0.050) impaired in between exposed (43.91 %) and nonexposed group (23.85 %). In addition, highly significant decrements in the pulmonary volumes of exposed subjects were also noted. Furthermore, a high negative correlation was observed between spirometric results and exposure time in exposed group than nonexposed group.

Conclusion: This study suggested a positive relationship between exposure time and lung function deterioration.

Keywords: Coal miners, Pulmonary function, Respiratory morbidity, Dust exposure, Work experience

1.Introduction

Mining operations is historically known for its serious occupational health hazards. Now-a-days, it is still considered as a hazardous occupation due to its continuous deleterious health effects. In addition, coal is a beneficial and bountiful natural global resource and it is the biggest national asset of India as well as other country also [1]. Coal has played this important role for centuries, not only for providing electricity, but also as necessary fuel for steel and cement production, and other industrial activities. Around 60% world's steel construction and 40% of the current electricity generation are powered by coal [2].

Occupational induced respiratory disorders have been documented in workers of coal mining sector exposed to variety of dusts during their production process [3]. Prolonged exposure to respirable coal mine dust can cause inflammation of alveoli which results in irreversible lung damage and ultimately leads to the development of Coal Worker's Pneumoconiosis (CWP) [4]. Respirable dust which can pass upper respiratory tract usually specify the particles size below 4-5μm, while inhalable dust with particle size 5-10μm range is not considered as serious factor for deterioration of lung function [5]. Other than CWP which may be simple or advanced, there are many other respiratory disorders such as silicosis, asbestosis, pleural plaques, lung cancer, mesothelioma, chronic obstructive airways disease caused due to inhalation of coal dust [6]. Among these, silicosis is another serious occupational health hazards in coal mining sector, caused due to exposure of crystalline silica dust [7].

The exposure of occupational coal dust is known to be the most crucial factor for development of pneumoconiosis [8]. The onset of pneumoconiosis among coal miners is seen after approximately 10 years of working in coal dust environment [9]; however, it varies on different coal mining activities performed by the miners which may be less than 5 years [10].

It has been documented since 1960s that exposure to respirable dust among coal miners leads to accelerated decline in lung function. A study by Naidoo et al. (2005) confirmed the dust-related dose-response decrements in the lung volumes between current and ex-miners [11]. A high prevalence of lung function impairment was also observed in this workforce. According to the Federal Mine Safety and Health Administration (MSHA), the concentration of respirable dust limits from 2 mg/m^3 to 1.5 mg/m^3[12]. Earlier studies reported that respirable dust at different work sites of underground coal mine are above the recommended level [2, 8].

Though the occupation induced health hazards increasing with respect to length of service, there are paucity of literature that tried to explore the relationship between duration of exposure to coal dust and lung function impairment. Literature survey revealed no such reports on coal dust exposure dependent lung function impairment in coal miners of West Bengal (India). Therefore, this study was designed to explore the relationship between deterioration of different lung volumes and service duration. Outcome of this study would help the coal mine management to adopt the appropriate preventive measures and in implementing awareness programs to combat against different lung disorders in coal mine workers. In order to reduce occupational health hazard and to improve the health status of the workers they might take help from safety departments, medical officers and other related organization.

2. Materials and methods

This is a cross-sectional study involving underground coal dust exposed workers of one of the underground coal mines in the state of West Bengal, India. For the selection of subjects, a meeting was arranged between the employees and the project committee members. Details of the study and aims were explained to the workers. The interested workers were selected by simple random sampling technique after stratifying the population based on department and experience of the service (exposure time). The control subjects who had no direct exposure to underground coal dust were selected from office, dispensary, security personnel and executives by the same method. The study was performed after having approval from Human Ethics Committee of Serampore College, affiliated to University of Calcutta. Sample size of the study was calculated based on the actual number of the underground workers. Since, prevalence of lung function impairment was unknown in the population of miners, it was assumed to be at 50%. Therefore, the calculated sample size from finite population of underground miners (600) and infinitely large population (384) was 247 (after adjusting for a non-response of 5%) [13]. Personnel dust exposure data were collected based on the files in the Dust Detection (Safety) Department of the coal mine. Personnel dust exposures of workers were measured during their working hours at different workface of underground and supplemented by the Safety Department.

A total of 230 underground coal dust exposed workers and 130 nonexposed workers were examined for different selected parameters. Using a standard protocol, all physical and physiological data including age, height, weight, heart rate, blood pressure were measured. Body mass index (BMI) of each subject was calculated using Quetelet's index [14]. Information on service details, respiratory symptoms and smoking habits were obtained using a structured questionnaire. Spirometer (Schiller, Spirovit SP-1) was used to perform lung function test (LFT). Different lung function indices including Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_{1s}), Forced Expiratory Flow 25-75% (FEF25-75%), Peak Expiratory Flow (PEF) and Maximum Voluntary Ventilation (MVV) were measured. The LFT test of each subject was performed thrice and mean of these three readings was considered as the reading for a particular subject. Further analysis of data were done using Microsoft excel. FEV_{1s}/FVC ratio was calculated and categorized as FVC < 80% and FEV_{1s}/FVC > 70% was defined as restrictive pulmonary dysfunction; FVC > 80% and FEV_{1s}/FVC < 70% was defined as obstructive pulmonary dysfunction; and FVC < 80% and FEV_{1s}/FVC < 70% was defined as mixed type pulmonary dysfunction [15]. Average lung function value in the categories restrictive, obstructive or mixed type, was considered as impaired lung function. To analyze exposure dependent effects, total numbers of exposed and nonexposed subjects were further divided into four groups based on service experience. Per year change in different lung function indices were also calculated by finding the difference between minimum service experience and maximum service experience:

$$\text{Per year change}=\frac{\text{Lung function indices of subject having minimum work experience} - \text{Lung function indices of subject having maximum work experience}}{\text{Maximum work experience} - \text{Minimum work experience}}$$

The Student's t test, Pearson's r correlation coefficient, uncorrected Pearson's Chi square and the Fischer's exact tests were used for statistical analysis. The level of statistical significance was set at 5%.

3. Results

3.1. Comparisons of physical and physiological variables between exposed and nonexposed groups

Table 1 showed different physical and physiological data which includes age, height, weight, BMI (Body Mass Index), HR (Heart Rate), SBP (Systolic Blood Pressure), DBP (Diastolic Blood Pressure) and experience of service of coal dust exposed as well as nonexposed group. It is evident from this table that there were no statistical significant differences ($p>0.050$) in age (years), height (cm), weight (kg), BMI and experience (years) of service between exposed and nonexposed groups. But, heart rate and systolic blood pressure were found to be significantly high ($p<0.050$) in exposed group as compared to nonexposed group. In addition, diastolic blood pressure was also high in exposed group as compared to nonexposed group but the difference was not significant statistically ($p>0.050$).

3.2. Comparisons in smoking addiction and pulmonary function status between exposed and nonexposed groups

Table 2 showed the association of smoking addiction and lung function status between exposed and nonexposed group. It can be seen from the table that addiction rate of smoking was slightly higher in nonexposed group (43.85 %) than exposed group (34.78 %) which is statistically insignificant as revealed by Chi square test ($p>0.050$). Besides this, abnormal lung function was found to be significantly high ($p<0.050$) in exposed group (43.91 %) when compared with nonexposed group (23.85 %).

3.3. Comparisons in respiratory morbidity between exposed and nonexposed group

Table 3 summarized respiratory ailments of exposed and nonexposed groups. A high prevalence of different respiratory ailments was reported by exposed workers than nonexposed workers. Among different respiratory complaints in exposed group, phlegm first thing in the morning (30%) were more prevalent which was also elevated when compared to the nonexposed group (8.46 %). Other complaints such as wheezing (26.52%), chest tightness (24.78%), coughing first thing in the morning (23.48%), shortness of breathing (16.99%) and coughing during the day or night (15.65%) were also found to be high in exposed group as compared to nonexposed group (wheezing-9.23%, chest tightness-15.38%, coughing first thing in the morning-12.31%, shortness of breathing-13.85% and coughing during the day or night-7.69%). It was found that there were significant ($p<0.050$) differences in respiratory ailments (except shortness of breath and chest tightness in the past) between exposed and nonexposed group.

3.4. Personnel Dust Exposure

The personnel dust exposure of the workers was monitored at different sites of underground by the safety department of that respective coal mine. Direct measurements of dust levels at different coalfaces showed that main return [network of airways that run from different workings to the bottom of the exit gate for polluted air from the mine to the surface are termed as returns] was the dustiest area where level of dust concentration was 3.36 mg/m^3. The mean level of coal dust exposure at work face was found to be 2.02 mg/m^3 which were higher than the recommended value of NIOSH (1 mg/m^3). The value of personnel dust exposure of workers worked at main intake [network of airways running from the bottom of downcast i.e. entry gate for fresh air from the atmosphere that is surface to the underground, to different workings in underground are termed as intakes] was 0.96 mg/m^3 (Table 4).

3.5. Comparisons in different pulmonary function indices between exposed and nonexposed group

Different lung function indices of pulmonary function test can be used to diagnose ventilatory disorders and differentiate between obstructive and restrictive lung diseases. These lung function indices include FVC (it is the amount of air that can be forcibly exhaled from lungs after taking the deepest breath possible), FEV_{1s} (it is the maximum volume of air that can be forcefully expired within 1 second after maximal inspiration), FEV_{1s}/FVC ratio also called Tiffeneau-Pinelli index (it is the ratio of FEV_{1s} to forced vital capacity expressed as a percentage), FEF_{25-}

$_{75\%}$(it is the amount of air of forced expiratory flow over the middle one half of the FVC), PEF (it is the maximum airflow rate attained during forced expiration) and MVV (it is the maximum volume of air expired in a specified period during repetitive maximal effort).

Quantitative measurements of respiratory functions by spirometer, which is one of the best tools for measuring lung volumes, showed that coal dust exposed workers have lower pulmonary volumes as compared to the nonexposed workers. Table 5 summarizes different observed and predicted values of pulmonary function indices of exposed workers as well as nonexposed workers. Evaluation of pulmonary function data revealed that observed value of FVC (L), FEV_{1s} (L), FEV_{1s}/FVC ratio (%), FEF25-75% (L/s), PEF (L/s) and MVV (L/min) were significantly decreased in exposed group (2.72, 2.14, 78.13, 2.21, 4.78 and 70.84, respectively) when compared to nonexposed group (2.97, 2.46, 82.61, 2.54, 5.56 and 83.83, respectively). Moreover, the percent predicted value was also found to be more near to 100% in case of nonexposed group but coal exposed workers showed much lower value of percent predicted than 100%. This decline of pulmonary volumes was associated with the exposure of coal dust.

3.6. Comparisons in pulmonary function indices stratified by length of service

Table 6 showed the data of pulmonary function indices based on length of the service. Exposed and nonexposed subjects were further divided into four different groups according to their work experience: ≤ 10 years, 11-20 years, 21-30 years, and 31-40 years.

It can be seen from the table 6 where exposure time was ≤10 years, the deterioration of lung volumes was not affected that much and there were no statistical significant difference in between exposed and nonexposed group which may be due to low time exposure to coal dust areas. But as the experience increases (exposure time), the pulmonary function indices were significantly deteriorate in exposed group as compared to nonexposed group (Table 6). This result is an indicative of the fact that impairment of pulmonary function depends on the duration of coal dust exposure.

3.7. Comparisons in lung function status according to exposure time between exposed and nonexposed groups

Experience based association of pulmonary function between exposed and nonexposed group depicts that there were no significant differences (p>0.050) in the groups of ≤ 10 years and 11-20 years. But the subjects having working experience of 21-30 years and 31-40 years showed statistical significant difference when lung function status was compared according to subjects' working experience as revealed by chi square test (Table 7).

3.8. Correlation between lung function indices and service length

Figure 1- 6 showed the scatter plots of different lung function indices and duration of work in the respective areas of both exposed and nonexposed workers. It was found that the variables analyzed showed higher level of negative correlation in exposed workers than the nonexposed workers indicating the exposure dependent deterioration of lung volumes in coal dust exposed employees (Table 8).

3.9. Description of per year change in lung function indices of exposed and nonexposed group

Table 9 represents the change in lung volumes in respect to duration of exposure. Results revealed that per year change in different lung volumes was more in coal exposed employees than the nonexposed employees.

4. Discussion

Occupation induced respiratory diseases among coal miners at the workplace have dreadful effects on miners' health and also the national asset. It has been reported by National Institute for

Occupational Safety and Health (NIOSH) that mortality from occupation induced respiratory diseases and cancers responsible for about 70% of all occupation induced deaths [16]. With the advancement of technology and increasing mechanization, the dust concentration is also being increased. Consequently, research in order to control respirable and inhalable dust, and ultimately to reduce work related hazardous injuries and diseases, remained to be the big demand in underground coal mining. Though, there are few cross sectional and longitudinal studies that explored the relation between increased exposure to respirable coal dust and impairment of lung function [11], there is a paucity of literature particularly in West Bengal, India that tried to establish the exposure dependent implications of coal dust on lung function impairment. So, this study was aimed to evaluate the exposure dependent degree of deterioration in lung volumes among coal miners and, to create and improve an advanced understanding of the occupational health for such workers.

Pneumoconiosis among coal miners is one of the most prevalent lung disease caused due to inhalation of coal dust at work site [17]. In this study, high percentage of lung function impairment was found in exposed group (43.91 %) than nonexposed group (23.85 %), indicating the increased deterioration in pulmonary function are the risk factors for development of CWP among coal miners [18]. Result on the prevalence of lung function impairment in the present study is comparable to those reported in coal miner of Tangshan, China where prevalence of lung function impairment was 35.1 % in coal exposed workers and 10.1 % in control subjects [15].

In the present study, respiratory ailments were more severe and prevalent among coal exposed employees as compared to nonexposed employees. Phlegm first thing in the morning was the most common symptoms in exposed group which was in consistent with other study in which the percentage of subjects with phlegm was 36.4% in coal miners [9]. Other respiratory ailments were also higher in case of coal exposed workers than nonexposed workers. These results were comparable to those where rate of wheezing and coughing were 33.0 % and 31.9 %, respectively [9]. Moreover, significant associations were observed between variables of different respiratory symptoms in exposed and nonexposed subjects suggesting that coal mine workers are more susceptible to respiratory impairment due to the environmental conditions and their lifestyle.

Coal dust produced during mining, crushing or transporting are continuously being inhaled by workers at their working time. In this study, the mean dust concentration at work face ($2.02 mg/m^3$) was found to be higher than the NIOSH ($1 mg/m^3$) and MSHA ($2 mg/m^3$ to $1.5 mg/m^3$) recommended permissible exposure limit for respirable coal dust [12,19]. Long term inhalation of coal dust which contains fine carbon-rich suspended particulate, mainly below the diameter of 2.5 μm can cause chronic health situations like CWP and silicosis [2]. CWP and silicosis are major lung disease associated with reduced lung volumes and ultimately premature death. This study also demonstrates that long term exposure to coal dust at underground mine significantly decreased the pulmonary function in coal exposed workers. It has been reported earlier that in coal dust exposed employees the occurrence of pneumoconiosis seen after the average exposure of 10 years [9]. Findings of the present study also revealed that significant decrease was observed in the group where the length of service was more than 10 years. Different pulmonary function indices were significantly decreased in the exposed group according to the increasing length of the service, suggesting that with the advancement of service the continuous inhalation of coal dust hampers pulmonary ventilation. Prolonged exposure to coal dust can disturb normal process of lung ventilation and exchange of air by causing lung nodules and interstitial fibrosis [20, 21].

In addition, the correlation between lung function indices and duration of exposure to coal mine dust had been assessed by other study and reported that there was lack of significant differences between the variables [9]. However, in this study high negative correlation was found between the variables of lung function indices and duration of occupational exposure in the coal exposed group than the nonexposed group. Similar alterations in lung function were also reported by a group of researchers in a cross sectional study among ceramics industry workers [22]. The workers showed a negative correlation between the duration of exposure to pollutants in ceramics industry and lung function indices. Furthermore, study on workers of Norwegian silicon carbide plants showed a consecutive decline in FEV_{1s} each year after the exposure [23]. The exposure dependent implications not only affect the workers' life quality but also hamper the output of that occupation. This study explored the successive deterioration in lung volumes with respect to exposure time which results in deleterious effects on workers' health. So, the result found in this study represents important information on lung function and other respiratory problems which would help the management of the occupation to continuously guide the workers for good health, inspire the workers towards a good health practices and monitor the working site.

5. Conclusion

Occupational exposure to coal dust has high impact on lung function impairment among coal miners. In continuation, a high percentage of reduction in different lung function indices was found in exposed group as compared to nonexposed group in the present study. In addition, a significant association was found in respiratory symptoms between exposed and nonexposed workers. Moreover, the value of mean dust concentration at workforce was exceeded than recommended levels (NIOSH and MSHA) and also, significant negative correlation was found in work experience and lung function indices. Based on the findings of experience related deterioration it is required to reduce dust level at working site. The management should improve health checkup facility and arrange awareness programme to combat against long term exposure dependent health hazards caused due to occupational exposure. Workers should also go for their health checkup at an interval of at least two consecutive years including the lung function test (spirometry) and should use precautionay remedies during their working hours.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Figure Legends

Figure 1. Scatter plots of the correlation between FVC (observed value and % predicted) and work experience of exposed and nonexposed group. (A and C – Exposed), (B and D – Nonexposed)

Figure 2. Scatter plots of the correlation between FEV_{1S} (observed value and % predicted) and work experience of exposed and nonexposed group. (A and C – Exposed), (B and D – Nonexposed)

Figure 3. Scatter plots of the correlation between FEV_{1S}/FVC (ratio) and work experience of exposed and nonexposed group. (A – Exposed), (B – Nonexposed)

Figure 4. Scatter plots of the correlation between FEF25-75% (observed value and % predicted) and work experience of exposed and nonexposed group. (A and C – Exposed), (B and D – Nonexposed)

Figure 5. Scatter plots of the correlation between PEF (observed value and % predicted) and work experience of exposed and nonexposed group. (A and C – Exposed), (B and D – Nonexposed)

Figure 6. Scatter plots of the correlation between MVV (observed value and % predicted) and work experience of exposed and nonexposed group. (A and C – Exposed), (B and D – Nonexposed)

Table 1.Comparisons of physical, physiological variables and experience of service between coal dust exposed and nonexposed group.

Parameter	Exposed (n=230)		Nonexposed (n=130)		Significance level (*p*)
	M±sd	*Mdn*	*M*±sd	*Mdn*	
Age (years)	44.06±8.56	45.00	44.05±8.34	45.00	ns
Height (cm)	165.56±6.69	165.40	166.71±6.04	166.10	ns
Weight (kg)	67.44±9.78	68.00	68.48±9.77	68.50	ns
BMI	24.56±2.88	24.52	24.62±3.21	24.54	ns
HR (bpm)	78.86±10.04	79.00	76.54±11.02	76.00	<0.050
SBP (mmHg)	139.26±16.44	138.00	135.47±16.31	132.00	<0.050
DBP (mmHg)	85.34±9.20	86.00	83.59±9.14	83.00	ns
Experience (years)	20.96±8.73	22.00	19.73±8.43	20.00	ns

Note: HR = Heart Rate; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure

Table 2. Comparisons in smoking rate and lung function status between coal dust exposed and nonexposed group.

Group	Exposed (n=230)	Nonexposed (n=130)	χ^2	Significance level (*p*)
Smoking distribution				
Smoker	80 (34.78)	57 (43.85)	2.89	ns
Nonsmoker	150 (65.22)	73 (56.15)		
Pulmonary function				
Normal	129 (56.09)	99 (76.15)	14.4	<0.001
Impaired	101 (43.91)	31 (23.85)		

Table 3.Comparisons in respiratory ailments between coal dust exposed and nonexposed group.

Respiratory disorder		Exposed (n=230) Frequency	Exposed (n=230) Percent	Nonexposed (n=130) Frequency	Nonexposed (n=130) Percent	χ^2	Significance level (*p*)
Coughing 1st thing in the morning	Yes	54	23.48	16	12.31	6.6165	<0.050
	No	176	76.52	114	87.69		
Coughing during the day or night	Yes	36	15.65	10	7.69	4.7217	<0.050
	No	194	84.35	120	92.31		
Phlegm	Yes	69	30	11	8.46	22.2923	<0.001
	No	161	70	119	91.54		
Phlegm during the day or night	Yes	38	16.52	5	3.85	12.6877	<0.001
	No	192	83.48	125	96.15		
Wheezing	Yes	61	26.52	12	9.23	15.3606	<0.001
	No	169	73.48	118	90.77		
Shortness of Breath	Yes	39	16.96	18	13.85	0.6029	ns
	No	191	83.04	112	86.15		
Chest tightness	Yes	57	24.78	20	15.38	4.3628	<0.050
	No	173	75.22	110	84.62		
Chest tightness in the past	Yes	21	9.13	5	3.85	3.4612	ns
	No	209	90.87	125	96.15		

Table 4.Value of coal dust at different work face

Mine area	(n)	Personnel dust exposure M (range) mg/m^3
Main intake	24	0.96 (0.208-1.87)
Face miners	230	2.02 (0.62-4.6)
Main return	25	3.36 (1.25-4.79)

Table 5.Comparisons in pulmonary function indices between coal dust exposed and nonexposed group.

	Exposed (n=230)		Nonexposed (n=130)		
Parameter	M±SD	*Mdn*	M ±SD	Median	Significance level (p)
FVC (L)	2.72±0.58	2.72	2.97±0.73	2.88	<0.001
FVC (% predicted)	82.94±14.25	84.98	88.84±19.25	87.89	<0.010
FEV_{1s} (L)	2.14±0.57	2.18	2.46±0.64	2.44	<0.001
FEV_{1s} (% predicted)	87.22±20.17	88.72	98.29±22.45	97.91	<0.001
FEV_{1s}/FVC ratio (%)	78.13±9.66	80.25	82.61±5.98	83.78	<0.001
FEF25-75% (L/s)	2.21±0.69	2.18	2.54±0.62	2.51	<0.001
FEF25-75% (%predicted)	86.51±23.62	85.60	98.47±22.55	101.83	<0.001
PEF (L/s)	4.78±1.34	4.60	5.56±1.17	5.50	<0.001
PEF (% predicted)	68.05±17.41	67.96	78.06±14.62	77.52	<0.001
MVV (L/min)	70.84±19.58	69.36	83.19±20.55	83.83	<0.001
MVV (% predicted)	71.67±17.73	71.80	82.87±19.13	81.58	<0.001

Note: FVC = Forced Vital Capacity; FEV_{1s} = Forced Expiratory Volume in one second; FEF25-75% = Forced Expiratory Flow 25-75%; MVV= Maximum Voluntary Ventilation; PEF= Peak Expiratory Flow.

Table 6.Comparisons in pulmonary function indices based on service duration between coal dust exposed and nonexposed group.

Nonexposed (n=130)								
	≤ 10 Years (n=21)		11-20 Years (n=46)		21-30 Years (n=49)		31-40 Years (n=14)	
Parameter	*M*±SD	*Mdn*	*M* ±SD	*Mdn*	*M* ±SD	*Mdn*	*M* ±SD	*Mdn*
Age (years)	30.95±4.30	30.00	41.07±3.78^{a***}	40.00	49.14±3.73^{b***}	49.00	55.64±3.05^{c***}	55.50
Experience (years)	6.48±2.24	6.00	15.98±2.62^{a***}	16.00	25.00±2.54^{b***}	25.00	33.50±2.68^{c***}	33.00
FVC (L)	3.38±0.82	3.15	3.09±0.67$^{a\ ns}$	2.94	2.73±0.65^{b***}	2.75	2.81±0.76^{c*}	2.77
FVC (% Predicted)	98.02±24.81	90.73	92.24±16.22$^{a\ ns}$	89.43	82.89±17.33^{b**}	85.84	84.72±19.52$^{c\ ns}$	86.55
FEV_{1s} (L)	2.82±0.62	2.69	2.58±0.58$^{a\ ns}$	2.53	2.24±0.59^{b***}	2.25	2.29±0.69^{c*}	2.29
FEV_{1s} (% Predicted)	108.73±25.40	95.73	102.78±18.53$^{a\ ns}$	100.52	91.03±21.72^{b**}	93.48	93.28±24.54$^{c\ ns}$	100.90
FEV_{1s}/FVC (%)	83.95±4.56	85.54	83.41±4.14$^{a\ ns}$	84.13	81.75±7.52$^{b\ ns}$	83.61	81.03±6.59$^{c\ ns}$	81.90
FEF25-75% (L/s)	2.89±0.60	2.79	2.70±0.55$^{a\ ns}$	2.78	2.32±0.61^{b***}	2.40	2.25±0.53^{c**}	2.27
FEF25-75% (%Predicted)	107.33±21.08	110.96	104.13±20.42$^{a\ ns}$	106.48	91.58±23.82^{b*}	94.87	90.68±18.48^{c*}	90.90
PEF (L/s)	6.38±0.82	6.45	5.67±0.89^{a**}	5.60	5.20±1.33^{b***}	4.94	5.25±1.23^{c**}	5.23
PEF (%Predicted)	87.38±9.76	87.42	79.67±10.25^{a**}	78.92	73.66±17.08^{b**}	71.16	74.23±17.12^{c**}	72.48
MVV (L/min)	92.19±13.39	92.71	88.69±15.42$^{a\ ns}$	88.88	76.67±23.43^{b**}	73.80	74.43±24.14^{c**}	74.23
MVV (% Predicted)	89.63±15.92	92.49	88.35±14.24$^{a\ ns}$	88.24	77.23±21.42^{b*}	77.00	74.47±21.71^{c*}	76.57
Exposed (n=230)								
	≤ 10 Years (n=37)		11-20 Years (n=70)		21-30 Years (n=97)		31-40 Years (n=26)	
Parameter	*M*±SD	*Mdn*	*M* ±SD	*Mdn*	*M* ±SD	*Mdn*	*M* ±SD	*Mdn*
Age (years)	30.37±3.49$^{d\ ns}$	30.00	40.21±3.67$^{a***e\ ns}$	40.00	48.75±3.53$^{b***f\ ns}$	49.00	56.38±2.68$^{c***g\ ns}$	56.50
Experience (years)	7.13±2.19$^{d\ ns}$	8.00	16.57±2.75$^{a***e\ ns}$	17.00	25.45±2.46$^{b***f\ ns}$	26.00	35.65±2.73^{c***g*}	35.00
FVC (L)	3.34±0.54$^{d\ ns}$	3.20	2.86±0.45^{a***e*}	2.91	2.48±0.47^{b***f*}	2.51	2.28±0.42^{c***g**}	2.27
FVC (% Predicted)	93.60±12.00$^{d\ ns}$	92.90	86.22±11.13^{a**e*}	87.21	78.67±14.52$^{b***f\ ns}$	79.65	74.87±12.77$^{c***g\ ns}$	73.14
FEV_{1s} (L)	2.75±0.46$^{d\ ns}$	2.69	2.29±0.42^{a***e**}	2.26	1.91±0.47^{b***f***}	2.00	1.65±0.43^{c***g***}	1.68
FEV_{1s} (% Predicted)	101.52±15.14$^{d\ ns}$	102.76	92.60±17.13^{a**e**}	91.68	81.13±20.35^{b***f**}	83.40	75.08±17.75^{c***g*}	75.00
FEV_{1s}/FVC (%)	82.41±6.34$^{d\ ns}$	82.28	79.95±6.45$^{a\ ns\ e**}$	81.61	76.84±11.09^{b**f**}	78.96	71.96±11.25^{c***g**}	71.84
FEF25-75% (L/s)	2.83±0.78$^{d\ ns}$	2.63	2.38±0.57^{a**e**}	2.36	2.01±0.57^{b***f**}	2.04	1.65±0.38^{c***g***}	1.64
FEF25-75% (%Predicted)	100.10±26.85$^{d\ ns}$	103.85	91.77±21.81$^{a\ ns\ e**}$	90.30	80.85±22.37^{b***f**}	81.70	74.10±14.25^{c***g**}	74.83
PEF (L/s)	6.15±1.61$^{d\ ns}$	5.70	4.96±1.20^{a***e***}	4.67	4.38±1.01^{b***f***}	4.47	3.83±0.71^{c***g***}	3.74
PEF (%Predicted)	82.33±20.20$^{d\ ns}$	77.37	70.29±16.17^{a**e**}	68.27	63.91±14.96^{b***f***}	67.35	57.09±9.94^{c***g***}	56.81
MVV (L/min)	89.73±19.13$^{d\ ns}$	84.90	76.98±15.25^{a***e***}	78.18	63.17±16.88^{b***f***}	63.30	55.99±12.42^{c***g**}	56.05
MVV (% Predicted)	84.09±16.47$^{d\ ns}$	82.61	77.28±14.97^{a*e***}	77.81	65.81±17.37^{b***f***}	66.39	60.75±11.73^{c***g*}	63.17

* *p*<0.050, ***p*<0.010, ****p*<0.001

[a] ≤ 10 years vs. 11-20 years, [b] 11-20 years vs. 21-30 years, [c] 21-30 years vs. 31-40 years, [d] nonexposed vs. exposed (≤ 10 years), [e] nonexposed vs. exposed (11-20 years), [f] nonexposed vs. exposed (21-30 years), [g] nonexposed vs. exposed (31-40 years).

Note: FVC = Forced Vital Capacity; FEV1s = Forced Expiratory Volume in one second; FEF25-75% = Forced Expiratory Flow 25-75%; MVV= Maximum Voluntary Ventilation; PEF= Peak Expiratory Flow.

Table 7.Comparisons in lung function status based on service experience between exposed and nonexposed group.

	Exposed (n=230)				Nonexposed (n=130)					
	Normal		Impaired		Normal		Impaired			
Experience	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	$\chi2$	Significance level (*p*)
≤ 10 Years	31	83.78	6	16.22	18	85.71	3	14.29	0.0381	ns
11-20 Years	52	74.28	18	25.72	39	84.78	7	15.22	1.8091	ns
21-30 Years	42	43.3	55	56.7	34	69.39	15	30.61	8.878	<0.010
31-40 Years	4	15.38	22	84.62	8	57.14	6	42.86	7.5563	<0.010

Table 8. Product-moment correlation coefficient between experience of the service and lung function indices of coal dust exposed and nonexposed group.

Parameter	Experience (Years) vs. Lung Function Test					
	Exposed (n=230)			Nonexposed (n=130)		
	r	R^2	Significance level (p)	r	R^2	Significance level (p)
FVC (L)	-0.6072	0.3687	0.001	-0.2929	0.0858	<0.001
FVC (% predicted)	-0.4759	0.2265	0.001	-0.2676	0.0716	<0.010
FEV_{1s} (L)	-0.6446	0.4155	0.001	-0.3128	0.0978	<0.001
FEV_{1s} (% predicted)	-0.4856	0.2358	0.001	-0.2753	0.0758	<0.010
FEV_{1s}/FVC ratio (%)	-0.3484	0.1214	0.001	-0.1617	0.0261	ns
FEF25-75% (L/s)	-0.5186	0.2689	0.001	-0.3697	0.1367	<0.001
FEF25-75% (% predicted)	-0.3672	0.1348	0.001	-0.2979	0.0887	<0.001
PEF (L/s)	-0.5199	0.2703	0.001	-0.3041	0.0925	<0.001
PEF (% predicted)	-0.4451	0.1981	0.001	-0.2875	0.0827	<0.001
MVV (L/min)	-0.5890	0.3469	0.001	-0.3287	0.1080	<0.001
MVV (% predicted)	-0.4899	0.2400	0.001	-0.3090	0.0955	<0.001

Note: FVC = Forced Vital Capacity; FEV_{1s} = Forced Expiratory Volume in one second; FEF25-75% = Forced Expiratory Flow 25-75%; MVV= Maximum Voluntary Ventilation; PEF= Peak Expiratory Flow.

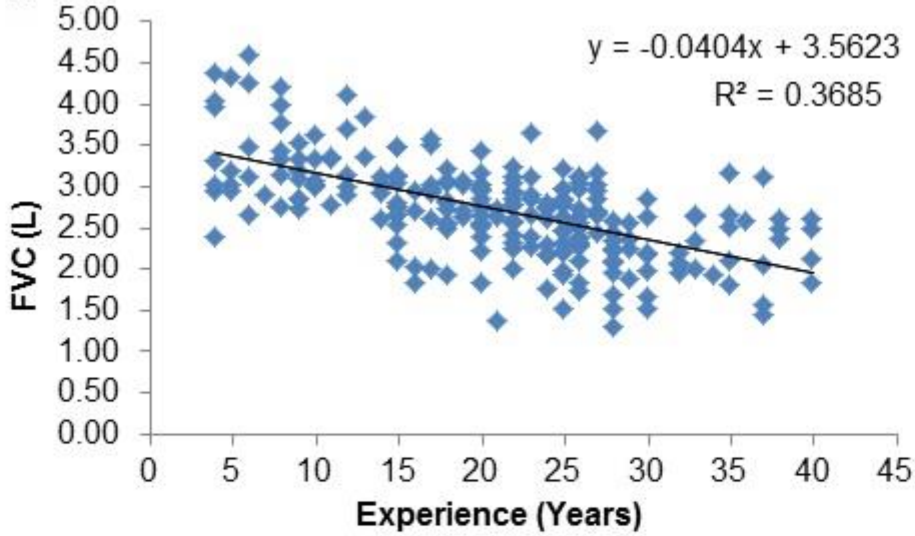
Table 9. Per year change in lung function indices of coal dust exposed and nonexposed subjects

Parameter	Exposed (n=230)	Nonexposed (n=130)
FVC (ml)	32.71↓	6.99↓
FVC (%)	0.67 ↓	0.03↑
FEV_{1s} (ml)	39.66↓	9.49↓
FEV_{1s} (%)	1.08↓	0.02↑
FEV_{1s}/FVC (%)	0.49↓	0.13↓
FEF25-75% (ml)	35.34↓	23.24↓
FEF25-75% (%)	0.63↓	0.32↓
PEF (ml)	72.82↓	48.00↓
PEF (%)	1.00↓	0.45↓
MVV (ml)	1368.52↓	625.55↓
MVV (%)	1.09↓	0.35↓

↑-Increase, ↓-Decrease

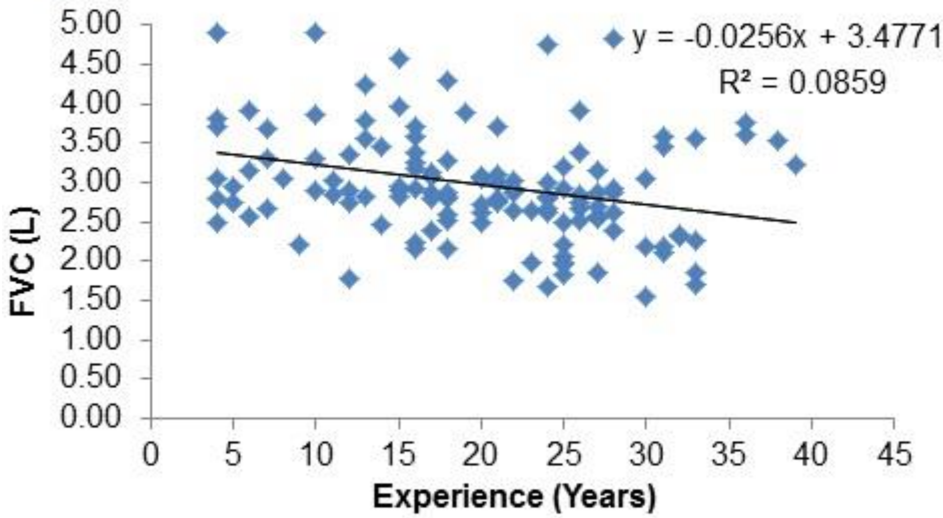
Note: FVC = Forced Vital Capacity; FEV_{1s} = Forced Expiratory Volume in one second; FEF25-75% = Forced Expiratory Flow 25-75%; MVV= Maximum Voluntary Ventilation; PEF= Peak Expiratory Flow.

A

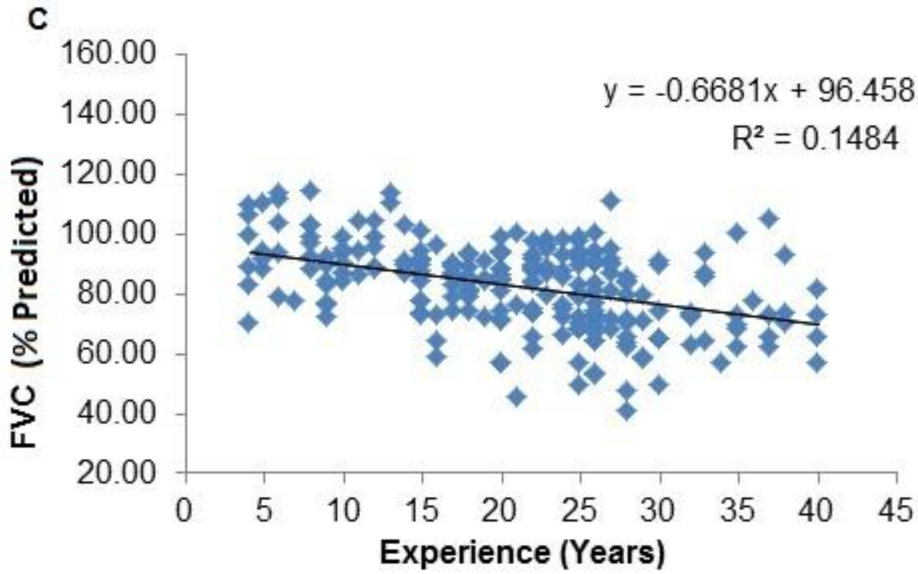


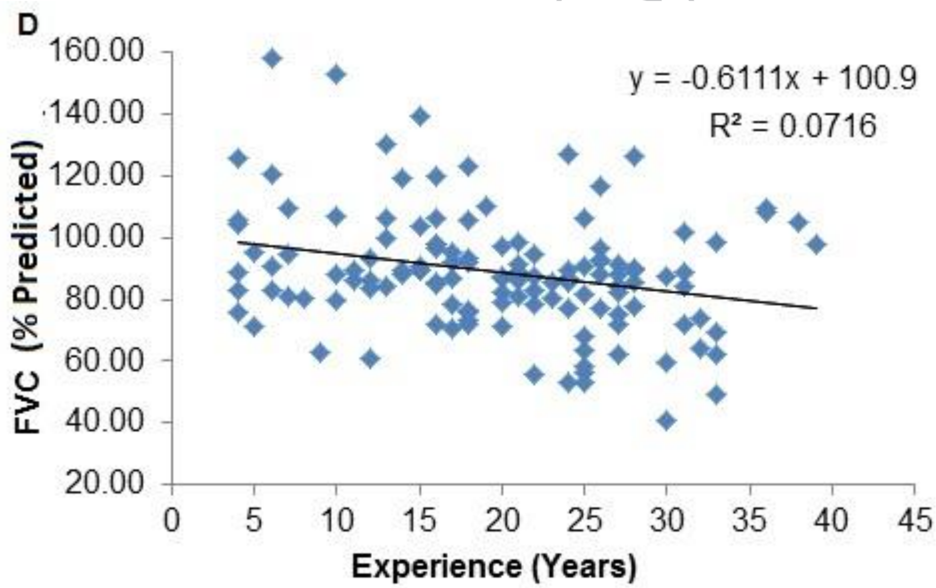
y = -0.0404x + 3.5623
R² = 0.3685
FVC (L)
Experience (Years)

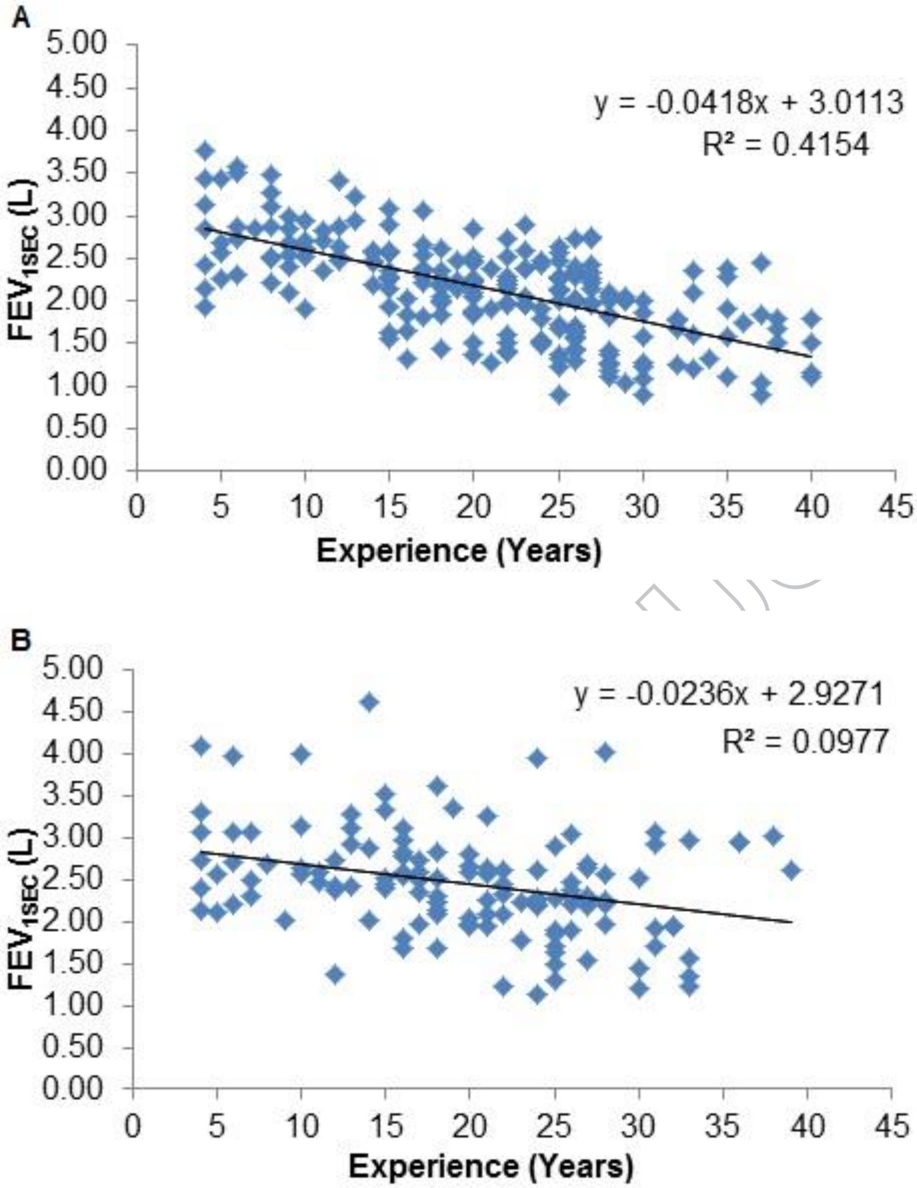
B

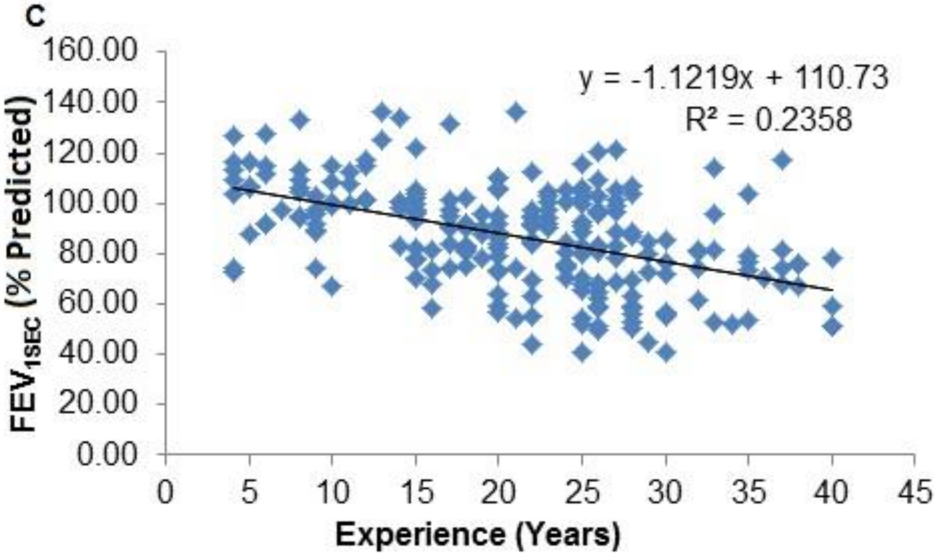


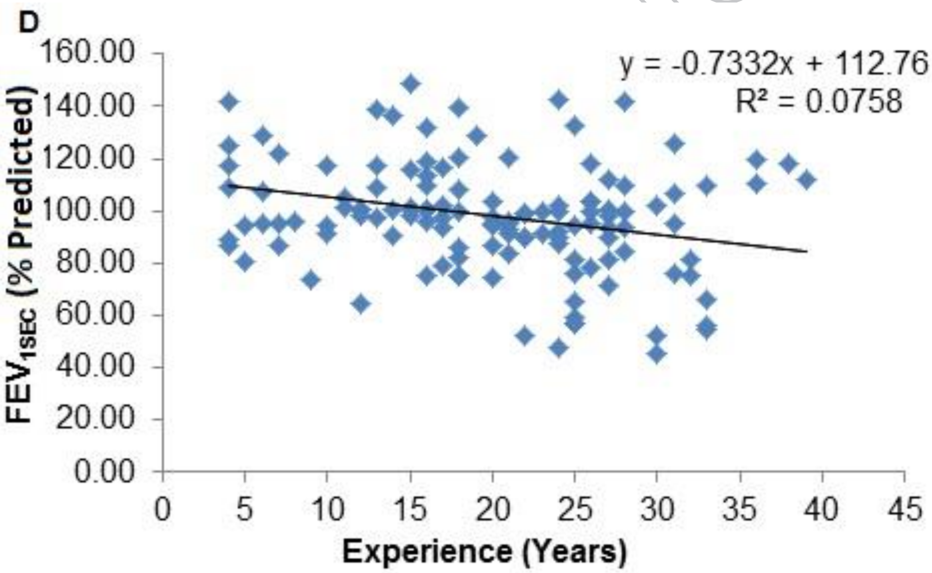
y = -0.0256x + 3.4771
R² = 0.0859
FVC (L)
Experience (Years)

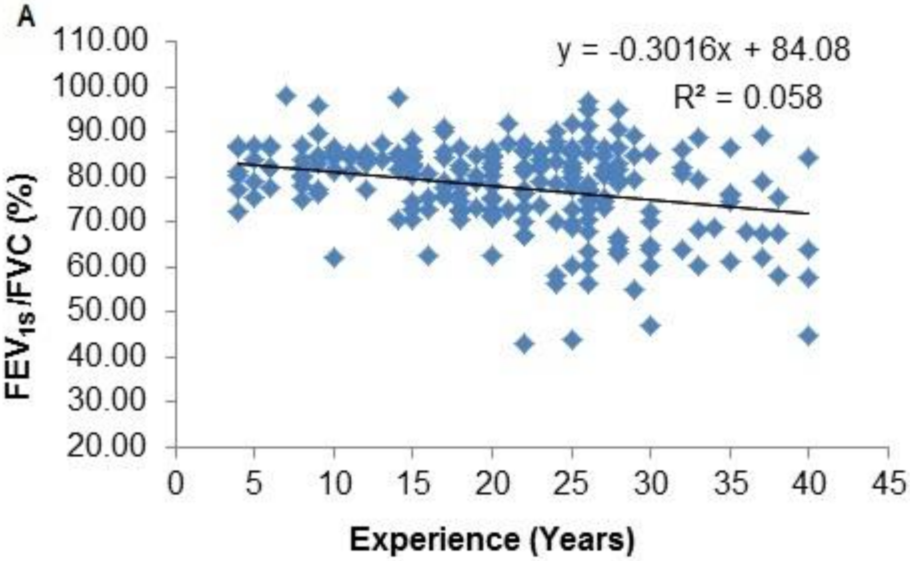

C
y = -0.6681x + 96.458
R² = 0.1484
FVC (% Predicted)
Experience (Years)

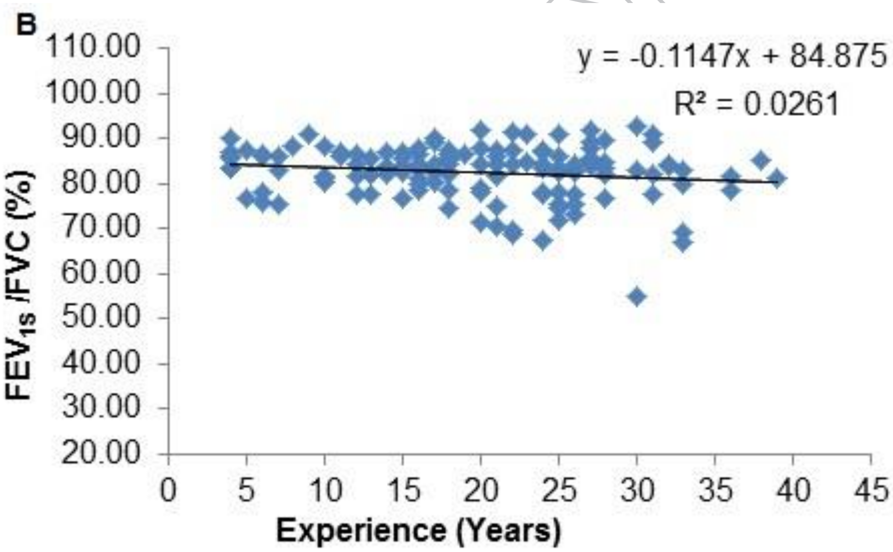

D
y = -0.6111x + 100.9
R² = 0.0716
FVC (% Predicted)
Experience (Years)

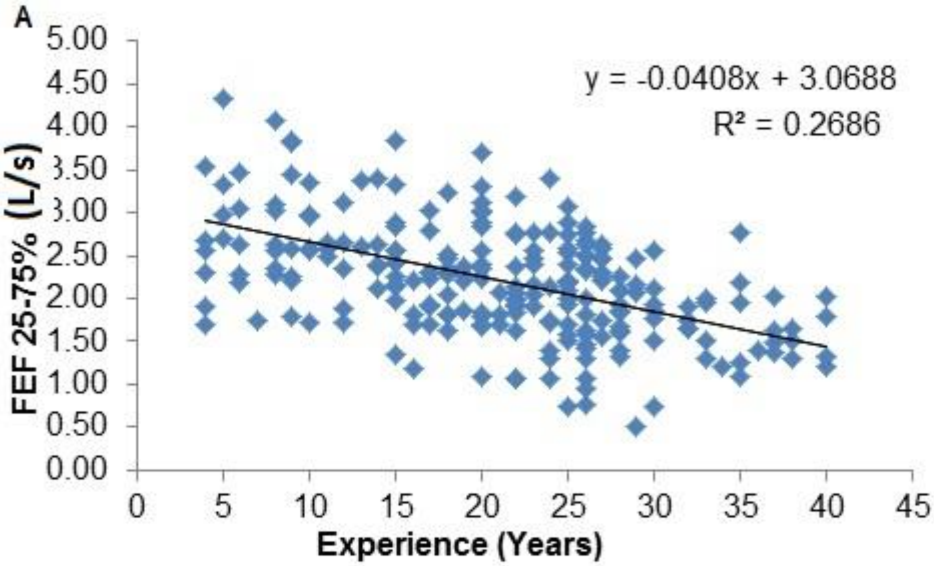

A
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
FEV1SEC (L)
y = -0.0418x + 3.0113
R² = 0.4154
0
5
10
15
20
25
30
35
40
45
Experience (Years)
B
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
FEV1SEC (L)
y = -0.0236x + 2.9271
R² = 0.0977
0
5
10
15
20
25
30
35
40
45
Experience (Years)

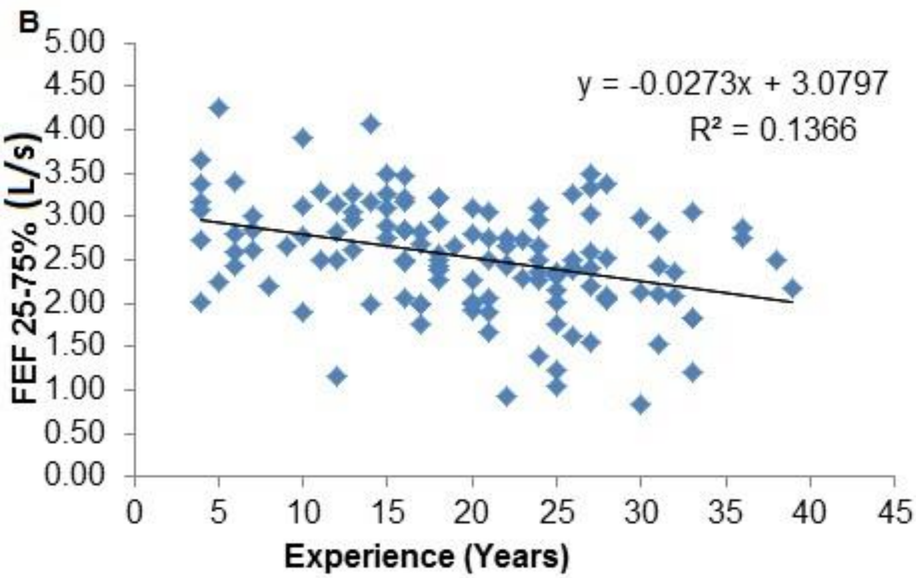

C
y = -1.1219x + 110.73
R² = 0.2358
FEV1SEC (% Predicted)
Experience (Years)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
15
20
25
30
35
40
45

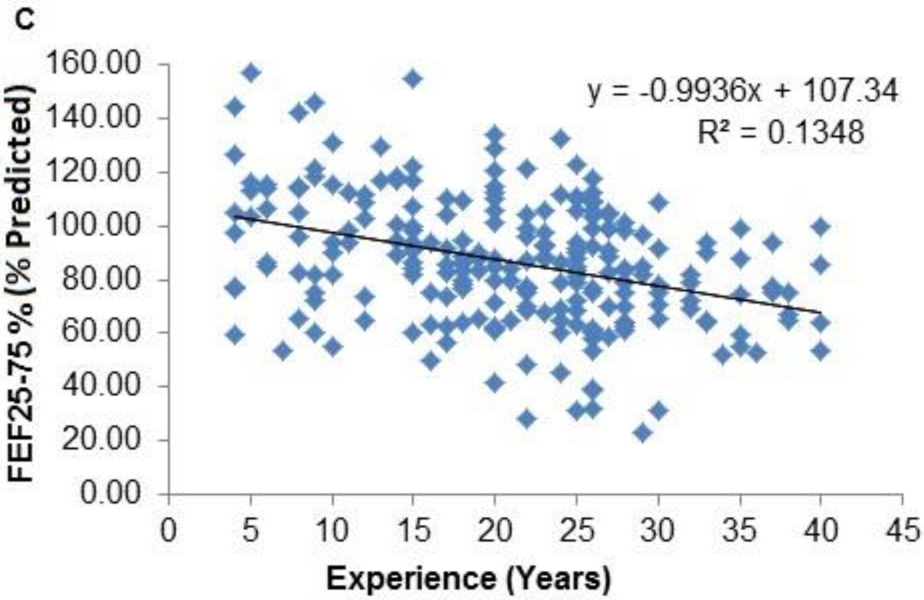

D
y = -0.7332x + 112.76
R² = 0.0758
FEV1SEC (% Predicted)
Experience (Years)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
15
20
25
30
35
40
45

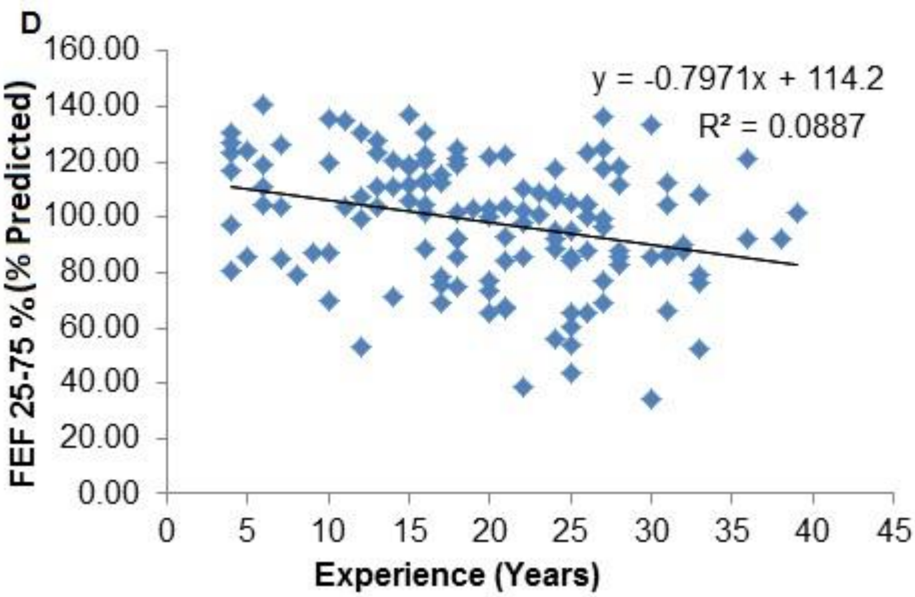

A
y = -0.3016x + 84.08
R² = 0.058
FEV1s /FVC (%)
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
0
5
10
15
20
25
30
35
40
45
Experience (Years)

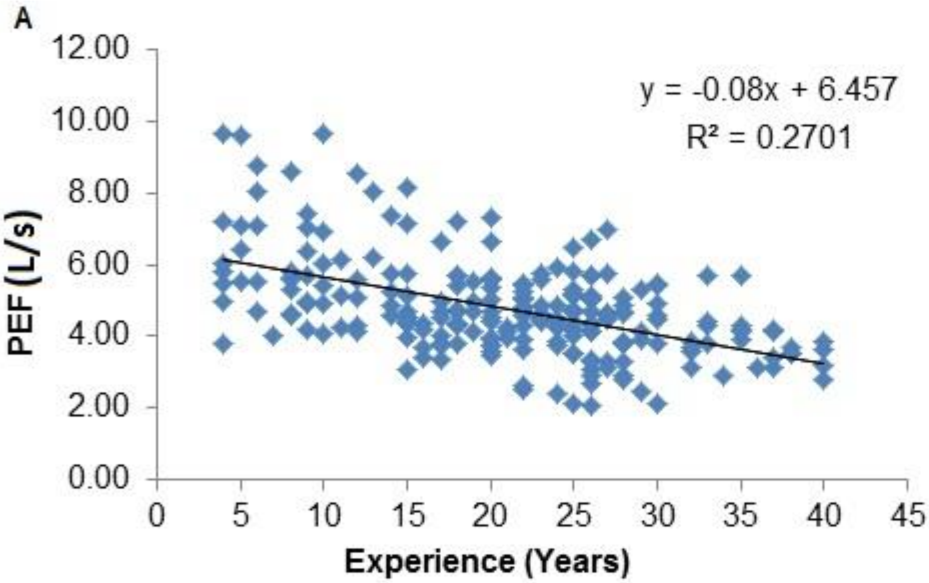

B
y = -0.1147x + 84.875
R² = 0.0261
FEV1s /FVC (%)
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
0
5
10
15
20
25
30
35
40
45
Experience (Years)

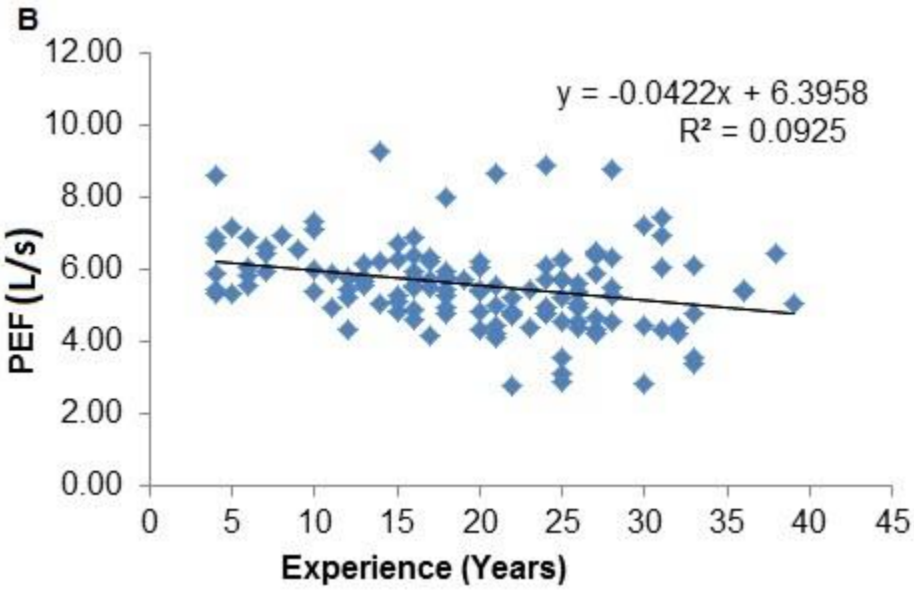

A
y = -0.0408x + 3.0688
R² = 0.2686
FEF 25-75% (L/s)
Experience (Years)

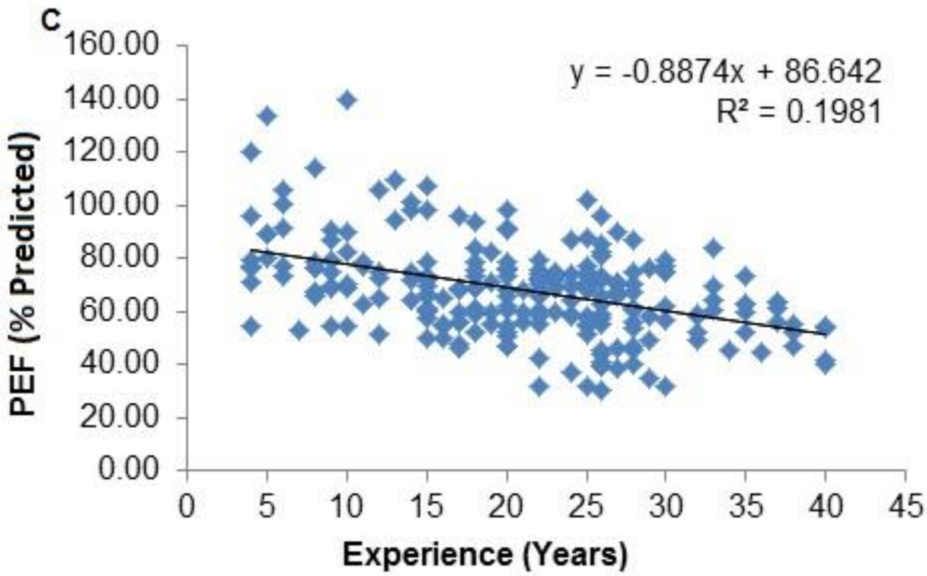

B
y = -0.0273x + 3.0797
R² = 0.1366
FEF 25-75% (L/s)
Experience (Years)

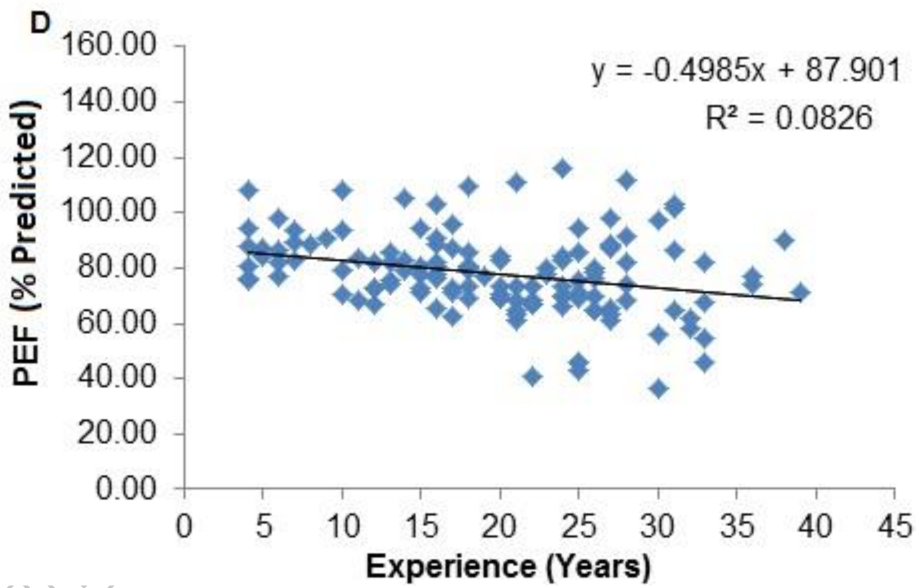

C
y = -0.9936x + 107.34
R² = 0.1348
FEF25-75 % (% Predicted)
Experience (Years)

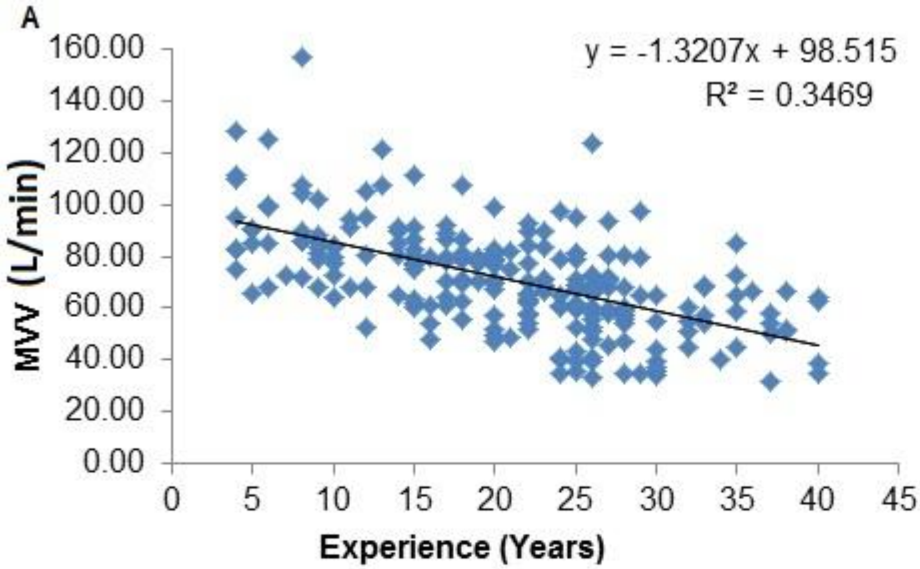

D
y = -0.7971x + 114.2
R² = 0.0887
FEF 25-75 % (% Predicted)
Experience (Years)

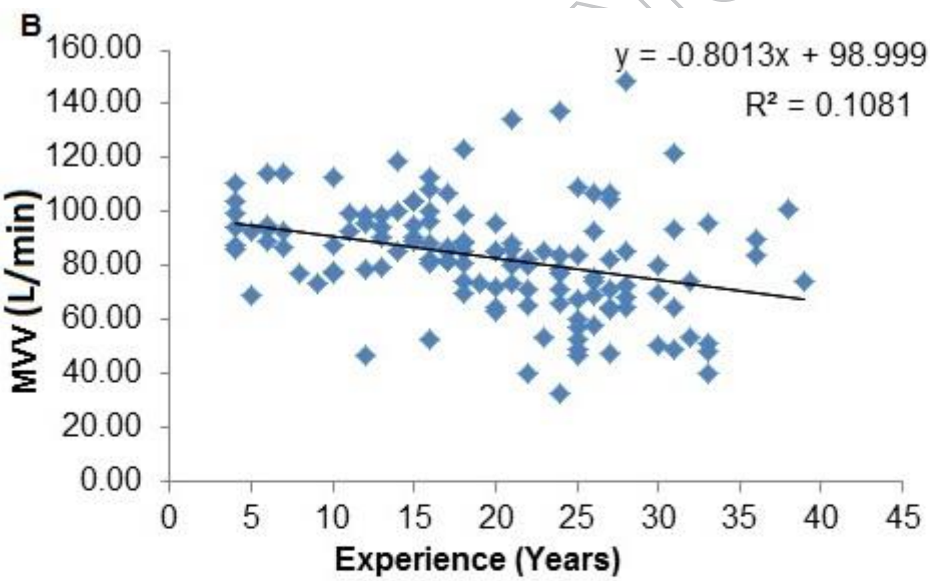

A
y = -0.08x + 6.457
R² = 0.2701
PEF (L/s)
Experience (Years)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
5
10
15
20
25
30
35
40
45

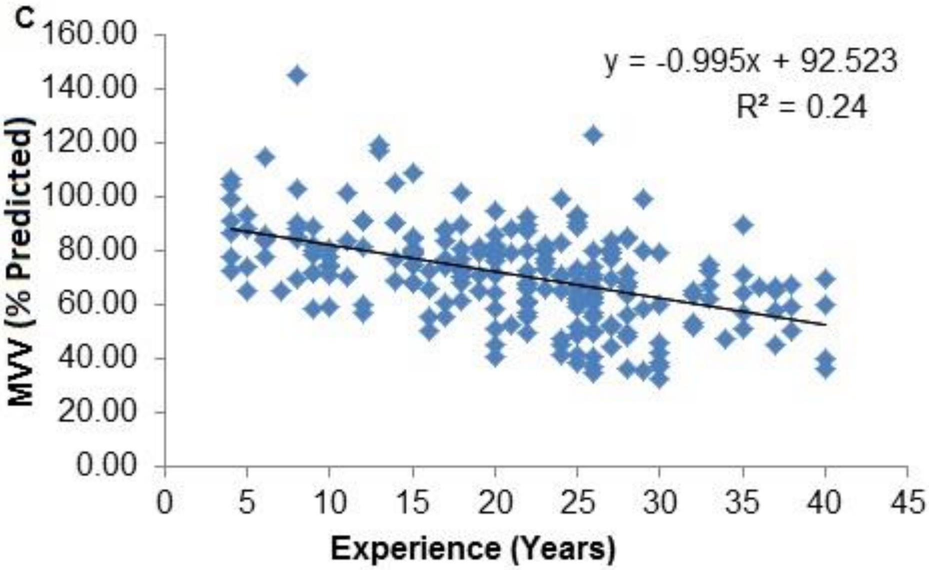

B
y = -0.0422x + 6.3958
R² = 0.0925
PEF (L/s)
Experience (Years)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
5
10
15
20
25
30
35
40
45

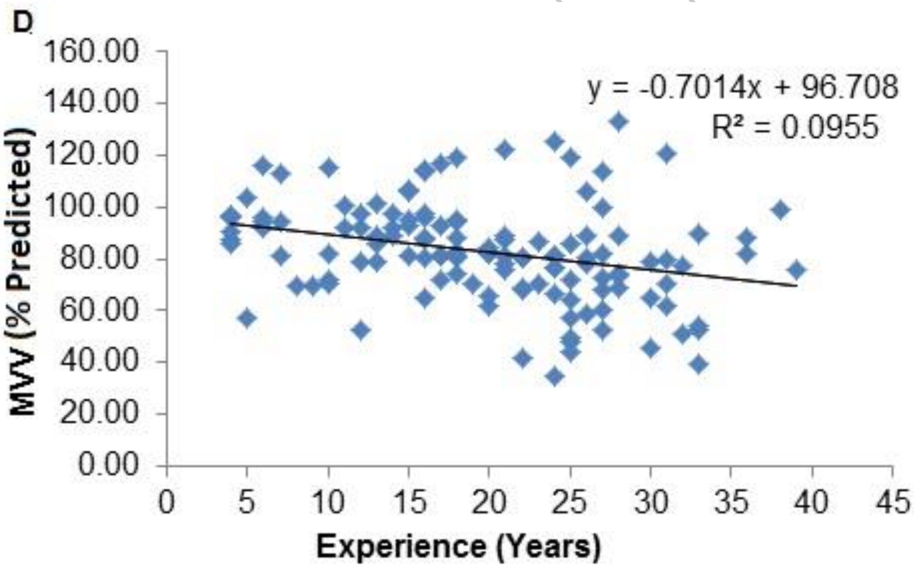

C
y = -0.8874x + 86.642
R² = 0.1981
PEF (% Predicted)
Experience (Years)


D
y = -0.4985x + 87.901
R² = 0.0826
PEF (% Predicted)
Experience (Years)


A
y = -1.3207x + 98.515
R² = 0.3469
MVV (L/min)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0 5 10 15 20 25 30 35 40 45
Experience (Years)


B
y = -0.8013x + 98.999
R² = 0.1081
MVV (L/min)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0 5 10 15 20 25 30 35 40 45
Experience (Years)


C
y = -0.995x + 92.523
R² = 0.24
MVV (% Predicted)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
15
20
25
30
35
40
45
Experience (Years)


D
y = -0.7014x + 96.708
R² = 0.0955
MVV (% Predicted)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
5
10
15
20
25
30
35
40
45
Experience (Years)