Turk Thorac J 2022; 23(6): 387-394 DOI: 10.5152/TurkThoracJ.2022.21230

Original Article

Post-COVID Pulmonary Function Test Evaluation

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Cite this article as: Afsin E, Demirkol ME. Post-COVID pulmonary function test evaluation. *Turk Thorac J.* 2022;23(6):387-394.

Abstract

OBJECTIVE: Since the lung is the most affected organ by COVID-19 disease, we aimed to evaluate the pulmonary function test, presence of hypoxemia, and Post-COVID-19 Functional Status Scale in 3- to 6-month post-COVID period.

MATERIAL AND METHODS: Post-COVID-19 Functional Status Scale, pulse oxygen saturation, and pulmonary function test were evaluated in 67 outpatients/inpatients after 3-6 months following COVID-19 (positive reverse transcription-polymerase chain reaction on nasopharyngeal swab) disease. Pre-COVID pulmonary function test parameters were available in 33 patients, and these were compared with post-COVID pulmonary function test parameters.

RESULTS: We found 20.9% (14 patients) restrictive and 11.9% (8 patients) obstructive patterns in pulmonary function test. Of those with forced vital capacity < 80%, 53.3% were patients without known lung diseases. When pulmonary function test values before and after COVID-19 were compared, only a loss of 130 mL in forced expiratory volume in 1 second was determined ($P = .005$). About 65.4% of the patients with dyspnea were in the group without a lung disease ($P = .002$) and 66.7% of patients with forced expiratory volume in 1 second and forced vital capacity of <80% had dyspnea complaint ($P = 0.048$, $P = 0.012$). Oxygen saturation was lower in patients with lung disease ($P = .012$) and was significantly lower in patients with forced vital capacity < 80% ($P = .023$). No correlation was found between Post-COVID-19 Functional Status Scale and pulmonary function test parameters ($P > .05$). Smoking, hospitalization, oxygen support, and the severity of computed tomography involvement did not impact pulmonary function test.

CONCLUSION: In post-COVID patients, the major disorder in the respiratory function test was determined as a restriction. However, advanced tests such as lung volumes and carbon monoxide diffusing capacity (DLCO) measurement and high-resolution lung tomography are needed to differentiate in terms of physical functional limitation or parenchymal fibrosis.

KEYWORDS: COVID-19, pulmonary function test, Post-COVID-19 Functional Status Scale
Received: *October 7, 2021* ***Accepted:*** *July 23, 2022* ***Publication Date:*** *September 12, 2022*

INTRODUCTION

Since the World Health Organization declared coronavirus disease 2019 (COVID-19) a pandemic on March 11, 2020, approximately 20% of infected patients required hospitalization and 6% need to be monitored in intensive care and invasive respiratory support.[1] Epidemiological reports have shown that 8.2% of total cases are admitted with rapid and progressive respiratory failure, similar to acute respiratory distress syndrome (ARDS).[2] Lungs are the organs most affected by COVID-19, with different pathophysiological events including extensive alveolar epithelial destruction, hyaline membrane formation, capillary damage and bleeding, alveolar septal fibrous proliferation, and pulmonary consolidation.[3] COVID-19 may cause lung fibrosis and/or pulmonary hypertension.[4,5] These results suggest that lung injury should be evaluated even in discharged patients.

Pulmonary function tests (PFT), such as spirometry, diffusion test, and lung volumes, are most commonly used to evaluate lung functions.[6] Recent clinical guidelines recommend that patients with severe pneumonia should be followed up with PFT 12 weeks after discharge.[7] Restrictive disorder and minor airway dysfunction, which may be permanent and not related to disease severity, were found in PFT.[8] Mo et al[3] reported restrictive respiratory disorder and decreased diffusion capacity, associated with the severity of the disease in patients during discharge. As with previous coronavirus infections such as severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome , it is thought that patients may experience permanent deterioration in respiratory functions for months or even years after discharge.[9,10]

In previous coronavirus infections, muscle weakness, lethargy, pain, depressive mode, anxiety, and various degrees of deterioration in the quality of life were also observed after discharge.[11-13] A new "Post COVID-19 Functional Status Scale (PCFS)" is recommended in the COVID-19 pandemic and suggested that it could be used to evaluate the functional sequelae of COVID-19.

Our study aimed to retrospectively investigate the development of restrictive or obstructive patterns in patients after polymerase chain reaction (PCR)-positive COVID-19 infection and to evaluate the functional status of patients.

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MATERIAL AND METHODS

In Pulmonary Diseases clinic between January 2021 and March 2021, among the outpatients or inpatients who were treated and who had passed 3-6 months after their COVID-19 disease (positive reverse transcription-PCR on nasopharyngeal swab), 67 patients for whom anamnesis, PCFS, PFT (results for the pre-COVID-19 period were also obtained in 33 patients), and computed tomography (CT) data were available in the files were included in the study. Demographic, radiological data, PFT parameters, PCFS grade, comorbidities, and oxygen therapy needs of the patients were recorded. Post-COVID-19 Functional Status Scale was graded from 0 to 4.[14] Spirometry tests were performed following the guidelines of the American Thoracic Society/European Respiratory Society. Disposable bacteria and virus filters were used for each patient during PFT. Using Global Lung Function Initiative 2012 reference values, forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) were found to be 80%, FEV1/FVC was 70%, and maximal mid-expiratory flow (MMEF) was 65%. Approval was sought from Abant İzzet Baysal University Ethics Committee (date: July 27, 2021, no: 2021/203), and written informed consent was obtained from all participants enrolled in the study.

Statistical Method

The analysis of the data obtained as a result of the research was performed using the Statistical Package for Social Sciences version 20.0 software (IBM Corp.; Armonk, NY, USA). Descriptive statistical methods (frequency, arithmetic mean, standard deviation, median, minimum, maximum, and crosstabs) were used, and the compliance to normal distribution was evaluated using Kolmogorov–Smirnov test. Independent sample *t*-test was used for 2 independent groups by comparing the arithmetic means of the normally distributed groups. A comparison of 2 dependent groups was evaluated using paired sample *t*-test. The Mann–Whitney *U* test compared 2 independent groups by the median values of the groups that did not show normal distribution. A comparison of 2 dependent groups was performed using Wilcoxon test. The chi-square test examined the relationship between categorical variables. Statistical significance level was accepted as a *P*-value of <.05.

The relationship between post-COVID pulmonary function test parameters and independent variables was examined by linear regression analysis (enter method). In order to detect the multiple correlations problem, the limits of variance inflation factor < 10, tolerance < 2, and Durbin–Watson < 2.5 were checked, and the conformity of the residuals to the normal distribution was examined based on the skewness-kurtosis ±1 range.

MAIN POINTS

- Major pulmonary function test disorder was found to be a restriction in those who had dyspnea in the 3- to 6-month post-COVID period.
- However, since this restriction may be associated with physical functional limitation, tests such as lung volume measurement, DLCO, and high-resolution computed tomography are needed for parenchymal diseases.
- Post-COVID-19 Functional Status Scale was not found to be effective in predicting respiratory dysfunction.

RESULTS

In total, 55.2% of the patients were male, and in men, the mean age was higher, the need for hospitalization and oxygen support was higher, and the oxygen saturation in the control visit was lower (Table 1). Dyspnea (38.8%), weakness–fatigue (13.4%), myalgia (4.5%), cough (3%), and taste–smell disorder (1.5%) were the most common symptoms. The complaints of fatigue were significantly higher in women than in men (Table 1).

When the patients were examined in terms of underlying lung disease (asthma, chronic obstructive pulmonary disease, interstitial lung disease), those with lung disease were found to be older, and their SpO_2 was lower ($P = .012$) (Table 2). SpO_2 was significantly lower in patients with FVC < 80% ($P = .023$, Table 3).

PCFS was categorized as 0 in 43.3%, 1 in 47.8%, and 2 in 9% of patients. There was no significant difference between male and female patients (Table 1).

Of the patients with dyspnea, 65.4% were in the group without lung disease, and this difference was statistically significant ($P = .002$). Although all patients with fatigue had no previous lung disease, the difference was not statistically significant ($P = .336$). Of those with FVC < 80%, 53.3% were patients without lung disease. Of those with FEV1 < 80%, 58.3% were those with lung disease, but the difference was not statistically significant as the results did not meet the chi-square assumption. Thirty-three of the patients had PFT records from the pre-COVID period in the hospital data system. When the pre-and post-COVID PFT values of 33 patients were compared using the Wilcoxon test, a statistically significant decrease of 130 mL was determined in FEV ($P = .005$) (Table 4).

When the factors affecting PFT parameters were examined, FEV1, FVC, and MMEF were significantly lower in the elderly. Forced expiratory volume in 1 second was lower in patients with lung disease, and MMEF was lower in patients without lung disease, but the difference did not meet the test's assumptions. Forced vital capacity was lower in the group without lung disease ($P = .001$). Forced expiratory volume in 1 second and FVC values were found below normal in patients with dyspnea (Table 3).

In the post-COVID 3- to 6-month period, the FEV1% variable was significant for the age and lung disease regression model and was lower in those with advanced age and lung disease (Table 5), as demonstrated by scatter plots (Figure 1). For the FVC% variable, the variables included in the model were not found to be significant. Forced expiratory volume in 1 second/FVC% was significant for the age regression model, but this value was lower in older age groups (Table 5), as indicated with scatter plots (Figure 2). The MMEF% variable was significant only for the lung disease regression model and was lower in those with lung diseases (Table 5).

Table 1. Demographic, Clinical, and PFT Evaluation of Patients According to Gender

	Female (n = 30)	Male (n = 37)	Total (n = 67)	*P*
Age	45.47 ± 10.7	53.59 ± 15.81	49.95 ± 14.26	**.042**
Smoking status				
Non-smoker	24 (80%)	15 (40.5%)	39 (58.2%)	**<.001**
Ex-smoker	1 (3.3%)	17 (45.9%)	18 (26.9%)	
Smoker	5 (16.7%)	5 (13.6%)	10 (14.9%)	
Pulmonary disease				
Yes	5 (16.7%)	6 (16.2%)	11 (16.4%)	.608
No	25 (83.3%)	31 (83.8%)	56 (83.6%)	
CT involvement				
CT not performed	19 (63.3%)	15 (40.6%)	34 (50.7%)	.174
<50% involvement	4 (13.3%)	9 (24.3%)	13 (19.4%)	
>50% involvement	7 (23.3%)	13 (35.1%)	20 (29.9%)	
Symptoms				
Dyspnea	10 (33.3%)	16 (43.2%)	26 (38.8%)	.283
Fatigue	7 (23.3%)	2 (5.4%)	9 (13.4)	**.037**
Taste–smell disorder	1 (3.3%)	0 (0%)	1 (1.5%)	.448
Myalgia	2 (6.7%)	1 (2.7%)	3 (4.5%)	.421
Cough	1 (3.3%)	1 (2.7%)	2 (3%)	.699
Need hospitalization	9 (30%)	21 (56.8%)	30 (44.8%)	**.029**
No	21 (70%)	37 (43.2%)	37 (55.2%)	
Need for O_2 support	9 (30%)	21 (56.8%)	30 (44.8%)	**.029**
No	21 (70%)	16 (43.2%)	37 (55.2%)	
FEV1 < 80%	5 (16.7%)	7 (18.9%)	12 (17.9%)	.811
FEV1 ≥ 80%	25 (83.3%)	30 (81.1%)	55 (82.1%)	
FVC < 80%	6 (20%)	9 (24.3%)	15 (22.4)	.673
FVC ≥ 80%	24 (80%)	28 (75.7%)	52 (77.6%)	
FEV1/FVC < 70%	6 (20%)	2 (24.3%)	8 (11.9%)	.073
FEV1/FVC ≥ 70%	24 (80%)	35 (75.7%)	59 (88.1%)	
MMEF < 65%	12 (40%)	8 (21.6%)	20 (29.8%)	.102
MMEF ≥ 65%	18(60%)	29(78.4%)	47(70.1%)	
PCFS				
0	11 (36.7%)	18 (48.6%)	29 (43.3%)	.616
1	16 (53.3%)	16 (43.2%)	32 (47.8%)	
2	3 (10%)	3 (8.1%)	6 (9%)	
SpO_2	97 (95-99)	97 (76-99)	97 (76-99)	**.037**

CT, computed tomography; SpO_2, oxygen saturation measured by pulse oximetry; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; MMEF, maximal mid-expiratory flow; PCFS, Post-COVID-19 Functional Status Scale; PFT, pulmonary function test.
Bold values indicate $P \leq .05$.

There were 14 patients with FEV1/FVC above 70% and FVC and FEV1 below 80%, and the restrictive pattern rate was 20.9%, while FEV1/FVC was <70% in 8 patients, and the obstructive pattern rate was 11.9%.

DISCUSSION

Different degrees of destruction in the alveolar structure and pulmonary interstitial fibrosis were observed in the autopsy series of COVID-19 patients.[15] Data published so far have investigated the pulmonary function of patients recovering from COVID-19 at discharge,[3] a few weeks after discharge,[5] and after 6 weeks of pulmonary rehabilitation,[16] and between 60 and 100 days after symptom onset.[17] No data on long-term follow-up are yet available, except for 1 study[18] comparing post-COVID tenth-week and sixth-month. The British Thoracic Society guide recommends PFT at the third month after discharge, especially for those with suspected interstitial disease.[7] Our study is critical in terms of evaluating the post-COVID third- to sixth-month period.

Table 2. Demographic, Clinical, and PFT Evaluation of Patients According to the Presence of Lung Disease

	With Previous Pulmonary Disease (n = 11)	With No Previous Pulmonary Disease (n = 56)	Total Patients (n = 67)	*P*
Age	58 (24-87)	47 (20-89)	48 (20-89)	**.025**
CT involvement				
CT not performed	4 (11.8%)	30 (88.2%)	34 (50.7%)	.057
<50% involvement	5 (38.5%)	8 (61.5%)	13 (19.4%)	
>50% involvement	2 (10%)	18 (90%)	20 (29.9%)	
Hospitalization need				
Yes	6 (20%)	24 (80%)	30 (44.8%)	.523
No	5 (13.5%)	32 (86.5%)	37 (55.2%)	
Need for O_2 support				
Yes	6 (20%)	24 (80%)	30 (44.8%)	.523
No	5 (13.5%)	32 (86.5%)	37 (55.2%)	
Dyspnea				
Yes	9 (34.6%)	17 (65.4%)	26 (38.8%)	**.002**
No	2 (4.9%)	39 (95.1%)	41 (61.2%)	
Fatigue				
Yes	0 (0%)	9 (100%)	9 (13.4%)	.336
No	11 (19%)	47 (81%)	58 (86.6%)	
FEV1 < 80%	7 (58.3%)	5 (41.7%)	12 (17.9%)	**<.001***
FEV1 ≥ 80%	4 (7.3%)	51 (92.7%)	55 (82.1%)	
FVC < 80%	7 (46.7%)	8 (53.3%)	15 (22.4%)	**.001**
FVC ≥ 80%	4 (7.7%)	48 (92.3%)	52 (77.6%)	
FEV1/FVC < 70%	3 (37.5%)	5 (62.5%)	8 (11.9%)	.117
FEV1/FVC ≥ 70%	8 (13.6%)	51 (86.4%)	59 (88.1%)	
MMEF < 65%	8 (40%)	12 (60%)	20 (29.9%)	**.002***
MMEF ≥ 65%	3 (6.4%)	44 (93.6%)	47 (70.1%)	
PCFS				
0	1 (3.4%)	28 (96.6%)	29 (43.3%)	**.034***
1	9 (28.1%)	23 (71.9%)	32 (47.8%)	
2	1 (16.7%)	5 (83.3%)	6 (9%)	
SpO_2	96 (76-98)	97 (92-99)	97 (76-99)	**.012**

*Does not meet the chi-square test assumptions.
CT, computed tomography; SpO2, oxygen saturation measured by pulse oximetry; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; MMEF, maximal mid-expiratory flow; PCFS, Post-COVID-19 Functional Status Scale; PFT, pulmonary function test.
Bold values indicate $P \leq .05$.

In severe acute respiratory syndrome, persistent anomalies in respiratory functions have been reported in 25%-40% of patients 1 year after discharge.[10,19] In a meta-analysis, 15% restrictive and 7% obstructive patterns were reported in COVID-19.[20] Our study determined the restrictive pattern to be 20.9% and the obstructive pattern to be 11.9% in 3- to 6-month post-COVID period. Chronic obstructive pulmonary disease was the underlying lung disease in 2 of 8 patients for whom an obstructive pattern was found. Some of the patients (33 patients) had PFT from the pre-COVID period, and when PFT parameters were compared, 130 mL loss was found only in FEV1 ($P = .005$), while no significant difference was found in FVC and FEV1/FVC ($P = .454$, $P = .066$).

In severe COVID-19, oxygen toxicity and ventilator-induced lung injury lead to fibrosis. Patients who develop post-COVID fibrosis have extensive radiological lung involvement and therefore require high concentrations of oxygen for a long time, often during the acute phase of their illness. Prolonged exposure to high concentrations of oxygen increases the production of oxygen-derived free radicals that can damage the pulmonary epithelium.[21] In the study by Masson et al[5] involving 45 post-COVID patients, they found a higher rate of PFT abnormality in patients with severe disease. However, in SARS, no significant difference was observed in FVC and DLCO when inpatients and non-inpatients were compared.[22] In our study, the severity of CT involvement, the need for oxygen support, and the history of hospitalization were not associated with PFT abnormalities.

Table 3. Factors Affecting Post-COVID Pulmonary Function Test Parameters

	FEV1 < 80%, n = 12	FEV1 ≥ 80%, n = 55	FVC < 80%, n = 15	FVC ≥ 80%, n = 52	FEV1/FVC < 70%, n = 8	FEV1/FVC ≥ 70%, n = 59	MMEF < 65%, n = 20	MEEF ≥ 65%, n = 47
Age (n = 67)	61 (42-87)	47 (20-89)	59 (32-87)	46.5(20-89)	49 (36-60)	48 (20-89)	53 (36-87)	47(20-89)
	P = .001		**P = .008**		P = .961		**P = .025**	
Smoking status								
Non-smoker	5 (41.7%)	34 (61.8%)	7 (46.7%)	32 (61.5%)	4 (50%)	35 (59.3%)	9 (45%)	30 (63.8%)
Ex-smoker	5 (41.7%)	13 (23.6%)	6 (40%)	12 (23.1%)	2 (25%)	16 (27.1%)	7 (35)	11 (23.4%)
Smoker	2 (16.7%)	8 (14.5%)	2 (13.3)	8 (15.4)	2 (25%)	8 (13.6%)	4 (20%)	6 (12.8%)
	P = .385		P = .424		P = .693		P = .359	
Had pulmonary disease	7 (58.3%)	4 (7.3%)	7 (46.7%)	4 (7.7%)	3 (37.5%)	8 (13.6%)	8 (40%)	3 (6.4%)
No	5 (41.7%)	51 (92.7%)	8 (53.3%)	48 (92.3%)	5 (62.5%)	51 (86.4%)	12 (60%)	44 (83.6%)
	P < .001*		**P = .001**		P = .117		**P = .002***	
Hospitalization need								
Yes	8 (66.7%)	22 (40%)	9 (60%)	21 (40.4%)	1 (12.5%)	29 (49.2%)	8 (40%)	22 (73.3%)
No	4 (33.3%)	33 (60%)	6 (40%)	31 (59.6%)	7 (87.5%)	30 (50.8%)	12 (60%)	25 (53.2)
	P = .092		P = .178		P = .066		P = .608	
CT involvement								
CT not performed	4 (33.3%)	30 (54.5%)	5 (33.3%)	29 (55.8%)	6 (75%)	28 (47.5%)	11 (55%)	23 (48.9)
<50% involvement	3 (25%)	10 (18.2%)	4 (26.7%	9 (17.3%)	1 (12.5%)	12 (20.3%)	3 (15%)	10 (21.3%)
>50% involvement	5 (41.7%)	15 (27.3%)	6 (40%)	14 (26.9%)	1 (12.5%)	19 (32.2%)	6 (30%)	14 (29.8%)
	P = .408		P = .309		P = .334		P = .824	
The need for O_2 support								
	8 (66.7)	22 (40%)	9 (60%)	21 (40.4%)	1 (12.5%)	29 (49.2%)	8 (40%)	22 (46.8%)
No	4 (33.3%)	33 (60%)	6 (40%)	31 (59.6%)	7 (87.5%)	30 (50.8%)	12 (60%)	25 (53.2%)
	P = .092		P = .178		P = .066		P = .608	
Dyspnea								
Yes	8 (66.7%)	18 (32.7%)	10 (66.7%)	16 (30.8%)	4 (50%)	22 (37.3%)	10 (50%)	16 (34%)
No	4 (33.3%)	37 (67.3%)	5 (33.3%)	36 (69.2%)	4 (50%)	37 (62.7%)	10 (50%)	31 (66%)
	P = **.048**		**P = .012**		P = .489		P = .220	
PCFS								
0	3 (25%)	26 (47.3%)	4 (26.7%)	25 (48.1%)	2 (25%)	27 (45.8%)	5 (25%)	24 (51.1%)
1	8 (66.7%)	24 (43.6%)	8 (53.3%)	24 (46.2%)	6 (75%)	26 (44.1%)	14 (70%)	18 (38.3%)
2	1 (8.3%)	5 (9.1%)	3 (20%)	3 (5.8%)	0 (0%)	6 (10.2%)	1 (5%)	5 (10.6%)
	P = .328		P = .136		P = .231		P = .059	
SpO_2	96 (76-99)	97 (92-99)	96 (76-98)	97 (92-99)	98 (96-99)	97 (76-99)	97 (76-99)	97 (90-99)
	P = .154		**P = .023**		**P = .013**		P = .331	

CT, computed tomography; SpO2, oxygen saturation measured by pulse oximetry; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; MMEF, maximal mid-expiratory flow; PCFS, Post-COVID-19 Functional Status Scale; PFT, pulmonary function test.
Bold values indicate $P \leq .05$.

Fatigue was reported in at least one-third of patients in 2 studies with a follow-up period of 18 months[23] and 40 months[24] in previous coronavirus pandemics. Fatigue and dyspnea have been reported in 30%-60% of individuals in the post-COVID period.[17,25] In our study, dyspnea (38.8%) and weakness–fatigue (13.4%) were the most common complaints in the post-COVID 3- to 6-month follow-up. 65.4% of the patients with dyspnea were in the group without a lung disease, and this difference was statistically significant ($P = .002$). Although all patients with fatigue were without lung disease, it was not statistically significant. Of those with FVC < 80%, 53.3% were patients without lung disease ($P = .001$).

Table 4. The Comparison of the Pre- and Post-COVID-19 PFT Parameters of 33 Patients with PFT Available in the Pre-COVID-19 Period

	FEV1*	FVC**	FEV1/FVC*
Pre-COVID	2.83 (1.04-4.83)	3.62 ± 0.95	84.6 (62.7-106.0)
Post-COVID	2.73 (1.00-5.00)	3.57 ± 1.01	82.0 (63.0-97.0)
P	**.005**	.454	.066

*Wilcoxon test; **Paired sample *t*-test.
FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; PFT, pulmonary function test.
Bold values indicate $P \leq .05$.

In patients who recovered from ARDS and described dyspnea, long-term physical function limitation was observed disproportionate to the degree of pulmonary dysfunction.[26] The results we obtained suggest non-pulmonary factors such as post-COVID fibrosis or critical illness neuromyopathy. Quarantine conditions and isolated hospitalization may also cause muscle weakness. Findings of dyspnea disproportionate to respiratory dysfunction have been reported in many COVID-19 survivors, even those with milder disease. It is unknown whether post-COVID-19 symptoms are more closely related to physical dysfunction than permanent lung function decrease.[27]

Skeletal muscle damage was observed during acute disease in 19% of patients with COVID-19.[28] Pulmonary function test

Table 5. Linear Regression Analysis for Post-COVID PFT Parameters

	FEV1 %		FVC %		FEV1/FVC %		MMEF %	
	B**	Sig	B**	Sig	B**	Sig	B*	Sig
Constant	115.335	0.183	4.752	0.961	178.186	**<0.001***	220.530	0.215
Age	−0.468	**0.032***	−0.410	0.097	−0.265	**0.020***	−0.650	0.143
Smoking	2.573	0.388	3.490	0.306	−1.328	0.394	6.127	0.319
Pulmonary disease	−18.940	**0.004***	−10.419	0.151	−5.697	0.087	-37.919	**0.005***
CT	3.962	0.580	1.325	0.871	3.918	0.296	22.458	0.130
O2 support	2.847	0.229	−0.049	0.985	1.417	0.251	6.314	0.196
Dyspnea	−3.912	0.501	−3.284	0.620	−3.287	0.280	−8.412	0.482
PCFS	-−1.759	0.683	1.522	0.757	−0.163	0.942	−2.011	0.820
SpO_2	0.010	0.990	1.131	0.243	−0.856	0.055	−1.126	0.517
P	**.002***		**.019***		**.030***		**.006***	
Model R^2	0.337		0.259		0.243		0.295	
Durbin–Watson	2.058		1.855		1.883		1.963	
Residuals	±1		±1		±1		±1	

*Statistically significant; **Unstandardized coefficients.
CT, computed tomography; SpO2, oxygen saturation measured by pulse oximetry; PCFS, Post-COVID-19 Functional Status Scale; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; MMEF, maximal mid-expiratory flow.
Bold values indicate $P \leq .05$.

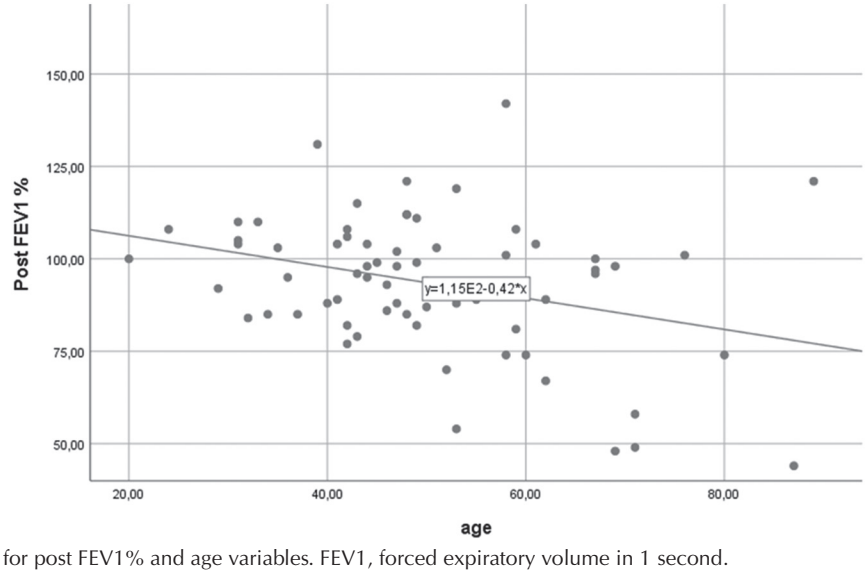

Figure 1. Scatter plot for post FEV1% and age variables. FEV1, forced expiratory volume in 1 second.

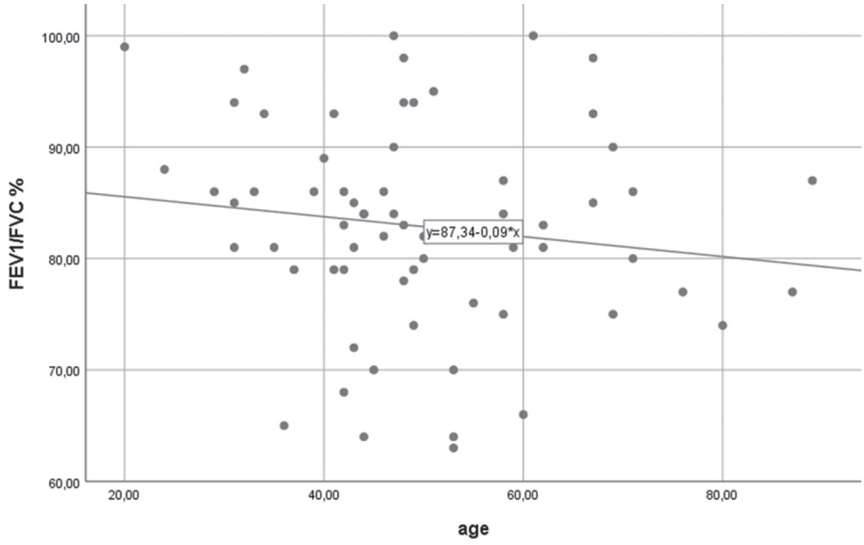

Figure 2. Scatter plot for FEV1/FVC % and age variables. FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second.

6-8 weeks after hospital discharge following SARS revealed a mild or moderate restrictive pattern consistent with muscle weakness in 6%-20% of patients.[29] In our study, FEV1 and FVC values were found to be below 80% in patients with dyspnea complaints. However, since this restriction was determined more frequently in the group without lung disease who also had symptoms of weakness–fatigue, it raises the question, "Is the restriction due to loss of physical function?" Although Hall et al[30] physicians did not identify any radiological or physiological abnormalities in 60% of 200 patients, they reported persistent subjective symptoms, and this situation is called "post-COVID-19 syndrome."

In our study, SpO_2 was significantly lower in patients with FVC < 80% and those with lung diseases ($P = .023$ and $P = .012$, respectively). When the literature is reviewed, we could not find any study on post-COVID hypoxemia. Hypoxemia may occur in both fibrotic disorders, obstructive pulmonary diseases, and neuromuscular disorders.[31]

The validity of PCFS has been tested, and it was reported that it could be used to refer patients to specialist clinics or rehabilitation programs.[32] Post-COVID-19 Functional Status Scale can be used after discharge from the hospital, 4-8 weeks after discharge, and in the 6th month.[14] In 444 patients who recovered from COVID-19, PCFS was reported as grade 0 in 20% of cases, grade 1 in 63.1%, grade 2 in 14.4%, grade 3 in 2%, and grade 4 in 0.5%.[33] In our study, PCFS was categorized as grade 0 in 43.3%, grade 1 in 47.8%, grade 2 in 9% of patients, and no patients were grade 3 or 4. There was no significant difference between male and female patients (Table 1). It was reported that PCFS is affected by age, gender, periodic influenza vaccination, smoking status, time from the onset of symptoms, presence of comorbidities, oxygen therapy, and need for intensive care unit.[33] However, we could not find any literature on its relationship with PFT. In our study, no significant relationship was found between PCFS and PFT parameters.

Post-COVID fibrosis is associated with advanced age, severe illness, long-term intensive care/hospital stay, mechanical ventilation, smoking history, and chronic alcoholism.[34,35] In our study, smoking and hospitalization history were not correlated with changes in PFT values ($P < .05$).

The limitations of our study are the absence of PFTs belonging to the pre-COVID period of all patients and that it is a single-center, retrospective study. It should be considered that previous respiratory diseases, obesity and smoking, and environmental pollution will also cause an impairment in lung functions. The restriction should also be investigated by lung volumes, DLCO measurements, and radiologically.

CONCLUSION

Major PFT disorder was found to be a restriction in those who had dyspnea in 3- to 6-month post-COVID period. However, since this restriction may be associated with physical functional limitation, tests such as lung volume measurement, DLCO, and HRCT are needed for parenchymal diseases. Post-COVID-19 Functional Status Scale was not found to be effective in predicting respiratory dysfunction.

Ethics Committee Approval: This study was approved by Ethics committee of Abant İzzet Baysal University: (Date: July 27, 2021, No: 2021/203).

Informed Consent: Verbal and written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – E.A.; Design – E.A.; Supervision – E.A.; Funding – E.A., M.E.D.; Materials – E.A., M.E.D.; Data Collection and/or Processing – E.A., M.E.D.; Analysis and/or Interpretation – E.A., M.E.D.; Literature Review – E.A., M.E.D.; Writing – E.A.; Critical Review – E.A.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

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