Long-Term Pulmonary Complications of COVID-19: A Comprehensive Analysis of Persistent Respiratory Symptoms, Pulmonary Function Abnormalities, and Risk Factors

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Abstract

Background: The COVID-19 pandemic has raised concerns about its long-term impact on respiratory health. This study investigated the prevalence of persistent respiratory symptoms, pulmonary function abnormalities, and associated risk factors in individuals recovering from COVID-19.

Methods: This observational study included 100 patients aged 18-60 years, at least one year post-COVID-19 diagnosis. Data on persistent symptoms, pulmonary function tests (PFTs), and clinical history were collected. Spirometry was used to assess pulmonary function, and statistical analysis was performed using SPSS version 25.

Results: A high proportion of patients experienced persistent symptoms, with fatigue (56%) and exertion-induced symptom worsening (54%) being the most common. Restrictive lung disease was the most prevalent PFT abnormality (47%), with reduced forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) observed in 56% and 79% of patients, respectively. The severity of acute COVID-19 illness, indicated by prior lung involvement, oxygen support, or hospitalization, was significantly correlated with reduced lung function. Persistent fatigue, exertion-induced symptom worsening, and dyspnoea were also associated with impaired pulmonary function.

Conclusion: This study demonstrates a significant burden of persistent respiratory complications among COVID-19 survivors. The severity of the acute illness and specific symptoms like fatigue and dyspnoea are crucial indicators of long-term pulmonary health. These findings underscore the need for comprehensive and ongoing monitoring of post-COVID-19 patients to facilitate early detection and management of pulmonary complications. Further research is needed to explore the

underlying mechanisms and develop effective treatment strategies for these complications.

Keywords: COVID-19, Pulmonary Complications, Long COVID, Spirometry, Restrictive lung diseases

Introduction

The COVID-19 pandemic has presented unprecedented challenges to healthcare systems worldwide, with its profound impact on respiratory health being a particular cause for concern[1]. As the virus binds to angiotensin-converting enzyme 2 (ACE2) receptors in the lungs, it triggers a cascade of inflammatory responses, leading to alveolar damage, impaired gas exchange, and potential long-term pulmonary dysfunction[2].

While the acute effects of COVID-19 on the respiratory system are well-documented, emerging evidence suggests that a significant proportion of individuals experience persistent respiratory complications long after the initial infection has resolved[3]. These complications, collectively termed "Post-acute sequelae of COVID-19" (PASC), encompass a range of respiratory issues, including dyspnoea, cough, and restrictive and obstructive lung disorders[4].

Several studies have highlighted the prevalence and severity of long-term pulmonary complications in COVID-19 survivors[5]. Notably, a study by Clavario et al. observed a high prevalence of impaired diffusing capacity of the lungs for carbon monoxide (DLCO) in individuals at the time of hospital discharge, particularly among those with severe disease[6,7]. These findings underscore the potential for long-term respiratory impairment even in those who have seemingly recovered from the acute phase of COVID-19[8].

This study aims to comprehensively analyse the long-term pulmonary complications experienced by COVID-19 survivors. Our objectives are to determine the prevalence and severity of persistent respiratory symptoms, assess pulmonary function abnormalities, and identify risk factors associated with poor long-term respiratory outcomes. By addressing these objectives, we aim to contribute to a deeper understanding of the complex and multifaceted long-term respiratory effects of COVID-19, ultimately informing clinical practice and public health interventions.

Materials and Methods

Study Design, Population, and Setting

This study employed an observational design, conducted over one year at the Department of Medicine, Gandhi Medical College, and the affiliated Hamidia Hospital and RIRD, Bhopal. The study population consisted of 100 patients aged 18-60 years who had previously tested positive for COVID-19 and were at least one year out from their initial diagnosis.

Inclusion and Exclusion Criteria

Inclusion Criteria:

- Age 18-60 years
- Prior positive COVID-19 test
- Discharge from Hamidia Hospital
- At least one year post-diagnosis
- Willingness to participate

Exclusion Criteria:

- Pre-existing pulmonary disease

Data Collection

Data were collected during outpatient visits. Participants were interviewed about their current symptoms and underwent pulmonary function tests (PFTs) to evaluate their pulmonary functional capacity. PFTs included measurements of forced expiratory volume in one second (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, peak expiratory flow (PEF), and maximum

expiratory flows at 75%, 50%, and 25% of FVC (MEF75, MEF50, and MEF25).

Procedure

Pulmonary function parameters were assessed using spirometry. Each participant underwent spirometry according to standardized protocols to ensure accuracy and reliability, and the results were recorded and analysed.

Statistical Analysis

Continuous variables were expressed as medians with interquartile ranges (IQR), while categorical variables were represented as counts and percentages. Chi-squared tests were used to compare categorical variables. Statistical analyses were done with SPSS version 25, using a significance level of $p \leq 0.05$.

Results

In the present study, most patients were 20–30 years old (32%), male (55%), with no initial lung involvement (35%). However, most required hospitalization (64%) and oxygen support (64%) during the acute phase, and varied HRCT lung involvement was observed (65%). (Table 1)

Table 1: Distribution of patients according to baseline variables and past history

Baseline variables	Frequency (n=100)	Percentage
Age (years)		
20-30	32	32
31-40	25	25
41-50	28	28
51-60	15	15
Gender		
Female	45	45
Male	55	55
Lung Involvement on COVID Positivity		
None	35	35
Mild	33	33
Moderate	21	21
Severe	11	11
Requirement of O2 on COVID Positivity		
None	36	36
Nasal prong	31	31
Face mask	13	13
NRBM	11	11

NIV	9	9
Hospitalization on COVID Positivity		
No	36	36
Yes	64	64
HRCT grading		
No Involvement	35	35
Mild	32	32
Moderate	22	22
Severe	11	11

Figure 1 illustrates the prevalence of various symptoms experienced by patients at their present visit after recovering from COVID-19. Fatigue (56%) and symptoms worsened by exertion (54%) were the most common. A substantial proportion also reported difficulty breathing (34%). Less frequent symptoms included headache (12%), sleep problems (16%), and dizziness (16%). Fever, depression/anxiety, chest pain, and abnormal mental health conditions were relatively rare. This data highlights the range of persistent symptoms affecting individuals' post-COVID-19 recovery.

Figure 1: Distribution of patients as per Symptomatology at Present
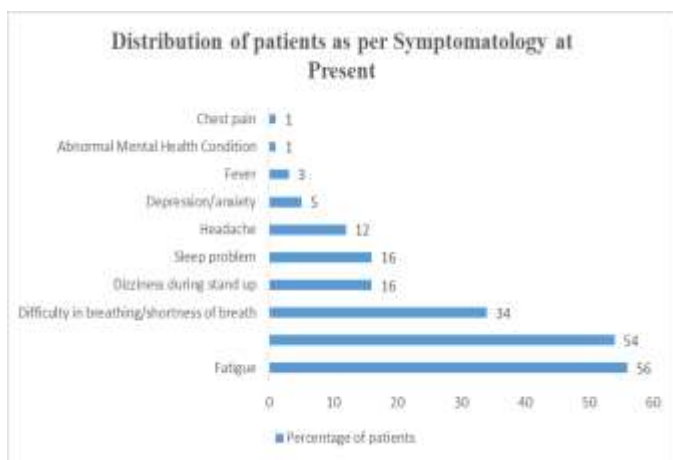
Spirometry results indicated varying degrees of pulmonary function impairment. The mean values for FVC, FEV1, and FEV1/FVC ratio were 79.39%, 71.09%, and 77.42%, respectively. A high proportion of patients exhibited decreased FVC (56%) and FEV1 (79%) values, while 29% had a decreased FEV1/FVC ratio.

In this study of 100 patients, vital signs including pulse (75.12 bpm), blood pressure (122.14/72.66 mmHg), oxygen saturation (97.89%), and respiration rate (15.82 breaths per minute) were generally normal. However, spirometry tests revealed that 47% of the patients had a restrictive lung pattern, indicating difficulty fully expanding their lungs. This was the most common finding, followed by normal spirometry (24%), obstructive patterns (20%), and mixed patterns (9%). The average forced vital capacity (FVC) was 79.39% of predicted, and forced expiratory volume in 1 second (FEV1) was 71.09% of predicted, with an FEV1/FVC ratio of 77.42%. The high prevalence of restrictive lung disease in this patient group highlights the need for further investigation to determine the underlying causes. (Table 2)

Table 2: Clinical findings and outcome at present visit

Clinical findings at present	Frequency/Mean SD (n=100)	Percentage
General examination		
Pulse	75.12±5.330	
SBP	122.14±10.500	
DBP	72.66±5.062	
SPO2	97.89±2.020	
RR	15.82±1.559	
Spirometry findings		
Mean SD - FVC	79.39±20.514	
Mean SD – FEV1	71.09±19.950	
Mean SD - FEV1/FVC	77.42±10.508	
Mean SD - FEF25-75 (%)	54.27±19.725	
Mean SD - PEFR (%)	67.68±17.571	
Outcome		
Normal	24	24
Obstructive	20	20
Restrictive	47	47
Mixed	9	9

Table 3 explores the relationship between lung function, patient characteristics, and COVID-19 history. Notably, age and gender did not significantly affect lung function. However, prior lung involvement during COVID-19 infection showed a strong correlation with reduced lung function. Patients with severe lung involvement during COVID-19 had significantly lower FEV1 (34.80%), FVC (33.00%), FEF25-75 (27.40%), and PEFR (40.40%) compared to those with no prior involvement. Similarly, patients requiring oxygen or hospitalization during their COVID-19 illness also demonstrated significantly reduced lung function across most parameters. These findings underscore the potential long-term impact of COVID-19 on respiratory health, particularly in those who experienced severe illness.

Table 3: Comparing mean PFT with baseline variables and past history of COVID

Variables	FEV1 (%)	FVC (%)	FEV1/FVC	FEF25-75 (%)	PEFR (%)
Age (years)					
20-30	75.06±17.4	82.62±17.8	79.86±7.1	60.75±19.1	68.56±13.47
31-40	81.64±19.0	73.60±17.9	77.77±10.9	56.56±15.t	70.52±17.1
41-50	78.07±20.2	68.86±18.5	76.63±10.4	52.18±20.8	68.21±18.7
51-60	71.20±27.5	62.60±28.3	73.15±10.4	40.53±20.8	60.07±18.7

P value	0.193	0.311	0.223	0.008	0.314
Gender					
Female	71.89±17.6	79.47±19.5	77.54±9.7	54.87±18.2	69.64±16.8
Male	70.44±21.8	79.33±21.5	77.33±11.2	53.78±21.1	66.07±18.2
P value	0.719	0.973	0.922	0.786	0.314
Initial Lung Involvement on Covid Positivity					
None	91.09±21.3	84.11±22.9	79.89±6.8	67.83±17.8	76.34±16.7
Mild	72.33±6.6	81.64±9.8	78.22±8.1	52.58±14.3	69.45±13.3
Moderate	71.29±13.7	63.95±8.6	75.18±12.2	48.14±14.2	63.71±12.2
Severe	34.80±5.4	33.00±5.1	80.58±0.5	27.40±13.3	40.40±15.6
P value	<0.001	<0.001	0.007	<0.001	<0.001
Requirement of O2					
No	90.61±21.2	83.78±22.7	79.93±6.7	67.56±17.6	76.44±16.4
Yes	63.95±13.9	73.08±17.3	76.02±11.9	46.8±16.8	62.75±16.3
P value	<0.001	<0.001	0.074	<0.001	<0.001
Requirement of Hospitalization					
No	90.61±21.2	83.78±22.7	79.93±6.7	67.56±17.6	76.44±16.4
Yes	74.71±17.8	64.10±14.7	74.33±12.8	44.87±17.5	61.81±17.3
P value	<0.001	<0.001	0.015	<0.001	<0.001
HRCT Grading					
No Involvement	84.11±22.9	91.09±21.3	79.89±6.8	67.83±17.8	76.34±16.7
Mild	82.03±10.2	72.03±6.9	77.64±8.3	51.43±14.5	69.43±13.7
Moderate	72.62±12.6	64.86+8.7	75.18±12.2	48.38±14.3	64.62+12.8
Severe	52.60±20.7	40.50±7.4	70.57±19.5	28.5015.6	43.40±15.8
P value	<0.001	<0.001	0.201	<0.001	<0.001

Table 4 examines the relationship between various symptoms and lung function. Fatigue, symptoms worsening after exertion, shortness of breath, and headaches were all significantly associated with reduced lung function across several measures, including FVC, FEV1, FEF25-75, and PEFR. For instance, individuals experiencing fatigue had an average FVC of 74.87% compared to 87.48% in those without fatigue. Similarly, those with shortness of breath had an average FEV1 of 59.22% compared to 76.92% in those without breathing difficulties. While fever, mental health conditions, dizziness upon standing, and chest pain also showed some associations with reduced lung function, these were not consistently significant across all measures. These findings suggest that certain symptoms, particularly fatigue and shortness of breath, may be important indicators of compromised lung function in this patient population.

Table 4: Comparing PFT parameters with symptomology

Variables	FVC (%)	FEV1 (%)	FEV1/FVC	FEF25-75 (%)	PEFR (%)
Fatigue					
No	87.48±18.7	79.00±19.8	79.17±7.9	62.89±19.8	73.05±17.5
Yes	74.87±19.6	66.09±18.3	74.89±12.8	47.53±17.4	63.36±16.4
P value	0.001	0.001	0.082	<0.001	0.024
Symptoms that get worse after physical or mental effort					
No	86.78±18.6	78.63±19.5	79.37±7.8	62.80±19.3	72.93±17.2
Yes	75.79±19.7	66.24±18.5	74.39±13.1	46.36±17.4	63.67±17.3
P value	0.001	0.001	0.044	<0.001	0.009
Fever					
No	80.39±20.1	72.19±19.5	77.59±10.1	55.21±19.4	68.45±17.1
Yes	57.0±35.4	35.50±6.4	61.33±28.4	16.0±5.7	32.50±3.5
P value	0.132	0.03	0.132	0.035	0.02
Difficulty in breathing/shortness of breath					
No	85.17±19.1	76.92±20.4	78.06±9.8	59.43±19.2	71.98±16.9
Yes	69.63±19.6	59.22±13.6	74.17±12.7	42.26±17.8	57.11±15.8
P value	<0.001	<0.001	0.144	<0.001	<0.001
Mental Health Condition					
Abnormal	34	32	80.32	24	36
Normal	80.03±20.2	71.54±19.8	77.26±10.6	54.55±19.8	67.86±17.5
P value	0.068	0.142	0.665	0.306	0.165
Headache					
No	82.41±19.1	74.30±18.7	77.99±8.9	56.92±18.5	70.32±16.0
Yes	61.45±18.2	50.36±13.8	72.08±19.1	36.27±19.6	49.91±17.5
P value	<0.001	<0.001	0.314	<0.001	<0.001
Sleep problems					
No	83.38±18.9	74.84±19.0	77.71±9.4	56.96±19.1	70.10±16.6
Yes	60.07±19.3	51.60±14.9	74.79±15.5	39.0±18.4	54.8±19.1
P value	<0.001	<0.001	0.609	<0.012	0.019
Depression/Anxiety					
No	81.69±18.7	72.93±18.9	77.05±10.7	55.46±19.4	68.86±16.9
Yes	39.4±8.4	38.6±10.5	83.21±4.0	31.6±14.4	45.0±16.3
P value	<0.001	0.001	0.363	0.029	0.011

Dizziness during stand up					
No	84.46±17.7	74.76±18.9	76.36±11.1	55.72±20.3	69.37±17.5
Yes	54.14±14.3	52.79±14.0	82.84±2.6	47.36±15.5	60.29±16.4
P value	<0.001	<0.001	0.167	0.355	0.184
Chest pain					
No	80.02±20.1	71.59±19.7	77.33±10.6	54.56±19.7	67.98±17.5
Yes	34	32	80.32	24	36
P value	0.059	0.125	0.785	0.307	0.193

Discussion

This study aimed to comprehensively analyse the long-term pulmonary complications experienced by individuals following COVID-19 infection. We investigated the prevalence of persistent respiratory symptoms, characterized the patterns of pulmonary function abnormalities, and identified potential risk factors associated with these complications. Our findings reveal that a substantial proportion of individuals continue to experience respiratory symptoms and exhibit impaired lung function even after recovering from the acute phase of COVID-19. Restrictive lung disease was the most common physiological abnormality observed, and the severity of the initial infection was strongly correlated with long-term pulmonary health. These findings underscore the importance of recognizing and addressing the persistent pulmonary consequences of COVID-19 to optimize patient care and improve long-term outcomes. The ongoing COVID-19 pandemic has brought to light the critical need to understand the full spectrum of its effects, including the long-term impact on respiratory health.

Our study population consisted predominantly of young adults (20-30 years old), with a slightly higher proportion of males (55%). This age distribution is notably younger than those reported in several other studies on long-COVID pulmonary complications. For instance, Wu et al. (2021)[9] reported a median age of 60 years, while Bellan et al. (2021)[10] focused on patients with severe COVID-19 who required hospitalization in Northern Italy, likely including a higher proportion of older individuals. This difference in age demographics may be attributed to variations in population characteristics or healthcare access across different regions. While our study did not find significant gender-related differences in lung function outcomes, it's important to note that some studies, such as Wu et al. (2021)[9], have identified female gender as a potential risk factor for persistent DLCO abnormalities. Further research with larger sample sizes is needed to explore potential gender-specific effects on long-term pulmonary outcomes.

Although a significant proportion of our patients initially presented with no lung involvement during their acute COVID-19 infection, the majority required hospitalization (64%) and oxygen support (64%). This indicates that a considerable number experienced moderate to severe COVID-19, despite the absence of initial radiographic evidence of lung involvement. These findings align with Huang et al. (2020)[11], who also observed a high prevalence of pulmonary function abnormalities even in patients with non-severe COVID-19. Furthermore, our study, like Huang et al. (2020)[11], demonstrated a strong correlation between the severity

of acute COVID-19 illness and the degree of long-term pulmonary function impairment. This highlights the potential for long-term respiratory consequences even in individuals who may not have exhibited severe lung involvement during the initial infection.

Our study revealed that fatigue (56%) and exertion-induced symptom worsening (54%) were the most prevalent persistent symptoms experienced by individuals following COVID-19. These findings are consistent with other studies on long COVID, such as Van den Borst et al. (2021)[12], who reported a high prevalence of fatigue and reduced exercise capacity in individuals three months after recovering from acute COVID-19. Similarly, Bellan et al. (2021)[10] found that a substantial proportion of patients experienced functional impairment and fatigue several months after hospital discharge. The high prevalence of these symptoms across different studies emphasizes their significance as key components of the long-COVID syndrome.

Dyspnea was also a common complaint in our study population (34%). This aligns with the observations of numerous studies, including Van den Borst et al. (2021)[12] and Bellan et al. (2021)[10], who reported a high prevalence of persistent respiratory symptoms, including shortness of breath. The consistent reporting of dyspnoea in post-COVID-19 patients highlights the potential for long-term respiratory sequelae and the need for ongoing monitoring and management of these individuals.

While our study observed a lower prevalence of symptoms such as headache, sleep problems, and dizziness compared to fatigue and dyspnoea, these symptoms were still reported by a notable proportion of patients. Variations in the reported prevalence of these less common symptoms across different studies may be attributed to factors such as differences in study populations, methodologies used for symptom assessment, and the time elapsed since the acute COVID-19 infection. Further research is needed to fully elucidate the spectrum and trajectory of persistent symptoms following COVID-19.

Our study demonstrated a strong correlation between the severity of acute COVID-19 illness and the degree of long-term pulmonary function impairment. As shown in Table 3, patients with prior lung involvement during their acute infection, those requiring oxygen support, and those who were hospitalized exhibited significantly reduced lung function across various spirometry parameters. These findings are consistent with those of Wu et al. (2021)[9], who observed that patients with more severe pneumonia during hospitalization were more likely to experience persistent radiological abnormalities and reduced DLCO values at 12 months follow-up. Similarly, Anastasio et al. (2021)[13] reported that the severity of pneumonia, as assessed by the SpO2/FIO2 ratio and pneumonia severity index, was correlated with decreased pulmonary function at four months.

Furthermore, our analysis revealed significant associations between persistent symptoms and lung function impairment. Fatigue, exertion-induced symptom worsening, and dyspnoea were all strongly correlated with reduced FVC, FEV1, and other spirometry measures. These findings suggest that these symptoms may serve as important indicators of underlying pulmonary dysfunction in post-COVID-19 patients. This aligns with the broader understanding of long COVID, where persistent symptoms are often indicative of ongoing physiological abnormalities.

The clinical implications of these correlations are substantial. Recognizing the link between acute COVID-19 severity and long-term pulmonary health underscores

the importance of early intervention and aggressive management during the acute phase to potentially mitigate long-term sequelae. Furthermore, clinicians should be vigilant in evaluating and monitoring patients with persistent symptoms, particularly fatigue and dyspnoea, as these may signal underlying pulmonary dysfunction. These findings advocate for a proactive and comprehensive approach to post-COVID-19 care, with a focus on early detection and management of pulmonary complications.

It is important to acknowledge the limitations of our study. Our sample size was relatively small and the single-centre design may limit the generalizability of our findings to other populations. Additionally, the retrospective nature of the study introduces the potential for selection bias and recall bias. Future research with larger, more diverse cohorts and prospective data collection is needed to further validate and expand upon our findings.

Conclusion

This study highlights the significant prevalence of persistent respiratory symptoms and pulmonary function abnormalities among individuals recovering from COVID-19. The severity of the acute illness and specific symptoms like fatigue and dyspnoea were identified as crucial indicators of long-term pulmonary health. These findings emphasize the need for comprehensive and ongoing monitoring of post-COVID-19 patients to facilitate early detection and management of pulmonary complications. Continued research is vital to further elucidate the underlying mechanisms, long-term trajectory, and effective treatment strategies for these complications.

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