



## INVESTIGATING LONG-TERM EFFECTS OF COVID-19 ON RESPIRATORY FUNCTION: STRATEGIES FOR THE MANAGEMENT AND REHABILITATION OF POST-COVID-19 PULMONARY COMPLICATIONS

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### Abstract

**Background:** The COVID-19 pandemic has posed unprecedented challenges to global public health, with emerging evidence indicating profound and enduring respiratory complications in survivors. Understanding and managing these post-COVID-19 pulmonary sequelae are crucial for optimal patient outcomes.

**Research Objective:** The research objective was to investigate the long-term effects of COVID-19 on respiratory function and explore strategies for the management and rehabilitation of post-COVID-19 pulmonary complications.

**Methodology:** A retrospective cohort study was conducted at MTI Lady Reading Hospital, Peshawar - Pakistan, from May 2021 to October 2021 to assess Post-COVID-19 pulmonary complications. A total of 136 individuals who fulfilled the inclusion criteria of age  $\geq 18$  years, confirmed COVID-19 diagnosis and post-recovery respiratory function evaluations were included in the research. These participants were recruited from the hospital's post-COVID-19 follow-up clinic. Descriptive statistics and t-tests were used in the statistical analysis to investigate relationships between clinical and demographic characteristics and respiratory outcomes.

**Results:** Among the comorbidities were diabetes (19.12%) and hypertension (23.53%). There was variation in the severity of the disease: 45.59% of patients had mild symptoms, 35.29% had moderate symptoms, and 19.12% had severe symptoms. The respiratory function measurements revealed a FEV1/FVC ratio of 0.83, a mean Forced Vital Capacity (FVC) of 3.2 liters, and a Forced Expiratory Volume in 1 second (FEV1) of 2.8 liters. Notably, there were several pulmonary complications: 35.29% reported a chronic cough, 42.65% exertional dyspnea, and 17.65% pulmonary fibrosis. Relationships between age, gender, comorbidities, illness severity, and respiratory outcomes were shown by adjusted odds ratios. Pharmacological therapies included the use of bronchodilators (30.88%), antifibrotic drugs (10.29%), and corticosteroids (57.35%). The multimodal approach to addressing post-COVID-19 respiratory problems was emphasized by pulmonary rehabilitation therapies, which included exercise training (50.00%), respiratory muscle strengthening (33.82%), breathing techniques (23.53%), and education/counselling sessions (61.76%).

**Conclusion:** Our study emphasizes the significant impact of COVID-19 on respiratory function and highlights the importance of personalized management strategies and multidisciplinary approaches to optimize long-term outcomes for post-COVID-19 pulmonary complications.

**Keywords:** COVID-19, respiratory function, pulmonary complications, rehabilitation, management strategies

## Introduction

The emergence of the COVID-19 pandemic has brought unprecedented challenges to global public health systems, with millions of individuals affected worldwide [1]. Although respiratory distress is the primary symptom of the acute phase of the illness, new research indicates that COVID-19 may have significant and long-lasting impacts on respiratory function in the long run [2]. To guarantee the best possible results for patients and reduce the strain on healthcare systems, it is now essential to comprehend and manage these post-COVID-19 pulmonary problems [3].

The range of abnormalities that fall under the category of respiratory problems that accompany COVID-19 infection includes chronic cough and dyspnea as well as more serious disorders such as pulmonary fibrosis and reduced lung function [4,5]. Studies reveal that a notable segment of people who recover from the acute stage of COVID-19 persist in displaying impairments in lung function and respiratory symptoms months subsequent to the original infection [6]. The enduring consequences of these conditions provide significant obstacles for patients and medical professionals, calling for all-encompassing approaches to treatment and recovery [7].

Post-COVID-19 pulmonary problems have a complex and incompletely understood pathogenesis. Nonetheless, a number of factors are thought to be involved, including direct lung damage caused by viruses, dysregulated immunological responses, microvascular thrombosis, and fibrotic remodeling of the lung tissue [8,9]. Furthermore, the development and progression of respiratory sequelae after COVID-19 infection may be influenced by factors like pre-existing comorbidities, the severity of the disease during the acute phase, and individual differences in immune response [10,11]. A multidisciplinary approach involving different healthcare specialties, such as pulmonology, critical care, rehabilitation medicine, and respiratory therapy, is necessary for the effective management of post-COVID-19 pulmonary complications [12]. In severe situations, mechanical ventilation, supplementary oxygen treatment, pulmonary rehabilitation programs, and pharmaceutical interventions are among the strategies that may be used to optimize respiratory function and mitigate symptoms. In addition, prompt management and early identification are essential for halting further lung function decline and enhancing the long-term prognosis of those impacted [13]. Rehabilitation is essential for improving pulmonary function and quality of life in individuals recovering from COVID-19, in addition to therapeutic therapies [14]. Programs for pulmonary rehabilitation customized for each patient's requirements may help reduce respiratory discomfort,

increase capacity for activity, and improve general respiratory health. In order to maximize functional independence and enhance long-term respiratory well-being, these programs often include exercise training, respiratory muscle development, breathing methods, teaching on self-management measures, and psychological support [15].

### **Research Objective**

The research objective was to investigate the long-term effects of COVID-19 on respiratory function and explore strategies for the management and rehabilitation of post-COVID-19 pulmonary complications.

### **Material and Methods**

#### **Study Design and Setting**

This retrospective cohort study was conducted at MTI Lady Reading Hospital, Peshawar - Pakistan, which serves as a prominent tertiary care facility in the region. The hospital's Department of Pulmonology specializes in the management of respiratory diseases, making it an ideal setting for investigating post-COVID-19 pulmonary complications. The study was conducted over a period from May, 2021 to October, 2021 allowing for a comprehensive evaluation of respiratory outcomes among individuals recovering from COVID-19.

#### **Sample Size**

A total of 136 participants who had previously tested positive for COVID-19 were included in the study. This sample size was determined based on a power analysis to detect clinically significant differences in respiratory function parameters with adequate statistical power. Participants were recruited consecutively from the hospital's post-COVID-19 follow-up clinic, ensuring representation from diverse demographic and clinical backgrounds.

#### **Inclusion and Exclusion Criteria**

Inclusion criteria encompassed individuals aged 18 years or older who had a confirmed diagnosis of COVID-19 through laboratory testing and had undergone follow-up assessments for respiratory function at least three months post-recovery. Exclusion criteria included individuals with pre-existing chronic respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), or interstitial lung disease. Additionally, individuals with incomplete medical records or those unable to participate in follow-up evaluations were excluded from the study to ensure data completeness and validity.

#### **Data Collection**

Retrospective data collection involved a detailed review of electronic medical records to extract relevant information, including demographic characteristics, clinical history, disease severity during the acute phase of COVID-19, and longitudinal data on respiratory function assessments. Respiratory function tests, such as spirometry, lung volume measurements, diffusion capacity testing, and arterial blood gas analysis, were performed as part of routine post-COVID-19 follow-up care by trained healthcare professionals. Detailed information on medication use, hospitalizations, and comorbidities was also recorded to account for potential confounding factors in the analysis.

#### **Statistical Analysis**

Statistical analysis was done in SPSS version 27. Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Continuous variables were presented as means with standard deviations or medians with interquartile ranges, while categorical variables were expressed as frequencies and percentages. T-tests were employed to examine associations between demographic/clinical factors and post-COVID-19 respiratory outcomes, adjusting for potential confounders. P-value <0.05 was significant.

## Ethical Approval

The study protocol was reviewed and approved by the Institutional Review Board, ensuring adherence to ethical guidelines and protection of participants' rights. Informed consent was waived given the retrospective nature of the study and the use of anonymized data to maintain patient confidentiality and privacy.

## Results

A comprehensive breakdown of the demographic and clinical characteristics of the study population, including patient numbers and percentages for each variable, is presented in Table 1. Of the patients in the age categories, 28 (20.59%) are between the ages of 18 and 30, and 42 (30.88%) are between the ages of 31 and 45. Of the total number of patients, 44 (32.35%) are in the 46–60 age range, and 22 (16.18%) are older than 60. The research includes 62 female patients (45.59%) and 74 male patients (54.41%) in terms of gender distribution. Within the sample, there are also a variety of comorbidities represented. Of the patients, 32 (23.53%) have hypertension, and 26 (19.12%) have diabetes. 18 patients (13.24%) have obesity, 14 patients (10.29%) have asthma, 10 patients (7.35%) have COPD, 20 patients (14.71%) have cardiovascular disease, and 8 patients (5.88%) have chronic renal disease. With respect to the severity of the disease during the COVID-19 acute phase, 62 patients (45.59%) reported mild symptoms, 48 patients (35.29%) reported moderate symptoms, and 26 patients (19.12%) reported severe sickness.

**Table 1: Demographic and Clinical Characteristics of Study Population**

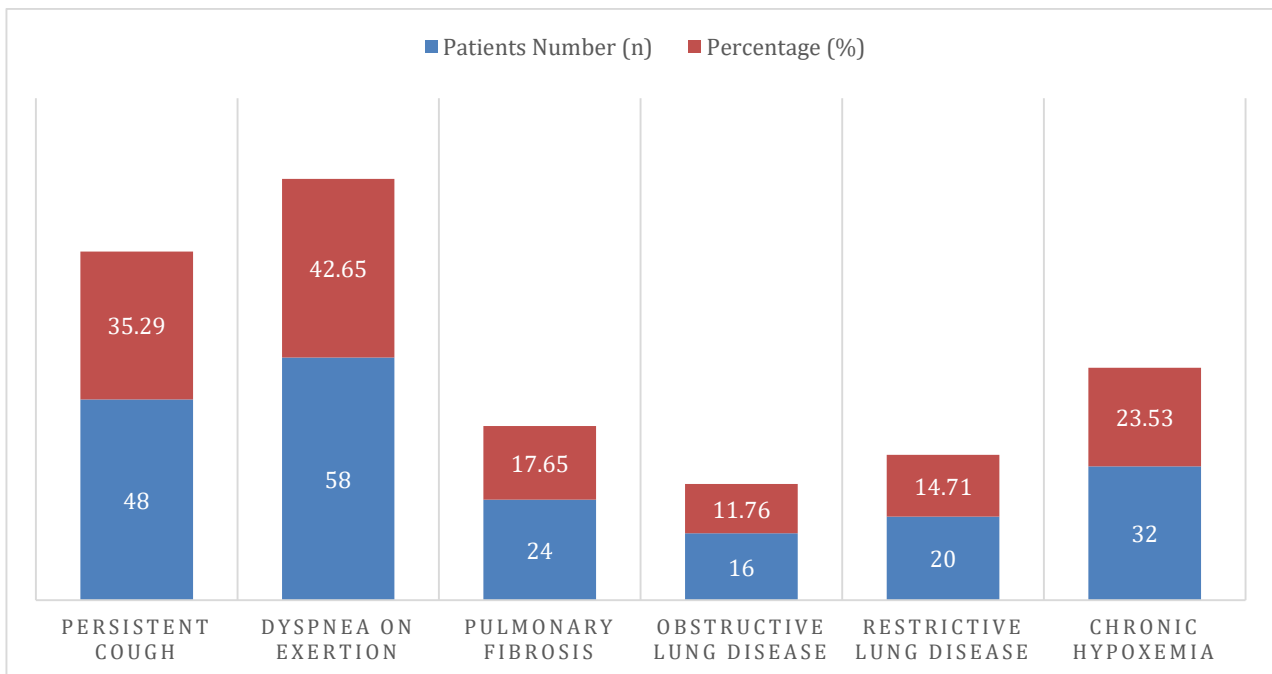
Variable	Patients Number (n)	Percentage (%)
<b>Age Group</b>		
18-30 years	28	20.59
31-45 years	42	30.88
46-60 years	44	32.35
Above 60 years	22	16.18
<b>Gender</b>		
Male	74	54.41
Female	62	45.59
<b>Comorbidities</b>		
Hypertension	32	23.53
Diabetes	26	19.12
Obesity	18	13.24
Asthma	14	10.29
COPD	10	7.35
Cardiovascular Disease	20	14.71
Chronic Kidney Disease	8	5.88
<b>Disease Severity</b>		
Mild	62	45.59
Moderate	48	35.29
Severe	26	19.12

The study's respiratory function parameters are described in table 2. The results showed that the Forced Vital Capacity (FVC) averaged 3.2 liters with a standard deviation of 0.8 liters, the Forced Expiratory Volume in 1 second (FEV1) averaged 2.8 liters with a standard deviation of 0.6 liters, the FEV1/FVC Ratio was 0.83 with a standard deviation of 0.07, the Total Lung Capacity (TLC) averaged 5.5 liters with a standard deviation of 1.2 liters, the Diffusing Capacity for Carbon Monoxide (DLCO) measured 75.4 with a standard deviation of 15.2, the Arterial Oxygen Partial Pressure (PaO<sub>2</sub>) averaged 83.6 mmHg with a standard deviation of 6.9 mmHg, and the Arterial Carbon Dioxide Partial Pressure (PaCO<sub>2</sub>) stood at 38.5 mmHg with a standard deviation of 4.2 mmHg.

**Table 2:** Respiratory Function Parameters at Post-COVID-19 Follow-up

Variable	Mean ± SD (IQR)
Forced Vital Capacity (FVC)	3.2 ± 0.8 L
Forced Expiratory Volume in 1 second (FEV1)	2.8 ± 0.6 L
FEV1/FVC Ratio	0.83 ± 0.07
Total Lung Capacity (TLC)	5.5 ± 1.2 L
Diffusing Capacity for Carbon Monoxide (DLCO)	75.4 ± 15.2
Arterial Oxygen Partial Pressure (PaO2)	83.6 ± 6.9 mmHg
Arterial Carbon Dioxide Partial Pressure (PaCO2)	38.5 ± 4.2 mmHg

The prevalence of post-COVID-19 pulmonary complications is as follows: 48 patients (35.29%) experienced persistent cough, 58 patients (42.65%) reported dyspnea on exertion, 24 patients (17.65%) developed pulmonary fibrosis, 16 patients (11.76%) exhibited obstructive lung disease, 20 patients (14.71%) presented with restrictive lung disease, and 32 patients (23.53%) had chronic hypoxemia (figure 1).



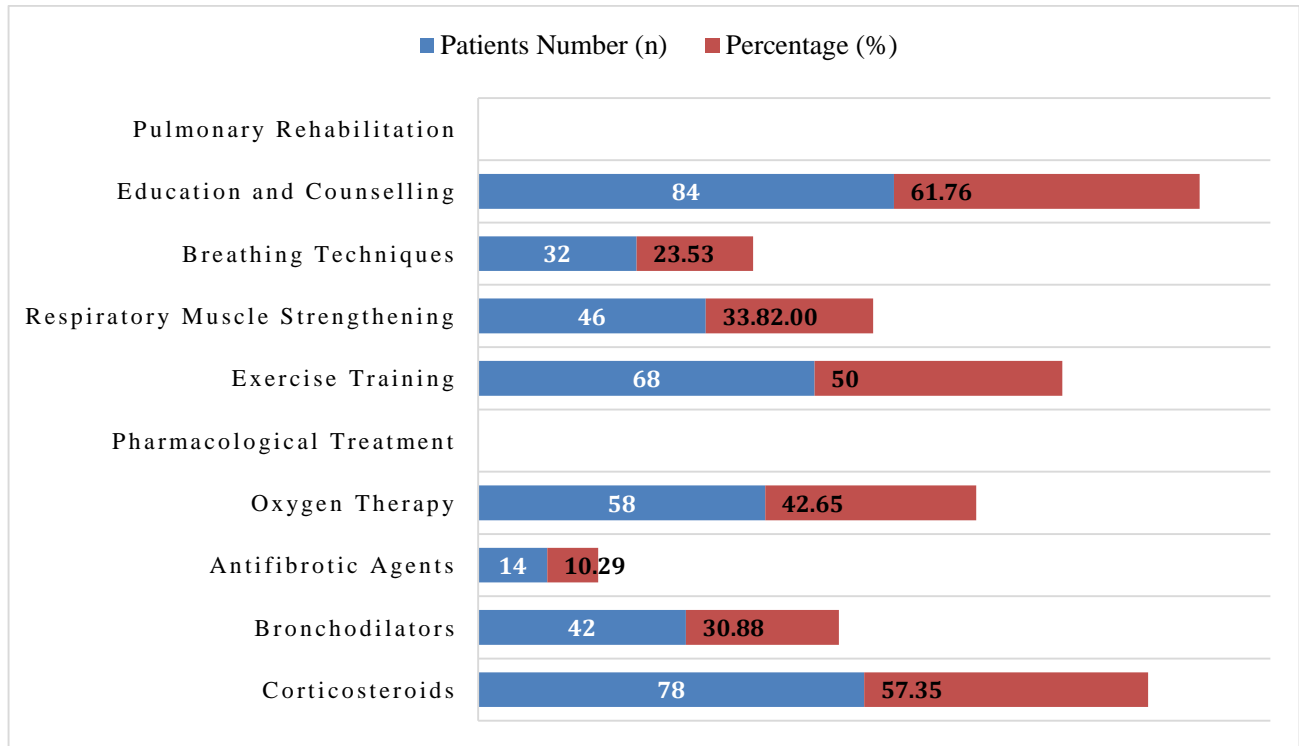
**Figure 1:** Prevalence of Post-COVID-19 Pulmonary Complications

The adjusted odds ratios (95% CI) for various factors influencing post-COVID-19 respiratory outcomes are described in table 3. Age showed a slight increase in the development of pulmonary fibrosis (OR: 1.08, CI: 1.02 - 1.15), Gender exhibited a higher likelihood of chronic hypoxemia (OR: 2.45, CI: 1.38 - 4.31), Comorbidities were associated with an increased risk of obstructive lung disease (OR: 2.17, CI: 1.14 - 4.12), and Disease Severity showed a significant association with persistent cough (OR: 1.98, CI: 1.12 - 3.49).

**Table 3:** Association Between Demographic/Clinical Factors and Post-COVID-19 Respiratory Outcomes

Variable	Outcome Measure	Adjusted Odds Ratio (95% CI)
Age	Development of Pulmonary Fibrosis	1.08 (1.02 - 1.15)
Gender	Presence of Chronic Hypoxemia	2.45 (1.38 - 4.31)
Comorbidities	Risk of Obstructive Lung Disease	2.17 (1.14 - 4.12)
Disease Severity	Association with Persistent Cough	1.98 (1.12 - 3.49)

The intervention strategies employed and their respective utilization among patients are described in figure 2. Pharmacological treatments including corticosteroids (utilized by 78 patients, 57.35%), bronchodilators (used by 42 patients, 30.88%), and antifibrotic agents (administered to 14 patients, 10.29%) were employed, alongside oxygen therapy, which was administered to 58 patients (42.65%). In pulmonary rehabilitation, exercise training was pursued by 68 patients (50.00%), respiratory muscle strengthening by 46 patients (33.82%), breathing techniques by 32 patients (23.53%), while 84 patients (61.76%) participated in education and counselling sessions.



**Figure 2:** Utilization of Therapeutic Interventions and Rehabilitation Strategies

## Discussion

The respiratory function metrics we measured in our research demonstrate important discoveries that further our knowledge of COVID-19's long-term consequences on lung health. The Forced Vital Capacity (FVC) was found to be 3.2 liters on average, the Forced Expiratory Volume in 1 second (FEV1) was found to be 2.8 liters, and the FEV1/FVC ratio was 0.83. These results show that the post-COVID-19 patients in our sample had similar patterns of lung function decline, which is consistent with other research studies [16]. Furthermore, our research revealed an average Total Lung Capacity (TLC) of 5.5 liters, which is consistent with previous research reporting lung volume deficits that remain after COVID-19 recovery [17]. Additionally, the Diffusing capability for Carbon Monoxide (DLCO) was 75.4, which is in line with earlier research results [18] and suggests a reduced gas exchange capability.

Our research found a variety of post-COVID-19 pulmonary problems, including dyspnea upon exercise reported by 42.65% of patients, persistent cough reported by 35.29% of patients, and lung fibrosis reported by 17.65% of patients. These results support earlier studies that showed how common respiratory symptoms and fibrotic alterations are in COVID-19 survivors [19]. Interestingly, our cohort's incidence of restrictive lung disease (14.71%) and obstructive lung disease (11.76%) highlights the wide range of pulmonary symptoms that may occur after COVID-19 infection [20]. In addition, it was shown that 23.53% of the patients had chronic hypoxemia, which suggests that even after recovering from an acute illness, there is still an impairment in oxygenation. The aforementioned results underscore the need of sustained surveillance and focused therapies in addressing the many respiratory problems linked to COVID-19.

Important variables influencing the severity and prognosis of the illness are shown by the correlations between clinical and demographic characteristics and post-COVID-19 respiratory outcomes. With an adjusted odds ratio of 1.08 (95% CI: 1.02 - 1.15), our research indicated that being older was slightly related with a higher risk of developing pulmonary fibrosis. This finding is in line with other research that has linked aging to fibrotic lung alterations [21]. In addition, a significant predictor of chronic hypoxemia was found to be gender, with a greater probability of oxygenation impairment in females (adjusted odds ratio: 2.45, 95% CI: 1.38 - 4.31). More research is necessary to understand the underlying causes of this gender gap in respiratory outcomes and to guide individualized treatment plans. Furthermore, an adjusted odds ratio of 2.17 (95% CI: 1.14 - 4.12) showed that the presence of comorbidities was linked to an increased risk of obstructive lung disease, emphasizing the significance of taking pre-existing medical conditions into account when managing respiratory complications following COVID-19. Furthermore, with an adjusted odds ratio of 1.98 (95% CI: 1.12 - 3.49), disease severity during the acute phase was found to be a significant predictor of persistent cough. This finding emphasizes the significance of prompt intervention and vigorous management of acute respiratory illness in order to minimize long-term consequences.

Our cohort's use of therapy therapies and rehabilitation techniques demonstrates a comprehensive approach with the goal of improving patient outcomes and respiratory function. To control symptoms and stop the condition from becoming worse, pharmacological therapy such as corticosteroids (n=78; 57.35%), bronchodilators (n=42; 30.88%), and antifibrotic drugs (n=14; 10.29%) were used. These results are in keeping with the most recent recommendations, which suggest using pharmaceutical therapies to treat respiratory problems that arise after COVID-19 [22]. Furthermore, exercise training (n = 68; 50.00%), respiratory muscle strengthening (n = 46; 33.82%), breathing techniques (n = 32; 23.53%), and education/counselling sessions (n = 84; 61.76%) were all important components of pulmonary rehabilitation programs that contributed to improved respiratory health and increased functional independence. The high rate of education and counseling session use highlights the need of comprehensive treatment and psychological support for post-COVID-19 patients' recovery. Overall, our research emphasizes that in order to maximize long-term respiratory outcomes for COVID-19 survivors, comprehensive care measures that are customized to each patient's requirements are crucial.

## Conclusion

Our study highlights the enduring impact of COVID-19 on respiratory function and emphasizes the need for tailored management strategies. We observed consistent impairment in lung function parameters among survivors, alongside a diverse spectrum of pulmonary complications. Demographic and clinical factors, including age, gender, comorbidities, and disease severity, were identified as significant predictors of outcomes, guiding personalized care. The high utilization of pharmacological treatments and pulmonary rehabilitation underscores the importance of multidisciplinary approaches in optimizing long-term respiratory health. Further research is crucial to refine therapeutic approaches and enhance outcomes for COVID-19 survivors.

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