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Original Article

# Breath After the Storm: Longitudinal Spirometry in COVID 19 Survivors- A Prospective Cohort Study

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## I N F O

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## A B S T R A C T

*Background*: Persistent pulmonary dysfunction after COVID-19 pneumonia recovery remains a concern, with restrictive patterns commonly reported. This study assessed spirometric abnormalities in patients recovered from COVID-19 pneumonia and their associations with comorbidities, smoking, and disease severity.

*Methods*: A prospective cohort study enrolled 53 adults (>18 years) discharged from COVID-19 wards after 6–12 weeks post-diagnosis. Inclusion required RT-PCR/RAT confirmation and bilateral infiltrates on chest imaging; exclusions included pre-existing respiratory/cardiac disease, obesity (BMI >30 kg/m²), and pregnancy. Spirometry (Schiller Spirovit SP1) was performed at 6–12 weeks and repeated 3 months later. Data was analyzed using SPSS v25, with chi-square, t-tests, ANOVA, and logistic regression ($p < 0.05$ is significant).

*Results*: The mean age of the subjects was 54.5 ± 12.3 years; 83% were male, 75% with comorbidities (mostly diabetes/hypertension), and 94% nonsmokers. Clinical severity: 49% of subjects had mild, 26% of subjects had moderate, and 25% of subjects had severe disease clinically and had a mean CTSS of 12.25 ± 5.96. Abnormal spirometry was found in 28.3% of subjects at the first follow-up (mostly restrictive, 20.8%) and 17% at the second follow-up (13.2% restrictive). Improvement noted in pulmonary function was statistically not insignificant ($p = 0.441$). Nonsmokers had better outcomes ($p = 0.043$ first and $p = 0.001$ second); severe cases showed more defects.

*Conclusion*: Restrictive ventilatory defect predominates post-COVID-19, with improvement over 3 months, influenced by smoking and severity. Larger studies including DLCO/plethysmography are needed.

**Keywords**: Spirometry, COVID-19, Post-COVID, Smoking

## Introduction

Coronaviruses are major pathogens that primarily target the human respiratory system. In late December 2019, a large number of patients were admitted to hospitals with pneumonia of unknown etiology. These patients were epidemiologically linked to a seafood and liveanimal wholesale market in Wuhan, Hubei Province, China.[1,2] Early reports predicted the onset of a potential coronavirus outbreak, given that the estimated basic reproduction number for the 2019 novel coronavirus (COVID19, named by WHO on 11 February 2020) was significantly greater than 1 (ranging from 2.24 to 3.58).[3] On 30th January 2020, India reported the first confirmed case of COVID19 in Kerala. The patient was a student who had returned from Wuhan, China, where the outbreak first occurred.[4] COVID19 is characterized by rapid onset, high infectivity, and a high incidence in susceptible populations, with symptoms that may include fever, fatigue, cough, and dyspnea.[5] The majority of cases are asymptomatic. In the later period of COVID19–induced illness, infection predominantly manifests as pneumonia clinically and as fibrosis radiologically.[6] The CT (computed tomography) hallmark of COVID19 is bilateral distribution of groundglass opacities with or without consolidation in the posterior or peripheral lung, while predominant findings in the later phase include consolidations, linear opacities, a crazypaving pattern, a reverse halo sign, and vascular enlargement. Recent studies have revealed that the lung is the organ most affected by COVID19, with pathologies that include diffuse alveolar epithelial destruction, capillary damage and bleeding, hyaline membrane formation, alveolar septal fibrous proliferation, and pulmonary consolidation.[7] Preliminary evidence suggests that impaired lung function in coronavirus pneumonia can persist for several months or years, with a reduction in diffusion capacity of the lung for carbon monoxide (DLCO) being the most common abnormality, followed by a decrease in total lung capacity (TLC).[8]

## Aims and Objectives

The main aim of the study was to assess and categorize abnormalities in pulmonary function, if present, as restrictive or obstructive in patients who had recovered from COVID19. The secondary aim was to compare the pulmonary function of patients who recovered from COVID19 pneumonia with and without comorbidities and to correlate these findings with disease severity.

## Materials and Method

The study was a prospective cohort study conducted over a period of one year on patients who were discharged from the COVID19 wards and 6 to 12 weeks after their diagnosis of COVID19. They underwent spirometry at the 1st follow-up visit at 6–12 weeks after the diagnosis of COVID19, and the spirometry test was repeated at the 2nd follow-up visit, three months after the first test.

Based on the prevalence reported in previous literature (in the study by Mo X et al.) and assuming a 95% confidence interval and an allowable error of 10%, the calculated sample size was 300; however, due to time constraints, 53 patients were recruited for our study.[9]

Patients older than 18 years who were diagnosed by reverse transcriptase polymerase chain reaction (RTPCR) or rapid antigen test (RAT) on nasopharyngeal swab and had bilateral lung infiltrates on chest Xray or CT during admission for COVID care were enrolled according to the inclusion criteria. Patients with preexisting respiratory illness (asthma, COPD, and ILD); cardiac illness (CAD); obesity (BMI > 30 kg/m²); and pregnant females were excluded.

Informed consent was obtained from all the subjects. All the study subjects underwent a detailed clinical history and examination using a structured proforma, including demographic details such as age, gender, residence, and smoking status. The history included clinical features at the time of admission and at the time of testing. Detailed physical examination findings, including vital signs (blood pressure, pulse rate, oxygen saturation), were recorded, and biochemical results and radiological findings (chest Xray and CT chest) obtained at the time of admission were also documented.

Spirometry was performed in the respiratory lab of the Department of Pulmonary Medicine. During testing, patients were seated on a stool in front of the spirometer (Schiller, Spirovit SP1). The mouthpiece was fitted snugly for each subject so that all exhaled air entered the spirometer. In addition, a nose clip was placed to prevent air leakage through the nose. The steps of the procedure were explained to each patient by the technician. Initially, the patients were asked to breathe normally and tidally. Once the patients were stabilized, they were instructed to inhale to full lung capacity and then exhale forcefully and rapidly into the spirometer, followed by another inhalation.

The spirometric parameters derived from the FVC maneuver were forced expiratory volume in the first second ($FEV_1$), forced vital capacity (FVC), $FEV_1$/FVC ratio, and peak expiratory flow rate (PEFR, 25–75%). Interpretations such as obstructive ventilatory defect, restrictive ventilatory defect, and small airway involvement were derived from these parameters and the flow–volume loop (FV loop).

For statistical analysis, data were entered into MS Excel and processed using SPSS version 25, MS Excel Office 365, and GraphPad Prism 8.4.2. Continuous variables were expressed as mean ± standard deviation if normally distributed and as

median with interquartile range if not normally distributed. Categorical variables were expressed as percentages. Comparisons of percentages between two or more groups were made using the chisquare test, while comparisons of continuous variables between two groups were made using the independent ttest and between three groups using oneway ANOVA. Comparisons between baseline and followup data were made using the paired ttest. A logistic regression model was constructed to identify significant covariates of impaired PFT at three months. A pvalue of less than 0.05 was considered statistically significant.

Patients' information was handled confidentially, and any abnormalities detected during screening were appropriately managed.

## Results

Fifty-three patients were recruited in this study. The age of the patient ranged from 26 to 75 years, with a mean age of 54.51 ± 12.3 years. Of these 53 subjects, 44 (83%) were male and 9 (17%) were female. In this study, 40 (75.47%) subjects had comorbidities; of these, 33 (82.5%) had diabetes, 33 (82.5%) had hypertension, and 26 (49.05%) had both. Diabetes and hypertension were also present in subjects with other comorbidities.[10]

The majority of subjects, 50 (94.3%), were nonsmokers at the time of spirometry. Of the 53 subjects, 26 (49%) patients had mild, 14 (26%) patients had moderate, and 13 (25%) patients had severe disease clinically at presentation. According to the CT severity score (CTSS) across all radiological categories, 22 (42%) subjects were in the mild category, 18 (34%) in the moderate category, and 13 (25%) in the severe category. [11] The mean CTSS of the study population was 12.25 ± 5.96.

Case distribution according to spirometry outcomes at first and second follow-ups (N = 53) is depicted in Table 1. Of the 53 subjects, 15 (28.3%) subjects had impaired lung function at the first follow-up visit (6-12 weeks after the diagnosis of COVID) and 9 (16.98%) subjects at the second follow-up (3 months from the 1st follow-up).

Distribution of cases according to spirometry outcomes at the first follow-up visit is depicted in Table 2 and Figure 1. In this study, the majority (71%) of subjects showed normal lung function on the first test. Among subjects with abnormal lung function, the most common ventilatory defect was restrictive (21%).

Distribution of Cases According to spirometry outcomes during the second follow-up visit (3 months after the first test) is depicted in Table 2. The majority (83%) of subjects showed normal lung function on the second test as well. Among subjects with abnormal lung function, the most common ventilatory defect was restrictive, affecting 7 (13.2%) subjects.

**Table 1.Spirometry Outcomes at First and Second Follow-up Visits**

| | Number of cases (%) | | p-value |
|---|---|---|---|
| | Normal | Impaired | |
| Spirometry at First Follow-up Visit | 38 (71.69%) | 15 (28.3%) | 0.441 |
| Spirometry at Second Follow-up Visit | 44 (83.01%) | 9 (16.98%) | |

**Table 2.Spirometry outcome at 1st and 2nd Follow-up Visits**

| Spirometry Outcomes | (At 1st Follow -up Visit ) Frequency (N) | (At 2nd Follow-up Visit) Frequency (%) |
|---|---|---|
| Normal | 38 (71.7%) | 44 (83%) |
| Obstructive | 2 (3.8%) | 1 (1.9%) |
| Restrictive | 11 (20.8%) | 7 (13.2%) |
| Small Airway Disease | 2 (3.8%) | 1 (1.9%) |
| Total | 53 (100%) | 53 (100%) |

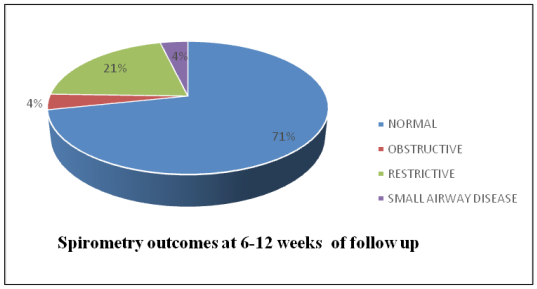


**Figure 1.Pie Chart showing Spirometry outcome at First Follow-up Visit**

Comparison of Spirometry outcomes from first to second follow-up (N=53) is depicted in Table 3. Improvement in lung function was seen at 2nd follow-up visit amongst subjects with ventilatory defects, although the improvement was statistically insignificant.

The present study showed that most patients with diabetes alone (42.9%) and those with both diabetes and hypertension (26.9%) had restrictive ventilatory defects during follow-up. Patients with hypertension alone had abnormal lung function in some cases (14.3%). Lung function was unaffected in patients without comorbidities. Spirometry findings at the first follow-up visit with respect to comorbidities in the study population are shown in Table 4.

Spirometry findings at the second follow-up visit with respect to various comorbidities in the study population are shown in Table 5.

The study showed that most patients with diabetes (28.6%) and those with both diabetes and hypertension (19.2%) had restrictive ventilatory defects during follow-up. Patients with hypertension alone who had abnormal lung function at the 6–12-week follow-up showed improvement at the second follow-up. Among diabetic and hypertensive patients, more than 70% had normal lung function, and the most common ventilatory defect was restrictive (affecting 21.2% of diabetics and 15.2% of hypertensives, respectively). The pvalue was >0.05, so the association was statistically insignificant.

**Table 3.Comparison of Spirometry outcome at 1st Follow-up visit and 2nd Follow-up Visit**

| Interpretation of Spirometry Outcomes | Number of cases (%) | | p-value |
|---|---|---|---|
| | At 1st Follow-up Visit | At 2nd Follow-up Visit | |
| Normal | 38 (71.69%) | 44 (83.01%) | 0.164 |
| Mild Restrictive | 7 (13.2%) | 6 (11.32%) | 0.767 |
| Moderate Restrictive | 3 (5.66%) | 1 (1.88%) | 0.308 |
| Severe Restrictive | 1 (1.88%) | 0 (0%) | 0.315 |
| Obstructive | 2 (3.77%) | 1 (1.88%) | 0.558 |
| Small airway disease | 2 (3.77%) | 1 (1.88%) | 0.558 |

**Table 4.Spirometry outcome in Post-COVID patients w.r.t. Comorbidities**

| Comorbidities (N) | Normal | | Obstructive ventilatory defect | | Obstructive ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| NONE (13) | 13 | 100.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| DM (7) isolated | 4 | 57.1% | 0 | 0.0% | 3 | 42.9% | 0 | 0.0% |
| HTN (7) isolated | 5 | 71.4% | 0 | 0.0% | 1 | 14.3% | 1 | 14.3% |
| DM+HTN (26) | 16 | 61.5% | 2 | 7.7% | 7 | 26.9% | 1 | 3.8% |
| Total (53) | 38 | 71.7% | 2 | 3.8% | 11 | 20.8% | 2 | 3.8% |

**Table 5.Spirometry Outcomes at 2nd Follow-up visit w.r.t. various Comorbidities**

| Comorbidities | Normal | | Obstructive ventilatory defect | | Restrictive ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| NONE (13) | 13 | 100.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| DM (7) | 5 | 71.4% | 0 | 0.0% | 2 | 28.6% | 0 | 0.0% |
| HTN (7) | 7 | 100.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| DM+HTN (26) | 19 | 73.1% | 1 | 3.8% | 5 | 19.2% | 1 | 3.8% |
| Total (53) | 44 | 83.0% | 1 | 1.9% | 7 | 13.2% | 1 | 1.9% |

Spirometry outcomes at the first follow-up visit with respect to smoking history are shown in Table 6. The majority of study subjects were nonsmokers (94.3%); out of 50 nonsmokers, 72% showed normal lung function, followed by 22% with restrictive ventilatory defects and 4% with obstructive defects. Among smokers, 66.7% had normal

lung function. Nonsmokers showed better spirometry outcomes (p = 0.043, statistically significant).

Spirometry outcomes at the 2nd follow-up visit with respect to smoking history are shown in Table 7. Of the 50 nonsmokers, 84% showed normal lung function, followed by 14% with restrictive ventilatory defects and 2% with obstructive defects. Among smokers, 66.7% had normal lung function, and one had small airway disease during follow-up. Nonsmokers had better spirometry outcomes and showed improvement in lung function during follow-up (p = 0.001, statistically significant).

Spirometry outcomes at first follow-up visit with respect to clinical severity of COVID-19 at admission is shown in Table 8. The study showed that 38.5% of severe cases had restrictive ventilatory defects, as did 28.6% of cases with moderate COVID. The p-value was 0.176 (>0.05), which was statistically insignificant.

Spirometry outcomes at the second follow-up visit with respect to clinical severity of COVID19 at admission are shown in Table 9. This study showed that 30.8% of severe cases had restrictive ventilatory defects, as did 14.3% of moderate cases. The majority of cases (>65%) had normal lung function during follow-up. The pvalue was 0.298 (>0.05), which was statistically insignificant.

**Table 6.Spirometry Outcomes at First Follow-up visit w.r.t. Smoking History**

| H/O SMOKING (N) | Normal | | Obstructive ventilatory defect | | Restrictive ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| YES (3) | 2 | 66.7% | 0 | 0.0% | 0 | 0.0% | 1 | 33.3% |
| NO (50) | 36 | 72.0% | 2 | 4.0% | 11 | 22.0% | 1 | 2.0% |
| TOTAL (53) | 38 | 71.7% | 2 | 3.8% | 11 | 20.8% | 2 | 3.8% |

**Table 7.Spirometry outcomes at second Follow-up visit w.r.t. Smoking**

| H/O SMOKING(N) | Normal | | Obstructive ventilatory defect | | Restrictive Ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| YES (3) | 2 | 66.7% | 0 | 0.0% | 0 | 0.0% | 1 | 33.3% |
| NO (50) | 42 | 84.0% | 1 | 2.0% | 7 | 14.0% | 0 | 0.0% |
| TOTAL (53) | 44 | 83.0% | 1 | 1.9% | 7 | 13.2% | 1 | 1.9% |

**Table 8.Spirometry outcomes at First Follow-up visit w.r.t. Clinical Severity of COVID-19 at Admission**

| Clinical Severiry of COVID (N) | Normal | | Obstructive ventilatory defect | | Restrictive ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Mild (26) | 20 | 76.9% | 2 | 7.7% | 2 | 7.7% | 2 | 7.7% |
| Moderate (14) | 10 | 71.4% | 0 | 0.0% | 4 | 28.6% | 0 | 0.0% |
| Severe (13) | 8 | 61.5% | 0 | 0.0% | 5 | 38.5% | 0 | 0.0% |
| Total (53) | 38 | 71.7% | 2 | 3.8% | 11 | 20.8% | 2 | 3.8% |

**Table 9.Spirometry Outcomes at second Follow-up Visit w.r.t Clinical Severity of COVID-19 at Admission**

| Clinical Severity(N) | Normal | | Obstructive ventilatory defect | | Obstructive ventilatory defect | | Small airway disease | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Mild (26) | 23 | 88.5% | 1 | 3.8% | 1 | 3.8% | 1 | 3.8% |
| Moderate (14) | 12 | 85.7% | 0 | 0.0% | 2 | 14.3% | 0 | 0.0% |
| Severe (13) | 9 | 69.2% | 0 | 0.0% | 4 | 30.8% | 0 | 0.0% |
| Total (53) | 44 | 83.0% | 1 | 1.9% | 7 | 13.2% | 1 | 1.9% |

## Discussion

In the present study, spirometry abnormalities were present in 15 (28.3%) of 53 subjects at the first follow-up visit (at 6-12 weeks after the diagnosis of COVID-19). Out of these, 11 (20.8%) subjects had restrictive ventilatory defects, 2 (3.8%) had obstructive ventilatory defects, and 2 (3.8%) had small airway disease. At the second follow-up (3 months after the first test), 9 (16.98%) subjects out of these 53 subjects had impaired lung function. Out of these, 7 (13.2%) subjects had restrictive ventilatory defects, 1 (1.9%) had obstructive ventilatory defects, and 1 (1.9%) had small airway disease. Among the 11 subjects with restrictive ventilatory defects at the first follow-up, the majority (n = 7, 63.6%) had mild defects, followed by moderate (n = 3, 27.3%) and severe (n = 1, 9.1%). At the second follow-up, among the 7 subjects with restrictive ventilatory defects, the majority had mild defects (n = 6, 85.7%), followed by moderate defects (n = 1, 14.3%). All three cases of moderate restrictive defects improved to mild restriction at the second follow-up.

Spirometry abnormalities were absent in the age group <40 years. Abnormalities were present in patients aged >40 years during follow-up and were maximal among those aged >70 years. Females were affected more often (33.3%) after COVID19 than males (27.3%), with obstructive ventilatory defects being the most common abnormality among females, although fewer females were included in the present study. Subjects with BMI ≥ 25 kg/m² (overweight) were affected more often (29.4%) than those with BMI < 25 kg/m².

Modi et al. conducted a study in which spirometry and diffusion capacity of the lung (DLCO) were assessed in 52 postCOVID patients. Abnormal spirometry parameters were present in 27 (51.9%) patients, with a restrictive pattern being the most common abnormality (n = 23, 44.2%).[12] The most common spirometry abnormality was restrictive, similar to the present study; however, fewer subjects were affected in the present study, possibly because mild cases were more numerous. This predominance of restrictive ventilatory defects may be attributed to postinfection complications of COVID19 disease, including longterm pulmonary effects, with pulmonary fibrosis being one of the serious complications. [13]

In the present study, most subjects had normal spirometry parameters at the first (71.69%) and second (83.01%) follow-up. Among subjects with impaired lung function, the most common abnormality was a restrictive ventilatory defect; obstructive ventilatory defects and small airway involvement were also present in some subjects. At follow-up (3 months after the first test), subjects with abnormal lung function showed improvement, although it was statistically insignificant.

In the present study, most subjects with comorbidities (n = 40) had normal lung function at the 6–12-week follow-up (n = 25) and at 3 months after the first test (n = 31). Diabetics were affected more than hypertensives and those with other comorbidities at the first follow-up (39.4%) and second follow-up (27.2%). The most common ventilatory defect among hypertensives and diabetics was restrictive, followed by obstructive ventilatory defects; some had small airway disease as well. Subjects with ventilatory defects showed improvement in lung function over time. No lung function abnormalities were present during the first and second follow-up among patients with hypothyroidism, anaemia, or thalassemia. Similar to the present study, Sibila et al. concluded that diabetics had altered spirometry 3 months after discharge, attributed to immune dysregulation caused by diabetes, which may contribute to pulmonary fibrosis postCOVID. 14

The present study included 53 subjects, of whom 3 (6%) were smokers and 50 (94%) were nonsmokers. Of these 50 nonsmokers, 11 (22%) subjects had restrictive ventilatory defects, followed by obstructive ventilatory defects in 2 (4%). The most common ventilatory defect among nonsmokers was restrictive (p = 0.043, statistically significant). Similarly, 3 months after the first test, restrictive ventilatory defect (14%) was the most common spirometry abnormality among nonsmokers, followed by obstructive ventilatory defect (2%) (p = 0.041, statistically significant).

Stockley et al. conducted a study in which nonsmokers showed greater hospitalization, possibly because smokers (more likely to have COPD) either shielded themselves from COVID19 and never became infected or were not followed up. 15 This could be misinterpreted as evidence of a “protective effect” of smoking against COVID19. Among smokers, 66.7% had normal lung function and 33.3% showed small airway involvement that persisted at follow-up (3 months after the first test). Restrictive ventilatory defects were not seen among smokers (p < 0.05, statistically significant). This may be attributed to a potential protective effect of smoking against COVID19, while persistent small airway involvement may be due to preexisting disease or ongoing smoking. Our study included only 3 smokers out of 53 subjects; the pattern would have been clearer with equal proportions of smokers and nonsmokers.

Patients of COVID in the present study were classified by clinical severity as mild (n = 26, 49%), moderate (n = 14, 26%), and severe (n = 13, 25%) according to Ministry of Health and Family Welfare (MoH&FW) criteria; approximately half fell into the mild category. Patients across all severities had ventilatory defects during both follow-ups, although most had normal spirometry. Maximal lung function abnormalities were observed among severe cases at both follow-ups. The most common ventilatory

defect among moderate and severe cases at both follow-ups was restrictive. Among mild cases, both restrictive and obstructive ventilatory defects were observed at both follow-ups, and small airway involvement was seen in some subjects. At the second follow-up (3 months after the first test), all 53 subjects across clinical severities showed improvement in lung function, with maximal improvement among mild and moderate cases. A study highlighted restrictive spirometry's association with COVID severity, echoing our observations in severe cases (38.5%). [16]

In the present study, cases were also classified by CT severity score (CTSS) at admission as mild (0–8; n = 22, 42%), moderate (9–17; n = 18, 34%), and severe (>18–25; n = 13, 25%). The mean (± SD) CTSS of patients was 12.25 (± 5.96). De Graaf et al. conducted a shortterm followup study on COVID19 patients in which the mean (± SD) CTSS in the study was 12.7 ± 4.9, similar to the present study.[17]

In the present study, the mean (± SD) CTSS of subjects with normal lung function was 11.78 (± 5.63) and 11.81 (± 5.67) at the first and second follow-ups, respectively. The mean (± SD) CTSS of subjects with restrictive ventilatory defects was 15.81 (± 6.3) and 16.57 (± 6.52) at the first and second follow-ups, respectively, while the mean CTSS (± SD) of subjects with obstructive ventilatory defects and small airway involvement was in the mild score range at both follow-ups. The pvalue for the CTSS and spirometry outcome at 6–12 weeks of follow-up was 0.049 (< 0.05), which was statistically significant. This may be attributed to COVID19 disease severity being a risk factor for postCOVID residual lung function abnormalities. In our study, most subjects across severity groups showed normal lung function at both follow-ups. Maximal abnormal lung function (38.46% and 30.76%) was observed at both follow-ups among patients with severe CTSS at admission. Among subjects with moderate and severe CTSS, the most common spirometry abnormality was restrictive ventilatory defect. Subjects with mild CTSS showed restrictive as well as obstructive ventilatory defects at follow-up, and small airway involvement was observed in some. Improvement in spirometry was observed from the first to the second follow-up across all CTSS severities. A Malaysian study reported restrictive patterns in one-third of moderate-severe COVID survivors at 5 months, associated with CT abnormalities, consistent with our CTSS findings (p=0.049). [18]

Strumiliene et al. conducted a study evaluating pulmonary function (spirometry, DLCO), exercise capacity, and residual radiological changes at 2 months after hospital discharge. Pulmonary function at follow-up was impaired in 24 (47.2%) patients, who had moderate, severe, or critical illness during admission; different levels of abnormality were found in 49/51 patients on follow-up chest CT. The study concluded that residual changes in the lungs on chest CT and in lung function were present among COVID19 pneumonia survivors at 2 months after hospital discharge. [19] In that study, pulmonary function was affected in 47.2% of subjects compared with 28% in the present study, possibly because the present study included more milder cases, which was one of the limitations of this study. Also, the follow-up duration was relatively short (up to six months), which may not adequately reflect the long-term pulmonary sequelae of COVID-19. The other shortcoming was that comprehensive pulmonary function assessment was not performed, as DLCO and body plethysmography were not included; therefore, true restrictive defects could not be confirmed.

## Conclusion

The effect on lung function after coronavirus disease 2019 (COVID-19) largely depends on age, sex, BMI, comorbid conditions, and conditions like smoking and severity of the disease. The most common ventilatory defect among patients during post-COVID was restrictive. There was gradual improvement in lung function in some patients during the follow-up. Larger clinical studies are required to validate these observations.

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**Conflict of Interest**: None

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