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Pulmonary Complications and Systemic Abnormalities in Post-COVID-19 Patients: A 3-Month

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ABSTRACT

Introduction: The coronavirus disease 2019(COVID-19) pandemic has had significant acute and long-term health impacts. Persistent pulmonary and systemic complications after recovery remain inadequately studied. This cohort study aimed to assess chronic respiratory and systemic abnormalities in patients three months post-COVID-19 recovery.

Methods: We evaluated 100 patients more than three months after recovery. Assessments included spirometry, high-resolution computed tomography (HRCT), arterial blood gas (ABG) analysis, and laboratory tests of inflammatory and hematologic parameters. Patients with preexisting lung disease or those to perform spirometry were excluded. Data were analyzed using SPSS version 27.

Results: The cohort consisted of 100 patients (mean age 49.8 ± 15.1 years; 50 males, 50 females). While clinical symptoms significantly decreased after three months, cough and dyspnea persisted in a notable proportion. Of the patients, 59.8% were managed as outpatients, 18.5% were hospitalized in general wards, and 21.7% required intensive care unit (ICU) admission. Spirometry revealed ongoing pulmonary dysfunction across obstructive, restrictive, and mixed patterns, with significantly reduced predicted forced expiratory volume in 1 second (FEV_1) and Forced Vital Capacity (FVC). The FEV_1/FVC ratio was notably decreased in obstructive and mixed groups, indicating persistent airflow limitation. Lung Computed Tomography (CT) scan showed significant resolution of ground-glass opacities (80.9% to 18.8%) and consolidation (19.1% to 3.5%). However, fibrotic-like changes, including septal thickening, persisted or slightly increased (21.3% to 32.9%). Other structural abnormalities were uncommon and largely unchanged.

Conclusion: Most patients showed symptomatic improvement by three months, but a significant subset continued to exhibit respiratory dysfunction and structural lung alterations. These findings highlight the importance of long-term clinical and radiological monitoring of post-COVID-19 patients and suggest broader implications for managing post-viral respiratory sequelae.

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Introduction

Since the initial reports of coronavirus disease 2019 (COVID-19) in China in late 2019, infections caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) have spread rapidly, resulting in a global pandemic, and causing millions of deaths worldwide (1). Based on available evidence, SARS-CoV-2 can affect multiple organs and cause both acute and long-term damage. However, the full spectrum of long-term effects has only become apparent more than two years after the onset of the pandemic (2).

In addition to the high mortality rate among the elderly and vulnerable populations, concerns have emerged regarding long-term complications and the potential for reinfection due to incomplete or reduced immunity following initial infection (3, 4). As a result, management has primarily relied on supportive care, alongside efforts to increase vaccination coverage to prevent further infections (5).

COVID-19 can significantly impact the quality of life of survivors, with the respiratory system being the primary site of viral invasion (6). SARS-CoV-2 can damage the lungs through three main mechanisms: 1) acute respiratory distress syndrome (ARDS) due to diffuse alveolar damage (DAD), 2) thrombotic microvascular obstruction of the alveoli, and 3) inflammation induced by inflammatory mediators of the respiratory tract. The consequences of these pathological processes include impaired alveolar oxygenation, hypoxemia, and acidosis (7,8).

In the absence of effective treatments, inadequate oxygen supply can lead to severe outcomes, including respiratory failure and death, or, in surviving cases, permanent lung damage with persistent functional impairment (9,10). This study aimed to investigate the pulmonary complications after three months of COVID-19 recovery.

Materials and Methods

Study Design

This cohort study was conducted at the Respiratory Diseases Clinic of Imam Reza (AS) Hospital in Mashhad, Razavi Khorasan, Iran, between October 2022 and December 2023. The primary objective was to investigate pulmonary complications among individuals who had recovered from COVID-19 after three months.

A total of 100 patients were enrolled. Inclusion criteria were: 1) a confirmed history of COVID-19 verified by a positive Reverse Transcription Polymerase Chain Reaction (RT-PCR) test for SARS-CoV-2, 2) a minimum of three months since recovery, and 3) no prior history of lung disease. Eligible participants provided written informed consent. Exclusion criteria included inability to perform spirometry due to physical limitations, chronic obstructive pulmonary disease (COPD) with hypercapnia, a history of severe asthma, and idiopathic pulmonary fibrosis.

Data Collection

Demographic characteristics, history of exposure, treatment setting (outpatient or inpatient), clinical symptoms, and recovery timeline were recorded for all participants. Each patient underwent a comprehensive evaluation, including spirometry for lung function assessment, high-resolution computed tomography (HRCT) for chest imaging, and pulse oximetry to measure arterial oxygen saturation. Laboratory investigations were performed, and inflammatory markers were documented to provide a comprehensive assessment of recovery status and ongoing pulmonary health.

Outcome Measures

The primary outcomes included pulmonary function assessed via spirometry, radiological changes detected on HRCT, and abnormalities in arterial blood gas (ABG) analysis. Secondary outcomes involved examining the associations between these pulmonary findings and clinical/laboratory parameters, including inflammatory and hematologic markers.

Statistical Analysis

Data analysis was conducted using SPSS version 27. Descriptive statistics were used to summarize the demographic and clinical characteristics of the participants, and frequency distribution tables were generated. The Chi-square test was used to compare categorical variables, while the

independent t-test was used for continuous variables with a normal distribution. Non-normally distributed continuous data were analyzed using the Mann-Whitney U test. The Kolmogorov-Smirnov test was used to assess the normality of variables. A p-value of less than 0.05 was considered statistically significant. The proportion test was used to compare cases between two groups. For comparisons involving more than two groups, analysis of variance (ANOVA) was performed for normally distributed data, while the Kruskal-Walli's test was used for non-normally distributed data.

Ethical Considerations

Informed written consent was obtained from all participants prior to their inclusion in the study. The research adhered to the ethical standards set by Mashhad University of Medical Sciences, and was approved by the University's Ethics Committee. The study was granted ethical approval under the authorization code IR.MUMS.REC.1399.16, dated 02/07/2019.

Results

Patient Characteristics

The study involved 100 patients, with an average age of 49.78 ± 15.05 years. The gender distribution was equal, with 50 males and 50 females. Male participants had an average of 48.32 ± 15.12 years, while female participants had an average age of 51.04 ± 14.95 years. Detailed baseline physiological, hematologic, and biochemical parameters for outpatients and general ward, intensive care unit (ICU) hospitalizations COVID-19 cases are presented in Table 1.

Table 2 displayed hematologic and biochemical data of COVID-19 patients during hospitalizations of less than 10 days, 10-20 days, and more than 20 days.

Clinical Symptoms: Initial Presentation vs. Three-Month Follow-Up

A comparative analysis of clinical symptoms between the acute phase of COVID-19 and the three-month follow-up revealed a significant decline in the prevalence of major symptoms (Table 3). Persistent pulmonary manifestations, such as cough and dyspnea, were still present in a considerable proportion of patients, although their frequency was notably reduced compared to the initial presentation.

Hospitalization and Disease Duration

Out of the study cohort, 55 patients (59.8%) were treated in an outpatient setting, 17 (18.5%) were hospitalized in general wards, and 20 (21.7%) required ICU admission due to severe illness. Disease duration varied significantly among these groups, with ICU-admitted patients experiencing the longest course.

ABG and Hematologic Parameters

The evaluation of blood gas parameters revealed significant differences, particularly in oxygenation levels (Table 4). Persistent abnormalities in spirometric indices and gas exchange suggested ongoing pulmonary impairment following recovery. Notably, reductions in Arterial Partial Pressure of Oxygen (PaO_2) and Peripheral Oxygen Saturation (SpO_2) were observed in specific patient groups, corresponding with restrictive and mixed ventilatory patterns, underscoring the enduring impact on respiratory function. Patients exhibiting persistent restrictive, obstructive, or mixed ventilatory abnormalities demonstrated significant alterations in arterial blood gas parameters, inflammatory markers, and hematologic indices compared to those with normal pulmonary function (Table 4). Specifically, lower PaO_2 levels, reduced lymphocyte percentages, and decreased serum albumin concentrations were associated with more severe pulmonary dysfunction. Moreover, levels of Aspartate Aminotransferase (AST) and Alanine Aminotransferase (ALT) were significantly elevated in both obstructive and restrictive groups relative to the normal group, which exhibited marked reductions. Elevated D-dimer and Lactate Dehydrogenase (LDH) levels in patients with persistent restrictive patterns further suggested ongoing endothelial dysfunction and heightened inflammatory activity.

There are significant differences in the variables SpO2, Partial Pressure of Carbon Dioxide (PaCO2), HCo3, PaO2, White Blood Cell Count (WBC), Lymphocyte, Red Blood Cell Count (RBC), Hemoglobin (Hb), Mean Corpuscular Volume (MCV), Serum protein,

Serum Albumin, ALT, D-dimer, and Direct Bilirubin between the three hospitalization groups. As indicated in Table 1.

Significant differences were observed in the variables SPO_2, PaO_2, Potential of Hydrogen (PH), WBC, Lymphocyte, Neutrophil, AST, D-dimer, LDH, and Alkaline Phosphatase (ALP) based on the duration of hospitalization. There were significant differences between hospitalization durations of less than 10 days and more than 20 days for all of the aforementioned variables.

Spirometric Assessment: Persistent Pulmonary Dysfunction

Pulmonary function tests (PFTs) conducted three months after recovery revealed significant changes in lung mechanics across various functional patterns (Table 5).

Table 1. Descriptive Information About the Variables.

Group variables	Out patient (n=50)	General ward (n=17)	ICU (n=20)	P-Value
ABG				
SPO_2	92.43 ± 3.53*	91.96 ± 3.96	85.94 ± 10.30*	0.024
$PaCO_2$	37.29 ± 2.85*	43.98 ± 8.15*	38.26 ± 2.63	0.007
HCo_3	21.54 ± 2.33	27.78 ± 6.08*	22.42 ± 4.37	<0.001
PaO_2	65.97 ± 12.62*	57.82 ± 9.80	55.12 ± 14.39*	0.035
pH	7.40 ± 0.05	7.37 ± 0.05	7.36 ± 0.13	0.216
Cardiac Echocardiography				
LVEF (%)	52.64 ± 3.04	52.72 ± 2.61	52.86 ± 3.78	0.984
PAP (mmHg)	29.17 ± 2.24	30.00 ± 3.69	28.85 ± 3.62	0.606
CBC				
WBC (×103)	10.50 ± 3.70*	12.05 ± 4.96	14.41 ± 3.52*	0.002
Lymphocyte (%)	26.27 ± 9.00*	17.98 ± 9.08	19.59 ± 16.92*	<0.001
Neutrophil (%)	76.32 ± 8.38	76.61 ± 14.18	79.19 ± 14.75	0.060
RBC	4.64 ± 0.43	5.04 ± 0.92*	4.05 ± 0.59*	0.024
Hb	12.91 ± 1.05	15.28 ± 8.33*	11.29 ± 1.98*	0.002
Hct	40.83 ± 2.38	37.30 ± 3.53	32.30 ± 0.41	0.213
MCV	81.03 ± 3.04*	84.91 ± 5.14	86.60 ± 10.33	0.003
RDW	15.50 ± 0.71	15.18 ± 6.70	16.57 ± 4.87	0.372
PLT	293.10 ± 105.33	295.81 ± 96.72	351.21 ± 129.67	0.101
Serum protein	7.71 ± 8.36	6.57 ± 0.44*	6.04 ± 0.67*	0.001
Serum Albumin	3.29 ± 0.32*	2.99 ± 0.43*	3.10 ± 0.75	<0.001
Serum Urea	20.35 ± 6.21	21.94 ± 9.56	26.26 ± 19.17	0.721
Serum Cr	0.83 ± 0.12	0.96 ± 0.31	1.01 ± 0.62	0.246
AST	28.15 ± 21.47	33.65 ± 23.17	43.06 ± 39.47	0.082
ALT	29.28 ± 22.90*	39.74 ± 38.35	54.59 ± 50.72*	0.013
Ferritin	348.29 ± 334.31	501.80 ± 465.44	795.00 ± 0.14	0.376
D-dimer	796.98 ± 733.86*	1286.30 ± 752.45	1504.89 ± 1377.42*	<0.001
LDH	640.74 ± 138.14	659.13 ± 254.34	685.28 ± 190.42	0.480
Total Bilirubin	0.86 ± 0.20	0.88 ± 0.53	0.83 ± 0.30	0.661
Direct Bilirubin	0.32 ± 0.08*	0.25 ± 0.12*	0.31 ± 0.18	0.036
ALP	198.24 ± 168.64	336.54 ± 413.70	214.07 ± 79.18	0.138

Abbreviations : ABG: Arterial Blood Gas; **SpO_2**: Peripheral Oxygen Saturation; **$PaCO_2$:** Arterial Partial Pressure of Carbon Dioxide; **HCO_3:** Bicarbonate; **PaO_2**: Arterial Partial Pressure of Oxygen; **pH :** Potential of Hydrogen (acid–base balance); **LVEF (%) :** Left Ventricular Ejection Fraction (percentage); **PAP (mmHg)**: Pulmonary Arterial Pressure (millimeters of mercury); **WBC ($\times 10^3$):** White Blood Cell Count ($\times 10^3/\mu L$); **Lymphocyte (%) :** Lymphocyte Percentage; **Neutrophil (%) :** Neutrophil Percentage; **RBC:** Red Blood Cell Count; **Hb:** Hemoglobin; **Hct:** Hematocrit; **MCV:** Mean Corpuscular Volume; **RDW:** Red Cell Distribution Width; **PLT:** Platelet Count; **Serum Cr:** Serum Creatinine; **AST:** Aspartate Aminotransferase; **ALT:** Alanine Aminotransferase; **Ferritin:** Serum Ferritin; D-dimer – Fibrin Degradation Product; **LDH:** Lactate Dehydrogenase; **Total Bilirubin :** Total Serum Bilirubin; **Direct Bilirubin** : Direct (Conjugated) Bilirubin; **ALP:** Alkaline Phosphatase

Table 2. Descriptive Information About the Variables at duration of hospitalization.

Duration variables	Less than 10 days (n=26)	10-20 days (n=31)	More than 20 days (n=26)	P-Value
ABG				
SPO_2	93.00 ± 3.56*	92.64 ± 3.77	85.93 ± 9.12*	0.002
$PaCO_2$	37.68 ± 4.69	38.56 ± 4.12	41.13 ± 8.28	0.309
HCo_3	23.00 ± 4.38	23.03 ± 3.97	23.74 ± 5.93	0.999
PaO_2	69.29 ± 12.46*	63.58 ± 10.81	52.08 ± 11.24*	0.002
pH	7.42 ± 0.04*	7.39 ± 0.05	7.35 ± 0.11*	0.039
Cardiac Echocardiography				
LVEF (%)	52.33 ± 3.20	52.71 ± 2.94	52.50 ± 3.65	0.926
PAP (mmHg)	29.33 ± 2.58	29.60 ± 2.47	29.00 ± 3.87	0.747
CBC				
WBC (×103)	10.05 ± 3.40*	11.41 ± 4.61	13.98 ± 3.53*	0.001
Lymphocyte (%)	30.26 ± 14.88*	22.39 ± 10.07	17.51 ± 7.35*	0.001
Neutrophil (%)	71.75 ± 14.06*	78.60 ± 9.03	81.30 ± 7.29*	0.016
RBC	4.71 ± 0.64	5.05 ± 1.02	4.12 ± 0.61	0.091
Hb	13.10 ± 1.33	13.98 ± 6.50	11.83 ± 2.03	0.090
Hct	39.25 ± 0.78	-	33.55 ± 1.77	0.121
MCV	81.74 ± 3.32	82.08 ± 4.54	86.27 ± 10.25	0.110
RDW	14.00 ± 0.11	16.12 ± 7.49	15.97 ± 4.69	0.805
PLT	286.00 ± 79.10	277.60 ± 104.86	328.96 ± 133.14	0.290
Serum Protein	9.21 ± 12.46	6.54 ± 0.39	6.18 ± 0.69	0.071
Serum Albumin	3.29 ± 0.34	3.14 ± 0.40	3.15 ± 0.70	0.066
Serum Urea	19.66 ± 6.86	21.53 ± 8.38	24.62 ± 17.05	0.692
Serum Cr	0.87 ± 0.15	0.87 ± 0.24	0.98 ± 0.55	0.851
AST	24.08 ± 10.03*	28.64 ± 17.20	40.58 ± 34.79*	0.014
ALT	30.08 ± 32.43	30.55 ± 17.27	46.74 ± 45.60	0.079
Ferritin	271.40 ± 172.32	454.83 ± 477.93	634.75 ± 345.22	0.282
D-dimer	881.43 ± 1066.10*	913.18 ± 620.27	1239.56 ± 979.90*	0.023
LDH	575.25 ± 153.54*	684.90 ± 193.50	703.48 ± 153.24*	0.008
Total Bilirubin	0.80 ± 0.24	0.95 ± 0.37	0.77 ± 0.27	0.426
Direct Bilirubin	0.31 ± 011	0.31 ± 0.08	0.30 ± 0.15	0.436
ALP	164.05 ± 56.71*	245.48 ± 305.45	235.88 ± 92.55*	0.025

Abbreviations : ABG: Arterial Blood Gas; **SpO_2**: Peripheral Oxygen Saturation; **$PaCO_2$:** Arterial Partial Pressure of Carbon Dioxide; **HCO_3:** Bicarbonate; **PaO_2**: Arterial Partial Pressure of Oxygen; **pH :** Potential of Hydrogen (acid–base balance); **LVEF (%) :** Left Ventricular Ejection Fraction (percentage); **PAP (mmHg)**: Pulmonary Arterial Pressure (millimeters of mercury); **WBC ($\times 10^3$):** White Blood Cell Count ($\times 10^3/\mu L$); **Lymphocyte (%) :** Lymphocyte Percentage; **Neutrophil (%) :** Neutrophil Percentage; **RBC:** Red Blood Cell Count; **Hb:** Hemoglobin; **Hct:** Hematocrit; **MCV:** Mean Corpuscular Volume; **RDW:** Red Cell Distribution Width; **PLT:** Platelet Count; **Serum Cr:** Serum Creatinine; **AST:** Aspartate Aminotransferase; **ALT:** Alanine Aminotransferase; **Ferritin:** Serum Ferritin; **D-dimer** : Fibrin Degradation Product; **LDH:** Lactate Dehydrogenase; **Total Bilirubin :** Total Serum Bilirubin; **Direct Bilirubin** : Direct (Conjugated) Bilirubin; **ALP:** Alkaline Phosphatase

Patients with restrictive and mixed ventilatory defects showed the greatest reductions in percent forced expiratory volume in 1 second (%FEV_1) and percent Forced Vital Capacity (%FVC), while those with obstructive and mixed patterns had a notably lower FEV_1/FVC ratio, indicating persistent airflow limitation.

Further post hoc analysis confirmed significant differences among normal, obstructive, restrictive, and mixed pulmonary patterns, suggesting that a subset of recovered patients may experience lasting functional impairment.

Table 3. Comparison of signs and symptoms between the initial presentation and the assessment after three months.

Signs and Symptoms	N (p) of initial presentation	N (p) after 3 months of Covid recovery	95 % Confidence Interval	P-Value
Cough	97 (0.99)	50 (0.51)	(0.38,0.58)	<0.001
Dyspnea	84 (0.86)	42 (0.43)	(0.33,0.53)	<0.001
Pleuritic Chest pain	65 (0.66)	24 (0.24)	(0.31,0.53)	<0.001
Fever	62 (0.63)	5 (0.05)	(0.48,0.68)	<0.001
Weakness	61 (0.62)	4 (0.41)	(0.48,0.68)	<0.001
Bone pain	16 (0.16)	1 (0.10)	(0.08,0.22)	<0.001
Anosmia	14 (0.14)	1 (0.01)	(0.06,0.20)	<0.001

Table 4. Comparison of factors and variable data between lung patterns.

Groups Variables	Normal	Obstructive pattern	Restrictive	Mixed	P-Value
ABG					
SPO_2	93.56±2.73†	89.90±7.68	88.17±6.87†	91.13±3.44	0.002*
$PaCO_2$	37.03±1.66†	37.83±2.48	38.27±5.81	42.85±8.00†	0.018*
HCO_3	21.93±2.51	22.67±2.34	21.20±3.42†	26.21±6.12†	0.014*
PaO_2	69.95±10.52†	59.17±10.80	52.25±8.03†	64.21±13.97	<0.001*
pH	7.41±0.04†	7.37±0.06	7.34±0.07†	7.38±0.04	0.003*
Cardiac Echocardiography					
LVEF (%)	53.18±2.46	51.67±2.89	52.50±4.52	51.92±3.25	0.659
PAP (mmHg)	29.54±2.13	28.33±2.89	28.64±3.23	29.23±3.44	0.739
CBC					
WBC (×103)	9.84±2.80†	12.02±3.92	14.18±4.88†	11.23±3.65	0.001*
Lymphocyte (%)	28.42±8.30†	23.35±12.02	20.43±16.66†	23.43±9.53	0.003*
Neutrophil (%)	76.34±7.25	73.48±12.40	79.90±14.99	73.97±12.13	0.064
RBC	4.64±0.48	4.35±0.62	4.45±0.13	4.91±0.40	0.164
Hb	13.17±0.97	12.46±2.05	12.18±1.54	13.04±1.38	0.247
Hct	41.85±4.45	37.30±5.03	39.30±0.71	39.10±6.08	0.945
MCV	80.78±2.22	83.56±7.09	81.83±6.27	83.39±3.63	0.199
RDW	15.50±0.71	15.00±2.83	13.00±1.41	13.20±0.28	0.419
PLT	282.54±79.48	259.12±90.22	367.84±122.48	282.47±100.98	0.021*
Serum protein	8.29±10.19	6.66±0.41	6.26±0.51	6.57±0.46	0.071
Serum Albumin	3.27±0.29	3.24±0.33	3.26±0.74	3.19±0.46	0.506
Serum Urea	20.02±6.79	23.23±5.01	21.09±10.97	19.39±7.67	0.573
Serum Cr	0.83±0.13	0.94±0.18	0.87±0.19	0.86±0.16	0.347
AST	23.88±8.43†	38.75±25.42	32.20±11.44†	26.82±13.74	0.002*
ALT	24.48±14.39†	34.50±8.77	41.89±34.15†	33.59±37.92	<0.001*
D-dimer	664.29±381.55†	979.57±443.74	1056.06±476.49†	734.38±258.19	0.017*
Ferritin	302.80±247.41	85.00	995.00	291.00±206.52	0.256
LDH	609.85±126.46†	653.37±195.19	753.22±183.74†	683.69±162.22	0.019*
Total Bilirubin	0.84±0.19	0.93±0.15	0.86±0.26	0.68±0.21	0.105
Direct Bilirubin	0.32±0.08	0.30±0.06	0.31±0.10	0.26±0.09	0.230
ALP	172.00±60.68	476.50±585.67†,Ŧ	165.67±55.57Ŧ	178.78±97.31†	0.025*

*Kruskal Wallis test, †, Ŧ Post Hoc test.

Abbreviations : ABG: Arterial Blood Gas; **SpO_2**: Peripheral Oxygen Saturation; **$PaCO_2$:** Arterial Partial Pressure of Carbon Dioxide; **HCO_3:** Bicarbonate; **PaO_2**: Arterial Partial Pressure of Oxygen; **pH :** Potential of Hydrogen (acid–base balance); **LVEF (%) :** Left Ventricular Ejection Fraction (percentage); **PAP (mmHg)**: Pulmonary Arterial Pressure (millimeters of mercury); **WBC ($\times 10^3$):** White Blood Cell Count ($\times 10^3/\mu L$); **Lymphocyte (%) :** Lymphocyte Percentage; **Neutrophil (%) :** Neutrophil Percentage; **RBC:** Red Blood Cell Count; **Hb:** Hemoglobin; **Hct:** Hematocrit; **MCV:** Mean Corpuscular Volume; **RDW:** Red Cell Distribution Width; **PLT:** Platelet Count; **Serum Cr:** Serum Creatinine; **AST:** Aspartate Aminotransferase; **ALT:** Alanine Aminotransferase; **Ferritin:** Serum Ferritin; **D-dimer**: Fibrin Degradation Product; **LDH:** Lactate Dehydrogenase; **Total Bilirubin :** Total Serum Bilirubin; **Direct Bilirubin** : Direct (Conjugated) Bilirubin; **ALP:** Alkaline Phosphatase

High-Resolution Computed Tomography (HRCT) Findings

HRCT imaging at follow-up showed significant resolution of ground-glass opacities and consolidation compared to the acute phase (Table 6). However, fibrotic-like changes, such as septal thickening and bronchial abnormalities, persisted in some patients, indicating the potential for early post-COVID structural lung alterations.

Table 5. Comparison of lung function parameters after three months of COVID-19 recovery.

	%FEV1 (Mean±SD)	%FVC (Mean±SD)	FEV1/FVC (Mean±SD)
Normal	96.14±12.82T̄,†	98.52±12.30T̄,†	81.14±6.93†,T̄
Obstructive pattern	73.25±15.07	90.00±11.47T̄,†	66.29±6.83T̄
Restrictive pattern	52.61±14.35†	50.64±13.90T̄	82.53±6.51T̄
Mixed pattern	49.26±18.11T̄	59.13±16.85†	64.53±8.42†
F	40.54	45.64	22.06
P-Value	<0.001*	<0.001*	<0.001*

* Kruskal Wallis test, †,T̄ post hoc tests

%FEV$_1$ (Mean ± SD) : Percent Predicted Forced Expiratory Volume in One Second (Mean ± Standard Deviation)
%FVC (Mean ± SD) : Percent Predicted Forced Vital Capacity (Mean ± Standard Deviation)
FEV$_1$/FVC (Mean ± SD): Ratio of Forced Expiratory Volume in One Second to Forced Vital Capacity (Mean ± Standard Deviation)

Table 6. Comparison of HRCT factors between the initial measurement and after three months.

Findings	Initial	After 3 months	P value
	Frequency(%)	Frequency(%)	
Grand glass opacities	72(80.9)	16(18.8)	<0.001
Septal thickening	19(21.3)	28(32.9)	0.052
Consolidation	17(19.1)	3(3.5)	<0.001
Nodules	15(16.9)	9(10.6)	0.238
Bronchial dilatation	4(4.5)	2(2.4)	>0.99
Atelectasis	1(1.1)	2(2.4)	>0.99
Air trapping	2(2.2)	1(1.2)	>0.99
Pneumothorax	0(0)	3(3.5)	>0.99

Discussion

This study provides critical insights into the pulmonary and systemic effects of COVID-19, demonstrating a significant reduction in major clinical symptoms over three months of recovery. However, a subset of patients continued to experience persistent respiratory symptoms, particularly cough and dyspnea, albeit with reduced severity. These findings align with previous research on post COVID, which has identified prolonged respiratory issues after infection (11, 12). While most patients experienced symptom resolution, a considerable proportion continued to report persistent pulmonary symptoms such as cough and dyspnea, albeit at a reduced frequency. These results are consistent with studies on post COVID, which have identified prolonged respiratory issues after recovery (13, 14). The persistence of symptoms may be attributed to residual lung inflammation or immune dysregulation, highlighting the need for further investigation into long-term recovery trajectories and patient quality of life.

The evaluation of blood gas parameters revealed significant differences, particularly in oxygenation levels. Persistent abnormalities in spirometric measures and gas exchange indicated ongoing pulmonary impairment following recovery. Notably, a reduction in PaO_2 and SPO_2 was observed in specific patient groups, aligning with restrictive and obstructive ventilatory patterns, highlighting the lasting impact on respiratory function. These findings align with previous studies that have demonstrated prolonged pulmonary dysfunction in post-COVID-19 patients (15, 16). Bellan et al. reported that four months post-infection, patients exhibited reduced diffusion capacity and restrictive ventilatory defects, while Guler et al. observed persistent lung function impairments, particularly in

those with severe initial disease (16, 17). Furthermore, studies suggest that septal thickening and reticulation changes and chronic inflammation may contribute to these abnormalities, warranting long-term pulmonary monitoring and rehabilitation strategies (18).

Patients with restrictive and mixed ventilatory defects exhibited the greatest reductions in %FEV_1 and %FVC, while those with obstructive and mixed patterns showed a markedly lower FEV1/FVC ratio, indicating persistent airflow limitation. These findings are in line with previous research indicating respiratory impairment following COVID-19, with restrictive and mixed ventilatory patterns commonly observed among recovered patients (19, 20). Frija-Masson et al. reported that COVID-19 survivors frequently exhibit reduced lung volumes and diffusion capacity, while Anastasio et al. found persistent airflow limitation among patients with severe disease.

However, fibrotic-like changes, including septal thickening and bronchial abnormalities, persisted in a subset of patients, consistent with findings by Han et al. and Myall et al., which suggest that post-COVID fibrotic remodeling may lead to long-term structural lung damage requiring ongoing surveillance and intervention (21,22).

Notably, lower PaO_2 levels, reduced lymphocyte percentages, and decreased serum albumin were associated with more severe pulmonary impairment, aligning with findings from previous studies that indicate hypoxemia and systemic inflammation as contributing factors to post-COVID respiratory dysfunction (23). Elevated AST and ALT levels in the obstructive and restrictive groups, as observed in this study, have been reported in prior research, suggesting potential hepatic involvement in COVID-19 recovery (24). Additionally, increased D-dimer and LDH levels in patients with persistent restrictive patterns further support the hypothesis of ongoing endothelial dysfunction and inflammatory activity, corroborating earlier studies that link hypercoagulability and inflammatory markers with post COVID-19 pulmonary impairment (25, 26). These findings emphasize the need for continuous monitoring and targeted interventions to mitigate long-term organ damage in post-COVID patients.

Limitations

This study was conducted during the peak of the COVID-19 pandemic, which presented significant logistical and safety challenges. As a result, patient follow-up was particularly challenging, limiting our ability to conduct long-term assessments. Despite these constraints, we were able to monitor patients for up to three months post recovery. Future studies should incorporate longer follow-up periods, ideally extending to several months or even years post-recovery, especially among patients who required intensive care unit admission or experienced severe disease in order to more fully understand the long-term pulmonary effects of COVID-19.

Conclusion

Most patients showed improvment within three months after COVID-19, but some continued to experience persistent respiratory and systemic issues. Ongoing lung impairments and fibrotic-like changes on HRCT scans suggest lasting pulmonary damage. Elevated inflammatory markers show that recovery can involve multiple organs. These findings highlight the importance of long-term monitoring and targeted rehabilitation. Further research is necessary to comprehend persistent abnormalities and identify effective treatments.

Abbreviations

ABG: Arterial Blood Gas; **ALT**: Alanine Aminotransferase; **ARDS:** Acute Respiratory Distress Syndrome; **AST:** Aspartate Aminotransferase; **COPD:** Chronic Obstructive Pulmonary Disease; **COVID-19:** Coronavirus Disease 2019; **CT:** Computed Tomography; **DAD:** Diffuse Alveolar Damage; **FEV_1:** Forced Expiratory Volume in 1 Second; **FVC:** Forced Vital Capacity; **HRCT**: High-Resolution Computed Tomography; **ICU:** Intensive Care Unit; **LDH**: Lactate Dehydrogenase; **PaO_2:** Partial Pressure of Oxygen in Arterial Blood; **PFTs**: Pulmonary Function Tests; **RT-PCR**: Reverse Transcription Polymerase Chain Reaction ;

SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2; **SPO_2:** Peripheral Capillary Oxygen Saturation; **SPSS:** Statistical Package for the Social Sciences

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