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A comprehensive study to determine effect of coronavirus disease on pulmonary function of the affected patients

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ABSTRACT

Background: As the global coronavirus disease-2019 (COVID-19) pandemic continues to unfold, understanding the implications of the disease on post-recovery lung function becomes crucial. This study aimed to investigate the early convalescent phase characteristics of lung function in patients recovering from COVID-19, shedding light on the extent and nature of lung impairments following acute infection. **Aims and Objectives:** This study aimed to investigate the early convalescent phase characteristics of lung function in patients recovering from COVID-19, shedding light on the extent and nature of lung impairments following acute infection. **Materials and Methods:** A cross-sectional analysis was conducted on 57 patients who had been diagnosed with COVID-19 and subsequently discharged from the hospital. Comprehensive lung function tests, chest computed tomography scans, and the 6-min walk test were performed approximately 30 days after discharge to assess pulmonary parameters, imaging abnormalities, and exercise tolerance. **Results:** The study revealed that more than half of the patients exhibited impairments in diffusing capacity (DLCO), respiratory muscle strength, and lung imaging abnormalities during the early convalescent phase. Notably, severe cases demonstrated a significantly higher incidence of DLCO impairment, accompanied by notable reductions in total lung capacity and 6-min walking distances compared to non-severe cases. Interestingly, the severity of illness or residual imaging changes did not consistently correlate with the observed lung function impairments. This observation challenges previous assumptions and underscores the complexity of the relationship between disease severity and post-recovery lung function. **Conclusion:** In the context of COVID-19 recovery, this study highlights the presence of early convalescent phase impairments in lung function, suggesting that the impact on respiratory health extends beyond the acute phase of infection.

Key words: Coronavirus disease-2019; Lung function; Convalescence; Respiratory impairment; Diffusing capacity; Respiratory muscle strength; Chest computed tomography scan; 6-min walk test

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INTRODUCTION

Coronavirus disease-2019 (COVID-19), caused by the highly contagious severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has emerged as a global health threat.[1] This novel virus, with human-to-human transmission capabilities, triggered a pandemic, resulting in significant morbidity and mortality. By June 7, 2020, the worldwide confirmed cases had reached 6,663,304, accompanied by 392,802 confirmed deaths. The disease's rapid progression led to instances of early respiratory failure, necessitating a deepened understanding of its clinical manifestations, pathogenesis, and treatment.[2,3] Notably, research insights and observations have mainly focused on the acute infection phase, where most patients achieved successful recovery. However, scarce investigations have delved into the early prognosis relative to the extent of lung injury and post-discharge rehabilitation for COVID-19 patients.

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Remarkably, although many patients exhibited imaging abnormalities on discharge, with some even displaying pulmonary fibrosis, no study has yet addressed the lung function impairments during the initial convalescence phase. Recognizing the significance of gaining comprehensive insights into potential clinical outcomes, we embarked on a retrospective analysis involving discharged COVID-19 patients undergoing rehabilitation. Within 30 days post-discharge, we meticulously evaluated serial lung function measurements, lung imaging assessments, and exercise capacities. Furthermore, we conducted outcome parameter comparisons between severe and non-severe patient cohorts to discern potential variations.

Aims and objectives

To investigate the early convalescent phase characteristics of lung function in patients recovering from COVID-19, and to assess the extent and nature of lung impairments following acute infection.

MATERIALS AND METHODS

Patient selection

This study constitutes a follow-up examination of COVID-19 patients at the 30-day mark after their discharge from our medical facility. Between January 2019 and 2021, a total of 103 individuals afflicted with COVID-19 were admitted to our tertiary health-care center. The diagnostic criteria for COVID-19 adhered to the guidelines provided by the CDC. All patients had received confirmation of SARS-CoV-2 infection through real-time reverse transcription polymerase chain reaction or next-generation sequencing. These patients had met the unified discharge criteria issued by Ministry of Health and Family Welfare and had been discharged for over a month. Eligibility for participation in the study required patients to be above 18 years of age within the 30-day post-discharge period. Individuals with a history of pulmonary resection, neurological disorders, or mental illnesses were excluded from the study. Written informed consent was procured from all participants before the commencement of pulmonary function testing. The research protocol obtained approval from the Institutional Ethics Committee.

Classification

A retrospective analysis was conducted on the medical records of these patients, resulting in their division into two groups based on disease severity: non-severe and severe. Patients were categorized as severe if they met any of the following criteria: experiencing shortness of breath with a respiratory rate of ≥30 breaths/min; resting-state blood oxygen saturation ≤93%; a partial arterial oxygen pressure (PaO_2)/fraction of inspired oxygen (FiO_2) ratio ≤300 mmHg; necessitating mechanical ventilation due to respiratory failure; encountering shock or requiring intensive care unit monitoring; and treatment due to combined organ failure. Cases not meeting these criteria were classified as mild.

Lung imaging acquisition and computed tomography (CT) quantitative evaluation

Each participant underwent high-resolution spiral CT scans while in the supine position during end-inspiration. Blinded to clinical information, two radiologists evaluated the images. We employed the method outlined by Chung et al., to quantify the severity of pulmonary inflammation.[4-6] In essence, each of the five lung lobes was evaluated for involvement degree, categorized as none (0%), minimal (1–25%), mild (26–50%), moderate (51–75%), or severe (76–100%). Correspondingly, a lobe score of 0 represented no involvement, 1 for minimal involvement, 2 for mild involvement, 3 for moderate involvement, and 4 for severe involvement. The summation of these scores across the five lobes resulted in an overall lung "total severity score" ranging from 0 to 20.

6-min walk test (6MWT)

The 6MWT gauges exercise capacity relevant to daily activities among individuals with cardiopulmonary ailments. The walking distance takes into account gender, age, and height, conventionally requiring hierarchical analysis based on these parameters. Given our study's limited sample size, which precluded stratified analysis according to age, gender, and height, we extrapolated the healthy individuals' walking distances with matching gender, age, and height using reference equations for healthy adults.[7] Subsequently, we calculated the ratio between the patients' measured values and the healthy individuals' predicted values under normal conditions. This ratio comparison enabled assessment of potential differences in the 6-min walk distance (6MWD) between non-severe and severe COVID-19 patients.

Pulmonary function test and respiratory muscle strength measurement

Every participant underwent a standard pulmonary function test. This comprehensive assessment covered various parameters, including total lung volume (TLC), forced vital capacity (FVC), residual volume (RV), forced expiratory volume in the 1 s (FEV1), maximum expiratory flow rate spanning 75–25% of FVC (MMEF 75/25), the ratio of FEV1 to FVC (FEV1/FVC), and the lung's diffusing capacity for carbon monoxide (DLCO). The impulse oscillation system was employed to gauge airway resistance at an oscillation frequency of 5 Hz (R5) and central airway resistance at 20 Hz (R20). Respiratory muscle strength was assessed using mouth pressure gauges, with outcomes encompassing maximum static inspiratory

pressure (PImax) and maximum static expiratory pressure (PEmax), which was measured. All measurements for spirometry, DLCO, and respiratory muscle strength were expressed as percentages relative to predicted normal values.

Statistical analysis

Statistical analysis was conducted using the Statistical Package for the Social Sciences version 20.0. Measurement data were presented as mean±standard deviation. Continuous variables were compared through independent sample t-tests, whereas non-parametric data were assessed using the rank sum test. The Chi-square test was employed for comparing proportions. Spearman correlation analysis was utilized to identify connections between lung function and the overall lung severity score. Throughout all statistical analyses, a two-tailed methodology was employed, and statistical significance was determined at a threshold of $P<0.05$.

RESULTS

Characteristics of the enrolled COVID-19 patients were thoroughly examined in this study, encompassing a total of 102 individuals. Out of these, five participants were excluded due to being underage. Furthermore, 24 individuals were not included as the evaluation occurred within a timeframe of <30 days post-discharge. An additional three patients were excluded due to underlying neurological or mental illnesses. In conjunction, eight patients had become untraceable for follow-up. Ultimately, a cohort of 57 patients was successfully included and underwent the complete sequence of assessments.

Within this cohort, there were 26 male and 31 female participants, with an average age of 46.72±13.78 years (age range: 19–71 years). The mean body mass index was measured at 23.99±3.55 kg/m^2. A total of nine patients (15.7%) had a smoking history. Furthermore, preexisting medical conditions were noted in 21 patients (36.8%). The most prevalent preexisting illnesses were hypertension, diabetes, malignant tumors, and cardiovascular diseases.

No instances of chronic respiratory diseases were reported among the patients. Among the total participants, 17 cases (29.8%) were categorized as severe, while 40 cases (70.2%) were classified as non-severe. The severe group predominantly consisted of male patients (70.6%), and these patients had a higher average age compared to those in the non-severe group. The mean Pao2/Fio2 ratio for severe cases was significantly lower than that for non-severe cases (198.47 [SD=97.04] vs. 355.51 [SD=37.23], $P<0.001$). In addition, severe cases exhibited elevated levels of serum lactate dehydrogenase and C-reactive protein, as well as a lower lymphocyte count in comparison to non-severe cases. However, no notable differences were observed between the two groups in terms of white blood cell count, creatine kinase levels, lactic acid peaks, and length of hospitalization (Table 1).

During the 1-month follow-up after hospital discharge, abnormal diffusion capacity was observed in 30 individuals (52.6%) among the 57 patients enrolled in our study. Following the ATS recommendations for assessing respiratory impairment,[8] mild impairment of DLCO was noted in 26 patients (86.7%), while four patients (13.3%) exhibited moderate impairment. A significant difference in impaired diffusing capacity was evident between the two groups, accounting for 42.5% in non-severe cases and 75.6% in severe cases, respectively ($P<0.05$, Table 2).

Table 1: Demographic and clinical characteristic of subjects

Characteristic	Total (n=57)	Severe (n=17)	Nonsevere (n=40)	P
Age, year	46.72±13.78	52.53±13.30	44.25±13.3	0.031
Male gender, n (%)	26 (45.6)	12 (70.6)	14 (35.0)	0.014
BMI, kg/m^2	23.99±3.55	25.54±3.43	23.33±3.42	0.103
Preexisting medical illness, n (%)	21 (36.8)	7 (41.2)	14 (35)	0.658
LOS, days	20.89 (7.22)	20 (16-24)	19 (15-24)	0.834
WBC, ×10^9/L	5.01±1.50	4.47±1.35	5.24±1.52	0.076
Lymphocyte count, ×10^9/L	1.60±0.55	1.30±0.35	1.72±0.58	0.008*
CRP, mg/dL	9.69±13.77	22.65±18.19	4.18±5.66	<0.001*
LDH, U/L	175.47±43.60	201.94±43.96	164.22±38.76	0.002*
CK, U/L	91.95±118.16	133.18±209.4	74.42±31.69	0.235
Lactic acid, mmol/L	1.59±0.61	1.51±0.65	1.62±0.59	0.511
PaO_2 to FiO_2 ratio, mmHg	308.67±94.40	198.47±97.04	355.51±37.23	<0.001*
TSS on the worst chest CT scan	4.28±4.26	8.59±4.15	2.45±2.73	<0.001*
TSS on chest CT on the 14th day after discharge	1.75±2.23	3.94±2.33	0.83±1.39	<0.001*
Glucocorticoids use, n (%)	16 (28.1)	11 (64.7)	5 (12.5)	<0.001*
Total methylprednisolone dosage, mg	213.75±323.87	289.09±370.4	48.0±17.89	0.019*

*Statistically significant. Values are expressed as mean±SD. SD: Standard deviation, BMI: Body mass index, LOS: Length of hospital stay, CRP: C-reactive protein, WBC: White blood cell count, LDH: Lactate dehydrogenase, CK: Creatine kinase, CT: Computed tomography, TSS: Total severity score, PaO_2: Partial arterial oxygen pressure, FiO_2: Fraction of inspired oxygen

Table 2: The abnormal rate of pulmonary parameters and respiratory muscle strength between severe cases and mild cases

Characteristic	Total (n=57)	Severe (n=17)	Non-severe (n=40)	χ^2	P
FEV_1 <80% of predicted	5 (8.8)	3 (17.6)	2 (5.0)	1.066	0.302
FEV_1 ≥80% of predicted	52 (91.2)	14 (82.4)	38 (95.0)		
FVC <80% of predicted	6 (10.5)	4 (23.5)	2 (5.0)	2.604	0.107
FVC ≥80% of predicted	51 (89.5)	13 (76.5)	38 (95.0)		
FEV1/FVC <80%	25 (43.9)	9 (52.9)	16 (40.0)	0.811	0.368
FEV1/FVC ≥80%	32 (56.1)	8 (47.1)	24 (60.0)		
TLC <80% of predicted	7 (12.3)	4 (23.5)	3 (7.5)	1.552	0.213
TLC ≥80% of predicted	50 (87.7)	13 (76.5)	37 (92.5)		
DLCO <80% of predicted	30 (52.6)	13 (76.5)	17 (42.5)	5.522	0.019*
DLCO ≥80% of predicted	27 (43.4)	4 (23.5)	23 (57.5)		
R5 ≥150 of predicted	8 (14.0)	2 (11.8)	6 (15.0)	0.103	0.554
R5 <150 of predicted	49 (86.0)	15 (88.2)	34 (85.0)		
R20 ≥150 of predicted	10 (17.5)	3 (17.6)	7 (17.5)	0.000	0.631
R20 <150 of predicted	47 (82.4)	14 (82.4)	33 (82.5)		
PImax <80% of predicted	28 (49.1)	9 (52.9)	21 (52.5)	0.001	0.976
PImax ≥0% of predicted	29 (50.9)	8 (47.1)	19 (47.5)		
PEmax <80% of predicted	13 (22.8)	4 (23.5)	9 (22.5)	0.007	0.592
PEmax ≥80% of predicted	44 (77.2)	13 (76.5)	31 (77.5)		

*Statistically significant. FVC: Forced vital capacity, FEV1: Forced expiratory volume in 1 s, TLC: Total lung capacity, DLCO: Diffusing capacity of the lung for carbon monoxide, R5: Airway resistance at an oscillation frequency of 5 Hz, R20: Airway resistance at an oscillation frequency of 20 Hz, PImax: Maximum static inspiratory pressures, PEmax: Maximum static expiratory pressures

Table 3: Results of pulmonary function tests and respiratory muscle strength among COVID-19 patients between glucocorticoid group and the regular groups

Parameter	All patients (n=57)	GC group (n=16)	Regular group (n=41)	P
FVC (% of predicted)	100.96 (15.93)	97.25 (18.69)	102.40 (14.72)	0.414
FEV1 (% of predicted)	97.89 (14.91)	94.35 (15.40)	99.27 (14.68)	0.279
FEV1/FVC (%)	81.22 (6.13)	80.74 (4.68)	81.40 (6.65)	0.804
TLC (% of predicted)	93.94 (12.75)	90.15 (16.01)	95.45 (11.06)	0.323
RV (% of predicted)	90.68 (28.08)	85.49 (19.01)	92.76 (30.95)	0.593
DLCO (% of predicted	78.38 (13.59)	74.67 (14.37)	79.78 (13.20)	0.657
Raw (% of predicted)	105.38 (31.38)	96.02 (25.81)	109.22 (32.93)	0.214
R5 (% of predicted)	126.64 (29.45)	119.66 (30.62)	129.37 (28.91)	0.127
R20 (% of predicted)	132.76 (30.95)	123.51 (31.99)	136.37 (30.15)	0.106
PImax (% of predicted)	76.16 (24.28)	85.21 (26.54)	72.53 (22.65)	0.059
PEmax (% of predicted)	102.73 (32.68)	104.22 (28.03)	102.14 (34.68)	0.479

FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 s, TLC: Total lung capacity, RV: Residual volume, DLCO: Diffusing capacity of the lung for carbon monoxide, R5: Airway resistance at an oscillation frequency of 5 Hz, R20: Airway resistance at an oscillation frequency of 20 Hz, PImax: Maximum static inspiratory pressures, PEmax: Maximum static expiratory pressures, Raw: Airway resistant

Table 4: Results of pulmonary function tests and respiratory muscle strength among COVID-19 patients

Parameter	Total (n=57)	Severe (n=17)	Non-severe (n=40)	P
FVC (% of predicted)	100.96 (15.93)	95.92 (19.59)	103.10 (13.83)	0.12
FEV_1 (% of predicted)	97.89 (14.91)	93.93 (16.79)	99.57 (13.92)	0.194
FEV_1/FVC (%)	81.22 (6.13)	80.58 (4.88)	81.49 (6.62)	0.614
TLC (% of predicted)	93.94 (12.75)	88.72 (16.20)	96.22 (10.35)	0.048*
RV (% of predicted)	90.68 (28.08)	86.57 (23.96)	92.47 (29.82)	0.327
DLCO (% of predicted)	78.38 (13.59)	74.14 (18.85)	80.12 (10.56)	0.139
Raw (% of predicted)	105.38 (31.38)	99.46 (26.32)	108.03 (33.38)	0.524
R5 (% of predicted)	126.64 (29.45)	118.75 (29.98)	130.00 (28.96)	0.072
R20 (% of predicted)	132.76 (30.95)	120.15 (31.46)	138.12 (29.50)	0.024*
PImax (% of predicted)	76.16 (24.28)	80.49 (29.24)	74.26 (21.93)	0.382
PEmax (% of predicted)	102.73 (32.68)	98.00 (27.11)	104.80 (34.96)	0.637
6MWD, m	561.97 (45.29)	517.43 (44.55)	573.52 (38.38)	0.012*
6MWD (% predicted)	94.61 (6.55)	88.46 (7.61)	96.20 (5.31)	0.011*

*Statistically significant. Values are shown as mean±SD severe versus non-severe with P values. SD: Standard deviation, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 s, TLC: Total lung capacity, DLCO: Diffusing capacity of the lung for carbon monoxide, Raw: Airway resistant, R5: Airway resistance at an oscillation frequency of 5 Hz, R20: Airway resistance at an oscillation frequency of 20 Hz, PImax: Maximum static inspiratory pressures, PEmax: Maximum static expiratory pressures, 6MWD: 6 min walk distance, RV: Residual volume

The group means of FEV1 and static lung volumes were found to be within the normal range (>80% predicted). However, several cases of abnormalities in FVC, FEV1, and FEV1/FVC ratio were identified. Eight patients (8.7%) showed mild impairment in FVC, one patient (1.8%) had moderate impairment in FVC, five patients (8.7%) exhibited mild impairment in FEV1, and 25 patients (43.9%) demonstrated mild impairment in FEV1/FVC. In addition, 8 patients (14.0%) and 10 patients (17.5%) displayed R5 and R20 values that exceeded 150% of the predicted value, respectively. A total of seven patients (12.2%) experienced a reduction in lung volume parameters (TLC) at 1 month, with six of them having mild impairment and one showing moderate impairment. Notably, the decline in TLC was more pronounced in severe cases (P=0.048). No significant differences were observed in FVC, FEV1, and FEV1/FVC between the two groups. The predominant impairment in FEV1 and FVC indicates a restrictive abnormality. One patient without a history of asthma exhibited obstructive abnormality with an FEV1/FVC ratio <70% predicted (increasing to 72% after bronchodilation), and this patient had a significant history of cigarette smoking. While no asthma symptoms were reported, another patient demonstrated a notable bronchodilator response with FEV1 increasing by more than 200 ml after salbutamol inhalation.

More than half of the subjects displayed impairment in respiratory muscle strength. A total of 28 patients (49.1%) had Pimax values below 80% of the predicted value, and 13 patients (22.8%) had Pemax values below 80%. Among the 13 patients with moderate impairment of respiratory muscle strength, 11 were categorized as non-severe cases (Table 3). When comparing the administration of steroids, no statistical significance in respiratory muscle strength was found between the group receiving glucocorticoids and the regular treatment group (Table 3).

Chest radiographs and correlations with lung function

During the 30-day follow-up after discharge, slight cough was reported by six patients (10.5%), while four patients (7.0%) experienced shortness of breath, and three patients (5.3%) had occasional wheezing. Subsequent CT scans during this period revealed residual abnormalities in 31 patients (54.4%), with 16 cases classified as severe (94.1%) and 15 cases as non-severe (37.5%). The majority of these residual imaging abnormalities were characterized by patchy ground glass opacity distributed at the periphery. Notably, these opacities exhibited noticeable absorption when compared to the most severe chest CT scan. In addition, pulmonary fibrosis was observed in four patients, all of whom were classified as severe cases. In comparison to non-severe cases, severe patients displayed a significantly higher CT score (3.94 [SD, 2.23] vs. 0.83 [SD, 1.39]; P<0.01). During the acute phase, the lung's total severity score demonstrated a negative correlation with TLC and R20 (P=0.049, 0.044). However, this correlation vanished during the follow-up period.

6MWD (6-min walk distance) observations

The average 6MWD among all participants was 561.97 m (±45.29 m). Comparatively, severe patients exhibited a shorter 6MWD in contrast to non-severe patients (517.43 m [SD, 44.55 m] vs. 573.52 m [SD, 38.38 m], P=0.012). In addition, the 6MWD achieved by severe cases only amounted to 88.4% of the predicted values, which was significantly lower compared to non-severe cases (P=0.011, Table 4).

DISCUSSION

With the global outbreak of COVID-19 in the past 6 months, despite extensive efforts, the precise understanding of the disease's mechanism, clinical attributes, prognosis, and effective treatments remained incomplete. Recent research, including our own findings, indicated that nearly half of the discharged patients exhibited residual abnormalities in chest CT scans.[6] This has prompted significant global concern over evaluating lung injuries in recovered patients.

Our study revealed that during the early recovery phase, approximately three-quarters of COVID-19 patients experienced impairment in pulmonary function. Among the most prevalent, impairments were reduced DLCO and a decline in the FEV1/FVC ratio. Abnormalities in DLCO were observed in over half of the COVID-19 patients, suggesting compromised intra-alveolar diffusion pathways. At present, no other comparable follow-up lung function data for COVID-19 patients exist. Meo et al. reported similarities between severe acute respiratory syndrome (SARS) and COVID-19 in terms of biological and clinical characteristics.[9] Prior investigations on SARS survivors indicated that impaired DLCO was the predominant abnormality, ranging from 15.5% to 43.6%.[10-15] Our findings were consistent with these studies. Autopsy examinations of COVID-19 patients who had succumbed to the disease revealed varying levels of alveolar structural damage and pulmonary interstitial fibrosis,[16,17] which can offer insight into the impaired DLCO. Severe patients exhibited a higher likelihood of DLCO abnormalities compared to non-severe cases. Remarkably, a small percentage of patients without residual imaging abnormalities also exhibited a slight reduction in DLCO. We hypothesize that these patients might have anomalies in tiny blood vessels or microthrombus formation. Previous long-term follow-up studies of SARS survivors suggested that DLCO abnormalities could persist for up to 3 years after recovery in some cases.[18] Continued long-term follow-up will provide insights into the trajectory of DLCO impairment.

Our results indicated that six patients (10.5%) experienced obstructive pulmonary dysfunction, while seven patients (12.3%) displayed restrictive ventilation dysfunction. Among the severe cases, two subjects demonstrated residual combined restrictive and obstructive functional impairment. Consistent with our research, series of articles on SARS survivors reported similarly low rates of either obstruction or restriction.[10,11] Pathological findings in severe COVID-19 patients revealed the presence of mucous plugs in small airways,[17] which could account for the observed decline in ventilatory function.

Aside from acute lung injury, neuromuscular weakness can also contribute to reduced lung function. However, in some cases, lower FEV1 or FEV1/FVC ratio could be attributed to factors such as long-term smoking or atypical airway hyperresponsiveness.

Remarkably, during the initial rehabilitation phase, we observed that the lung's total severity score did not exhibit a significant correlation with FEV1, FVC, or DLCO. This contrasted with research on SARS survivors.[19] This suggests that the impairment of lung function did not necessarily correspond to the severity of illness or residual imaging changes. This intriguing observation may stem from the fact that many severe patients in our study received glucocorticoid treatment during their hospitalization, which could potentially improve the prognosis of COVID-19 patients. However, given the small sample size and limitations in our CT quantitative evaluation, further investigations are required to confirm these findings. Our goal is to conduct a more comprehensive and extended long-term follow-up study with an expanded sample size to validate these conclusions.

More than half of the patients experienced a decrease in respiratory muscle strength. About 29.8% of patients were classified as severe or critical, necessitating oxygen supplementation and prolonged bed rest during their hospital stay. This extended bed rest could contribute to muscle disorders. In addition, systemic corticosteroid use might lead to steroid myopathy. However, our analysis indicated no statistical significance in respiratory muscle strength between the glucocorticoid and regular treatment groups. This suggests that corticosteroids might not be the primary cause of respiratory muscle weakness. Interestingly, no substantial differences were observed in declining respiratory muscle strength between severe and non-severe groups, underscoring the need for further research to explore the direct impact of the virus on respiratory muscles.

Early in convalescence, severe patients demonstrated significantly shorter 6MWD compared to non-severe patients, pointing to poorer exercise tolerance. In addition to impaired TLC and DLCO in the severe group, it is important to consider the patients' cardiac function. Further studies should incorporate exercise cardiopulmonary function assessments. Earlier research on SARS survivors indicated that impaired lung function persisted up to a year.[10,11] Prolonged follow-up of COVID-19 patients is essential to comprehend the characteristics and trends in lung function and exercise tolerance.

This study has several limitations. It is a cross-sectional study with a small sample size in stratified analysis, offering only a short-term follow-up. The findings' heterogeneity is not fully comprehensive. Furthermore, only 57 out of 102 COVID-19 patients (56%) at our hospital completed the serial assessments, potentially limiting the generalizability of the results. Finally, while comprehensive lung function tests and the 6MWT were conducted, cardiopulmonary exercise testing was omitted due to patients' complaints of generalized muscle weakness during follow-up and the demanding nature of CPET for individuals in early recovery.

Limitations of the study

The study has a small sample size and short follow-up duration, but our findings emphasize the importance of extended follow-up studies to elucidate the long-term trajectory of lung recovery and its clinical implications. These insights are crucial for enhancing patient care, monitoring, and management strategies as we navigate the complexities of post-COVID-19 recovery.

CONCLUSION

This study provides valuable insights into the lung function impairments observed during the early convalescent phase in COVID-19 patients. More than half of the patients exhibited issues such as impaired diffusing capacity, decreased respiratory muscle strength, and lung imaging abnormalities. Notably, severe cases showed a higher incidence of DLCO impairment, along with significant reductions in TLC and 6MWD compared to non-severe cases. These findings underscore the need for ongoing monitoring and longer-term follow-up to better understand the recovery trajectory and clinical outcomes of COVID-19 patients. While certain limitations exist, including a small sample size and the cross-sectional nature of the study, these results contribute to our understanding of post-recovery lung function in the context of COVID-19. Further research with larger cohorts and extended follow-up periods is warranted to validate and expand on these findings.

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ARR- Literature survey, Prepared manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation and submission of article; **AJJ-** Concept, design, clinical protocol, manuscript preparation, editing, and manuscript revision; **SYW-** Design of study, statistical Analysis and Interpretation, Review Manuscript, Literature survey and preparation of Figures, Coordination and Manuscript revision.

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