Original Article

Monitoring the Adverse Implications of Coronavirus 2019-induced Pulmonary Complications on Patients' Respiratory Capacity and Physical Abilities with Moderate and Severe Signs during Interval Follow-up

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Abstract

Background: The respiratory system of individuals with coronavirus 2019 (COVID-19) experiences significant strain due to the body's immunological response and inflammation, leading to organ failure. Over time, patients have improvement in symptoms such as radiological abnormalities, pulmonary function impairment, and decline in respiratory and physical abilities. This research aimed to assess the impact of COVID-19 on the pulmonary function and physiological performance capacity of patients with moderate and severe problems who were hospitalized and subsequently released. These parameters were evaluated during 3, 6, and 12-month follow-up periods. **Methods:** The participants in this research were individuals hospitalized with COVID-19 at Hajar Shahrekord Hospital. They evaluated using spirometry tests, a 6-min walk test (6MWT), and spiral lung high-resolution computed tomography (HRCT) scans. The assessments were conducted from their first diagnosis until 12 months after release. The sampling was performed employing the head-counting approach, and an expert examined the data collected from spirometry and 6MWT in statistics and epidemiology. Expert radiologists and pulmonologists examined spiral lung HRCT data. **Results:** The combined data from spirometry (revealing improved lung function), the 6MWT (showing increased endurance), and HRCT (indicating reduced lung damage) demonstrated marked progress in both groups throughout the study period. While each group demonstrated statistically significant improvements at various follow-up points, no significant difference emerged between the moderate and severe patient groups in the study. Significant improvements in lung function, physical capacity, and radiological outcomes were observed in both moderate and severe COVID-19 patients at the 12-month follow-up. Notably, there were no statistically significant differences in improvement between the groups. **Conclusion:** This study emphasizes the importance of personalized extended care and rehabilitation for patients severely affected by COVID-19, aiming to tackle ongoing deficits and prevent long-term complications.

Keywords: *6-minute walk test, coronavirus 2019, high-resolution computed tomography, lung, spirometry*

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Introduction

As the coronavirus 2019 (COVID-19) pandemic emerges, there is growing concern about the lasting effects of COVID-19 infection.[1] Long COVID-19, also known as the postacute COVID-19 phenomenon in academic literature, refers to the ongoing or newly developed symptoms experienced by specific individuals who have previously survived acute COVID-19 infection.[2] Long COVID-19 encompasses a variety of symptoms that impact several organ systems, hindering daily activities and an individual's occupational performance.[3] Long COVID-19 may affect people who have completely recovered from COVID-19, regardless of their gender, age, or disease severity during the acute phase of the infection.[4] Elderly individuals and young people with mild episodes of acute COVID-19 have been seen to have persistent neuropsychiatric symptoms.[5] This may result in a long-term societal cost, presenting an opportunity for clinical investigations aimed at therapeutic progress and symptom alleviation.[6] Studies have shown that COVID-19 impacts patients' overall well-being, daily habits, and psychological well-being.[7]

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Nevertheless, there is little knowledge about the enduring effects of COVID-19 on health-related measures, such as quality of life (QoL), lifestyle modifications, and mental well-being, 1 year after the first infection.[8,9] The COVID-19 pandemic in Iran developed on February 19, 2020, with the first official cases documented in Qom, rapidly spreading to other areas of the nation.[10] The epidemic significantly affected Iran's economic, social, and health sectors. Official records from the Ministry of Health indicate that by the conclusion of 2020, many waves of illnesses and fatalities had been documented.[10,11] The fourth and fifth waves, characterized by the proliferation of the Delta variety, had one of the most incredible fatality rates among succeeding waves.[12] Consequently, a substantial cohort of patients has recuperated from COVID-19 infection, making this population sample appropriate for examining the long-term effects of COVID-19. To our knowledge, no previous research has evaluated the long-term effects of COVID-19 beyond 3, 6, and 12 months postacute infection in Iran.

Nucleic acid testing is regarded as the most reliable method for detecting SARS-CoV-2 infection. These assays may identify the presence of viral RNA fragments.[13,14] These tests are often performed on respiratory samples obtained from a nasopharyngeal swab. Alternatively, a nasal swab or sputum specimen may be used, with results frequently available within a few hours.[15] Chest computed tomography (CT) scans and molecular tests are essential diagnostic methods for COVID-19. A chest CT scan is a noninvasive diagnostic method to identify abnormalities linked to a disease.[16] In recent years, the COVID-19 pandemic has become one of the most significant public health challenges. The disease is characterized not only by acute and subacute symptoms but also by long-term and complex complications. One of the major concerns for patients with COVID-19 is the pulmonary complications caused by the virus, which can significantly affect individuals' respiratory capacity and physical abilities.[17] Therefore, patients with moderate and severe symptoms should be carefully monitored to identify the adverse effects of these complications.[18]

The impact of pulmonary complications on patients' QoL and daily abilities is significant. Therefore, continuous and regular follow-up of these patients can help identify changes in their health status and prevent further deterioration. In this regard, recognizing and monitoring complications caused by COVID-19 and how they affect patients' physical condition plays a key role in improving treatment and rehabilitation methods. This study aimed to determine the effect of COVID-19 on lung function and exercise capacity of hospitalized and discharged patients with moderate and severe complications, who were evaluated during 3-, 6-, and 12-month follow-ups.

Methods

This research examined COVID-19-positive individuals in the Hajar Hospital admitted, treated, released, and postrelease periods. Upon release from the hospital, patients who had fully recovered were encouraged to return to the lung clinic for follow-up examinations such as spirometry, 6-min walk test (6MWT), and spiral lung high-resolution computed tomography (HRCT) tests 3, 6, and 12 months after discharge. The author declared that the investigations were carried out following the rules of the Declaration of Helsinki of 1975, which was revised in 2013. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Shahrekord University of Medical Sciences (IR.SKUMS.REC.1399.254).

Patients experienced assessment with a multiparametric approach including HRCT, spirometry, a 6MWT, oxygen saturation evaluations, and physical examination. In this research, pulse rate (PR) is the heart rate quantified in beats per minute; it was documented before and after the 6MWT to evaluate cardiovascular responses to exertion. Patients were principally classified into moderate and severe categories according to the degree of lung involvement indicated by HRCT results during hospitalization. A quantitative scoring method was used for each of the five lung lobes, resulting in a total score. Patients exhibiting higher cumulative scores – reflective of more pronounced parenchymal abnormalities including ground-glass opacities, reticular patterns, and first fibrotic changes – were categorized as having severe pulmonary involvement. While demographic parameters (e.g., age, weight, height, and body mass index [BMI]) exhibit minor variations between the groups (with the severe group generally being slightly older and possessing a higher BMI), these discrepancies are modest and do not entirely explain the significant differences in pulmonary function and imaging outcomes observed. The patients were categorized based on whether their lung involvement was severe or moderate. The results of the spiral lung HRCT were compared quantitatively with the patient's previous CT scans taken during his hospitalization and evaluated qualitatively. In perspective of the apprehensions regarding radiation exposure from successive HRCT scans, especially during the 3-month follow-up, we implemented low-dose HRCT protocols adhering to the as low as reasonably achievable principle. All patients granted informed consent that explicitly delineated the potential risks and benefits related to these scans. Our work used noninvasive evaluations (spirometry, 6MWT, oxygen saturation, and physical examination) in conjunction with HRCT to comprehensively measure lung recovery. This integrated method establishes a foundation for future approaches that may reduce the usage of HRCT, particularly in mild situations when noninvasive data closely align with lung imaging results. The current research study employed a descriptive-analytical approach. This research included patients admitted to the hospital with positive COVID-19 results based on the spiral lung HRCT clinical examination

and PCR tests from the nasopharyngeal swab samples during the COVID-19 pandemic period. It is important to mention that in this investigation, whereas no prior underlying pulmonary illness was present in this trial, we relied on the patient's history. Participants were included in the study based on the following criteria: individuals without a history of previous breathing disorders such as asthma and chronic obstructive pulmonary disease, and a history of lung surgery before being admitted to the hospital. This research excluded patients who had a prior history of immobility, those under medication that could interfere with the study outcomes, pregnant or lactating women, and individuals with lifestyle habits such as smoking or excessive alcohol consumption. These criteria were carefully established to ensure the reliability and accuracy of our findings while minimizing potential confounding variables.

Statistical and epidemiological experts, radiologists, and lung specialists reviewed the patients' data collected from spirometry, 6MWT, and spiral lung HRCT and then assessed the results. The spirometry was conducted using the Italian Mir equipment, which is frequently calibrated and has adequate validity and reliability. Its quality control is also done periodically. The German emotion 16-slice instrument, frequently calibrated and has acceptable validity and reliability, was used for the spiral lung HRCT.

Statistical analysis

This project used SPSS statistical software to compare the spirometry and 6MWT test findings to normal values from people of the same age and gender. Finally, during the 3-, 6-, and 12-month follow-ups, the results of the lung tests were compared to the discrepancies seen in the spiral lung HRCT. Results were analyzed using statistical tools, including *t*-tests (independent and paired), variance analysis of repeated observations, and tests for linear relationships (Spearman's and Pearson's correlations, respectively).

This investigation commenced after acquiring the requisite authorizations from the ethics committee. The patients' characteristics were not documented, and the data were acquired through coding.

Results

Demographic features

Patients with COVID-19 who were hospitalized, treated, and discharged from Hajar Hospital in Shahrekord from the time of infection onset to 12 months after discharge constitute the study population. Table 1 provides the patients' demographic information, including age, weight, height, and BMI.

Patients in two groups with moderate to severe pulmonary involvement underwent follow-up in terms of pulmonary function using spirometry and a 6MWT test. The spirometric parameters studied included forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), FEV1/FVC, and forced expiratory flow 25/75 [$P < 0/001$, Table 2]. However, there was no significant difference in the comparison of spirometric parameters between the two groups. The interaction effect of the studied groups and time is given in Table 2.

Frequency of outcomes patients with coronavirus 2019

In the 3-month follow-up of patients with moderate involvement, 5 (10%) had mild obstruction, 5 (10%) had moderate obstruction, 3 (6%) had severe obstruction, and 27 (54%) had no obstructive involvement. Furthermore, in the group of patients with severe involvement, 4 (8%) had mild obstruction, 20 (40%) had moderate obstruction, 11 (22%) had severe obstruction, 2 (4%) had very severe obstruction, and 23 (46%) had no obstructive involvement. No significant difference was observed between the two groups ($P = 0.87$) [Table 3].

In the 6-month follow-up of patients with moderate involvement, 3 (6%) had mild obstruction, and 2 (4%) had moderate obstruction. Thirty-seven patients (74%) were without obstructive involvement [Table 3]. In the group of patients with severe involvement, four patients (8%) had mild obstructive involvement, five patients (10%) had moderate obstructive involvement, and two patients (4%) had severe obstructive involvement. Two patients (4%) had very severe obstructive involvement and 45 patients (90%) had no obstructive involvement. No significant difference was observed between the two groups [$P = 0.21$, Table 3].

No obstructive involvement was observed in the 12-month follow-up of patients with moderate participation [Table 3]. However, in the group of patients with severe involvement, three patients (6%) had mild obstructive involvement, one patient (2%) had moderate obstructive involvement, three patients (6%) had severe obstructive involvement, and one patient (2%) had very severe obstructive involvement, and 42 patients (84%) had no obstructive involvement. No significant difference was observed between the two groups [$P = 0.006$, Table 3].

In the intragroup comparison, at 3, 6, and 12-month follow-ups, all obstructive involvements in each group showed a decreasing and improving trend and were statistically significant [$P < 0.001$, Table 3]. In evaluating bronchodilator response in the two groups, at the 3-month follow-up in the moderate involvement group, out of 50 subjects, 30 subjects (60%) did not respond to bronchodilators, and 20 subjects (40%) responded to bronchodilators [Table 3]. In the severe involvement group, 22 subjects (44%) had a negative response to bronchodilators, and 28 subjects (56%) had a positive response to bronchodilators. No significant difference was found between the two groups [$P = 0.11$, Table 3].

At 6-month follow-up, 39 patients (78%) in the moderate involvement group had no response to bronchodilators, and 11 patients (22%) had a positive response to bronchodilators, and in the severe involvement group, 45 patients (90%) had

a negative response, and five patients (10%) had a positive response. No significant difference was found between the two groups [*P* = 0.01, Table 3]. At the 12-month follow-up, 46 patients (92%) had a negative response, four patients (8%) had a positive response in the moderate involvement group, 49 patients (98%) had no response to bronchodilators, and one patient (2%) had a positive response in the severe involvement group [*P* = 0.36, Table 3]. Considering the patients' improving course, the response to bronchodilators decreased in each group at 3-month, 6-month, and 12-month follow-ups, but no significant difference was observed between the two groups.

To improve clarity and respond to reviewer concerns about conflating distinct problems inside a single statement, we have reorganized the CT scan data as follows:

Moderate involvement group

Of the 45 patients, 14 demonstrated a CT score below five (indicating <5% involvement in the lung lobes), whereas the remaining 31 patients presented with entirely normal CT scans (CT score of 0).

Severe involvement group

Within this cohort, 16 patients (32%) had aberrant CT results. Specifically, two patients had lung involvement between 25% and 50%, and 14 patients showed involvement ranging from 5% to 25%. The remaining 34 patients (68%) in the severe group had normal CT scans (CT score = 0). This distinction guarantees that the outcomes for each group are clearly defined.

Evaluated of the average data for 6-min walk tests in two groups

MWT 6 data included heart rate per minute (PR) and per cent arterial blood oxygen saturation (O2SATURATION) before and after the test, and the distance covered by the patient during a 6-min walk. In the first 3-month follow-up, in the group of patients with moderate and severe involvement, the PR of patients was measured before and after the 6MWT test. No significant difference was observed comparing the mean difference in PR in the two groups of patients with moderate and severe involvement [*P* = 0.07, Table 4]. In the 6-month follow-up, a significant difference was observed between the two groups [*P* < 0.001, Table 4]. Furthermore, in the 12-month follow-up, the mean difference in PR in the two groups was significantly different [*P* < 0.01, Table 4]. However, in the 1-year follow-up, a statistically significant difference was observed between the differences in arterial blood oxygen saturation of patients in each group. In the 3-month follow-up in the group of patients with moderate and severe involvement, the patients' O2SATURATION was measured before and after the 6MWT test, and no statistically significant difference was observed in the mean arterial blood oxygen saturation (O2sat) between the two groups [*P* = 0.089, Table 4]. At the 6-month

Table 1: The demographic features of patients in the two moderate and severe coronavirus 2019 groups

Variable	Severe group			Moderate group		
	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD
Age	23	90	53.6±14.7	22	80	51.6±15.5
Weight	42	138	77.8±15.02	52	130	76.1±15.5
Height	147	188	167.6±11.2	150	186	169.7±9.05
BMI	17.7	42.5	27.6±4.5	18.9.7	43.9.5	26.4±5.3

BMI – Body mass index; SD – Standard deviation

Table 2: The interaction of group and time

Index (%)	Study duration	Mean±SD severe group	Mean±SD moderate group	*P*
FEV_1	3 months postdischarge	72.54±14.43	76.48±24.09	0.324
	6 months postdischarge	92.02±11.29	86.50±22.24	0.12
	12 months postdischarge	93.04±10.62	89.36±16.34	0.185
	P	<0.001	<0.001	0.005*
FVC	3 months postdischarge	78.4±12.54	83.88±24.21	0.088
	6 months postdischarge	96.08±11.14	93.2±22.43	0.416
	12 months postdischarge	97.78±8.99	93.2±18.36	0.136
	P	<0.001	<0.001	0.004*
FEV_1/FVC	3 months postdischarge	70.37±11.18	74.14±14.08	0.017
	6 months postdischarge	79.8±6.91	79.28±12.85	0.152
	12 months postdischarge	83.72±5.75	82.5±10.05	0.561
	P	<0.001	<0.001	0.023*
FEF25/75	3 months postdischarge	59.4±23.57	60.2±28.55	0.88
	6 months postdischarge	79.52±22.19	77.94±31.8	0.77
	12 months postdischarge	88.54±22.16	89.56±25.27	0.83
	P	<0.001	<0.001	0.729

*Significant *P* value. SD – Standard deviation; FEV_1 – Forced expiratory volume in 1 s; FVC – Forced vital capacity; FEF – Forced expiratory flow

Table 3: Frequency of some coronavirus 2019 outcomes in two groups of patients with moderate and severe involvement

Variable (%)	Phase (months)	Indicator Level	Moderate Amount (%)	Severe Amount (%)	*P*
Obstruction involvement	3	No obstruction	27 (54)	23 (46)	0.87
		Mild	5 (10)	4 (8)	
		Moderate	5 (10)	20 (40)	
		Severe	3 (6)	11 (22)	
		Very severe	0	2 (4)	
	6	No obstruction	37 (74)	45 (90)	0.21
		Mild	3 (6)	4 (8)	
		Moderate	2 (4)	5 (10)	
		Severe	0	2 (4)	
		Very severe	0	2 (4)	
	12	No obstruction	50 (100)	42 (84)	0.006
		Mild	0	3 (6)	
		Moderate	0	1 (2)	
		Severe	0	3 (6)	
		Very severe	0	1 (2)	
Response to bronchodilator	3	Negative	30 (60)	22 (44)	0.11
		Positive	20 (40)	28 (56)	
	6	Negative	39 (78)	45 (90)	1.01
		Positive	11 (22)	5 (10)	
	12	Negative	46 (92)	49 (98)	0.36
Restrictive involvement	3	Negative	36 (72)	24 (48)	0.024
		Positive	14 (24)	26 (52)	
	6	Negative	44 (88)	45 (90)	0.75
		Positive	5 (10)	6 (12)	
	12	Negative	50 (100)	46 (92)	0.059
		Positive	0	4 (8)	
Involvement of small airways	3	Negative	22 (44)	22 (44)	1
		Positive	28 (56)	28 (56)	
	6	Negative	41 (82)	37 (74)	0.33
		Positive	9 (18)	13 (26)	
	12	Negative	50 (100)	45 (90)	0.056
		Positive	0	5 (10)	
Normal spirometry	3	Negative	31 (62)	40 (80)	0.047
		Positive	19 (38)	10 (20)	
	6	Negative	14 (28)	16 (32)	0.66
		Positive	36 (72)	34 (68)	
	12	Negative	0	10 (20)	0.001
		Positive	50 (100)	40 (80)	

follow-up, the two groups observed a significant difference in arterial blood oxygen saturation [$P = 0.01$, Table 4]. At the 12-month follow-up, the difference in mean O2sat in the two groups was insignificant [$P = 0.54$, Table 4]. However, at the 1-year follow-up, a statistically significant difference was observed in arterial blood oxygen saturation between the patients in each group.

In examining the distance travelled by patients in the 6-min walk test

At 3, 6, and 12-month follow-ups, no significant differences were observed between the two groups in patients with moderate and severe involvement. However, in each group, the distance travelled at the final follow-up was greater than at the initial follow-up, and there was a statistically significant difference. The average data related to the 6MWT test in two groups of patients with moderate and severe COVID-19 involvement are presented in Table 4.

Pulmonary involvement and high-resolution computed tomography patterns in moderate and severe coronavirus 2019: A 3-, 6-, and 12-month follow-up analysis

HRCT lung examination was performed in two groups: 5 lung lobes were examined, and if the sum of the

involvement in all lobes was <5, the CT was considered healthy, and if the involvement was more than five, it was considered abnormal. In the 3-month follow-up, in the group of patients with moderate involvement, five people (10%) had abnormal CT with an involvement of 5%–25%, and 45 people (90%) were classified as normal CT. In fact, 14 out of 45 people had a CT score of <5, <5% involvement in the lobes, and 31 had completely normal CTs. Without pulmonary involvement and with a CT score of zero, and in the group of patients with severe involvement, 16 people (32%) had abnormal CT, with the involvement of two cases being 25%–50% and the involvement of the other 14 people being 5%–25%. Moreover, 34 people (68%) had normal CT. Eighteen of 34 patients had CT scores between 0 and 5, with an involvement rate of <5%, and 16 patients had no pulmonary involvement. In the 6-month and 12-month follow-ups, no abnormal scores were calculated in the CT scans in either group [Figure 1].

CT scan involvement in the moderate involvement group in the first 3 months was 21 patients with positive ground-glass opacity (GGO)/one patient with reticular pattern/one patient with subpleural line. CT involvement in the severe group was 31 patients with positive GGO/three patients with reticular pattern/4, patients with irregular line/2, and patients with subpleural lines. In the 6-month follow-up, in the moderate involvement group, we had six patients with GGO involvement on CT, who were considered to have normal CT scans since their CT scores were between 0 and 5 with an involvement rate of <5%. In the 6-month follow-up, in the severe group, 16 patients had CT involvement as GGO, and two patients had irregular lines, which were considered healthy based on a CT score of <5, with an involvement rate of <5% [Figure 2].

In the 12-month follow-up in the moderate group, all CT scans were classified as normal, with a CT score of zero without any pulmonary involvement. Still, in the 12-month follow-up in the severe group, five patients were GGO positive but had a CT score of <5% with an involvement rate of <5%. It should be noted that patients involved in CT scans underwent repeat CT scans during follow-ups, which were not performed for patients with normal CT scans. The CT scan results of patients in the two groups are given in Table 5.

Discussion

Researching the long-term implications of COVID-19 on pulmonary function, QoL, and task performance is extremely significant, especially for those with moderate-to-severe medical conditions.[19] This study aimed to examine the impacts of exercise capacity, pulmonary function, and imaging data over a 1-year period. It furnished us with relevant insights into the methods of individual recovery and the challenges they persistently encounter.[20] Previous continuous examinations indicate that the significant improvement in spirometric measures (FEV1, FVC, and FEV1/FVC) in both groups aligns with the results of earlier research.[21] Anastasio *et al.*[22] found that lung volumes and flow rates gradually returned to normal values, previously anomalous, after 6–12 months postinfection. No significant variation in the spirometry data was seen throughout the 12 months across the groups. The severity of the disease influences the initial level of disability; nonetheless, it is conceivable that the recovery process may become more uniform with time. This community bears a disproportionately significant burden of post-COVID-19 consequences, shown by the continued presence of blocking and limiting behaviours in the severe group.[23]

Previous research, including that by Zhang *et al.*,[24] has shown a correlation between these challenges and chronic inflammation, pulmonary changes, and postviral fibrosis.

Table 4: An average of patient’s vital signs and walking distance in the two moderate and severe groups

	Severe (mean±SD)	Moderate (mean±SD)	*P*
Heart rate (bpm)			
3 months			
Before	93.74±6.1	87.3±0.7	<0.001
After	117.5±17.7	115.6±16.6	0.54
Difference	84±23.8	28.3±13.2	0.07
6 months			
Before	82.9±5.4	81.6±436	0.19
After	96.8±6.9	102.5±7.9	0.001
Difference	13.8±7.3	20.6±7.7	<0.001
12 months			
Before	81±4.2	79.9±3.8	0.17
After	93.4±4.8	96.6±4.5	0.001
Difference	12.3±4.1	16.7±4.4	<0.001
P. value	<0.001	<0.001	
Arterial O_2 saturation (%)			
3 months			
Before	92.7±3.6	94.3±35	0.03
After	87.8±6.3	87.6±8	0.92
Difference	−4.9±4.4	−6.6±5.4	0.089
6 months			
Before	94.7±2.35	95.9±2.3	0.015
After	93.8±3.2	93.8±3.95	0.95
Difference	−0.9±1.9	−2.08±2.4	0.01
12 months			
Before	95.6±2	96.5±2	0.03
After	95.3±2.4	96±2.6	0.17
Difference	−0.2±1.4	−0.4±1.7	0.54
P	<0.001	<0.001	
6-min walk distance (m)			
3 months	476.8±96.6	487.5±93.9	0.58
6 months	505.5±92.1	519.3±94.5	0.46
12 months	511.06±91.1	526.08±93.6	0.42
P	<0.001	<0.001	

SD – Standard deviation

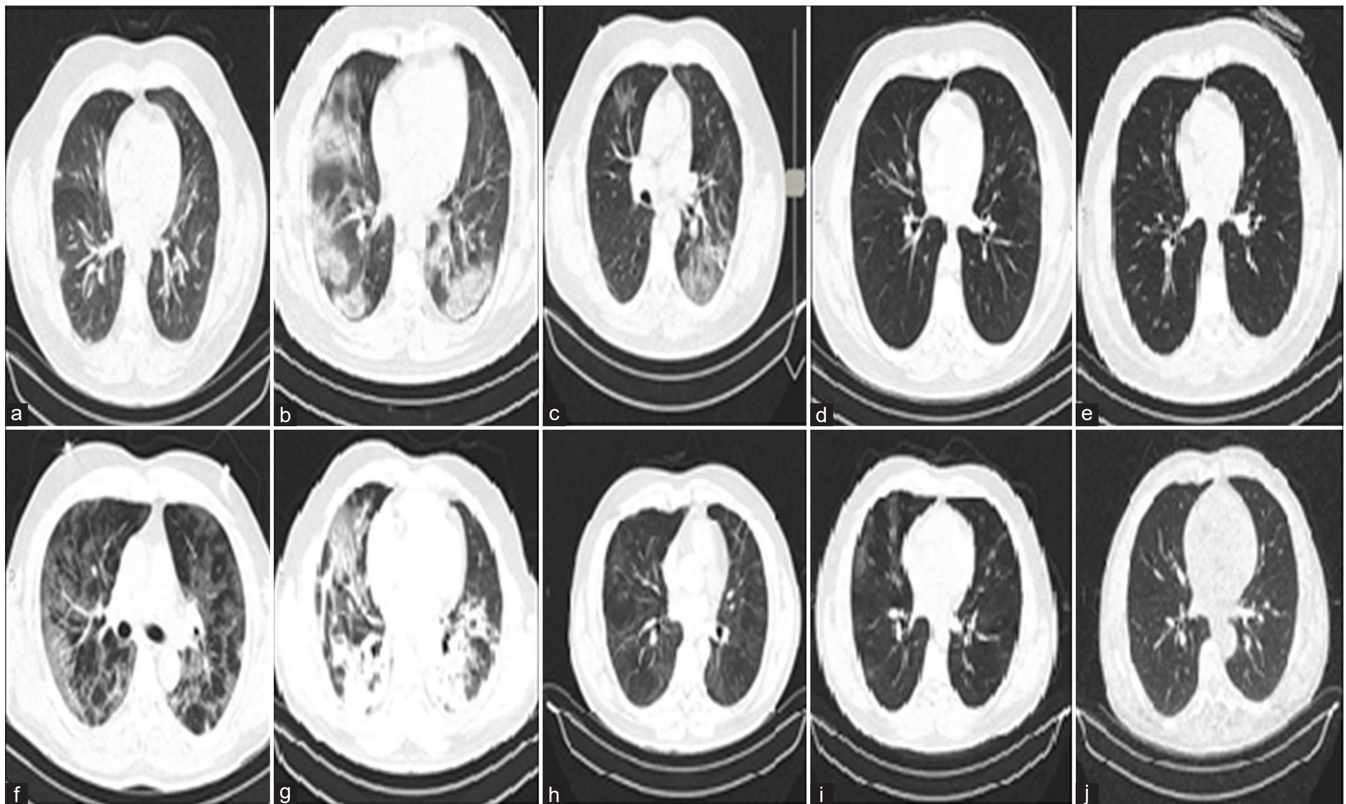

Figure 1: (a-d) High-resolution computed tomography (HRCT) of a 58-year-old man with COVID-19 at 3, 6, and 12-month follow-ups. (f-j) HRCT of a 43-year-old man with COVID-19 at 3, 6, and 12-month follow-ups. (a) Day 10 CT-score = 12, (b) Day 29 CT-score = 30, (c) Day 82 CT-score = 20, (d) Day 176 CT-score = 54, (e) Day 358 CT-score = 0, (f) Day 13 CT-score = 55, (g) Day 28 CT-score = 40, (h) Day 91 CT-score = 23, (i) Day 179 CT-score = 15, (j) Day 355 CT-score = 0

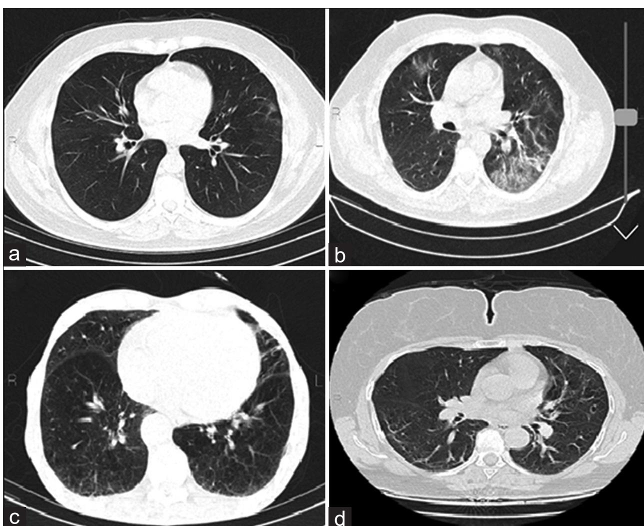

Figure 2: Abnormal computed tomography scan patterns in coronavirus 2019 patients at 3, 6, and 12-month follow-ups. (a) Ground-glass opacity, (b) Irregular lines, (c) Reticular pattern, (d) Subpleural line

This is especially applicable to those with considerable respiratory involvement at the study's start. Both cohorts had considerable enhancement in the 6MWT; still, the intermediate patients exhibited the most improvement. Nevertheless, even after 1 year, the serious group persisted

Table 5: Computed tomography scan results of patients in two groups with moderate and severe coronavirus 2019

	Severity		Moderate		*P*
	Normal (%)	Nonnormal (%)	Normal (%)	Nonnormal (%)	
3 months	34 (68)	16 (32)	45 (90)	5 (10)	0.007

in demonstrating oxygen desaturation during exercise. Lerum *et al.* found that exercise-induced hypoxia is a prevalent residual weakness in severe cases.[25] This deficiency is often linked to diffusion problems or unaddressed parenchymal changes. This study corroborates both of their findings.

In mild cases, the enhanced recovery in exercise capacity is likely due to less severe initial lung damage and superior retention of baseline cardiac reserve.[26] This requires additional investigation. These figures illustrate the need to initiate early treatment and use focused interventions to support individuals with substantial functional impairments.[27] In the severe group, the HRCT values remained abnormal after 1 year. This group included signs of early fibrosis and involvement of the small airways. The absence of these difficulties in mild cases illustrates how

the initial severity of the disease affects lung structure throughout the healing period. Polastri *et al.*[28] found that substantial instances exhibit chronic ground-glass opacities and fibrotic bands. These data substantiate the notion that this specific population needs prolonged radiological monitoring. These results may result from inadequate resolution of acute inflammatory processes, extended cytokine activity, and dysfunctional repair responses, contributing to fibrosis development.[29] Our research offers substantial insights into the progressive recovery of pulmonary function, physical ability, and radiological enhancements in moderate and severe COVID-19 patients during a 12-month period. The findings demonstrate notable advancements in spirometric metrics, 6MWT outcomes, and imaging data, linking these advances to the current literature. The authors have effectively correlated the severity of early lung involvement with the degree of remaining abnormalities, substantiating their claims using statistical analysis and prior research. The interpretation might be enhanced by a comprehensive examination of how various therapies, such as early rehabilitation, may impact these outcomes, particularly in patients with severe afflictions. Although our interpretations rely on rigorous statistical analyses and methodological precision, we recognize that certain biological and environmental variables may influence result differences. We acknowledge that our research has certain limitations that must be taken into account when evaluating the findings. The sample size, which may influence statistical power and the detection of minor effects, and the research design (e.g., cross-sectional/retrospective), which demonstrates associations rather than causations, are included. Furthermore, despite our attempts to account for covariates, unmeasured confounders may still affect the outcomes. The research population is sourced from Chaharmahal and Bakhtiari province, perhaps limiting the generalizability of the results to wider, more heterogeneous populations. Although our research provides significant insights, its applicability to other communities or contexts should be approached with caution. Genetic diversity, environmental factors, and dietary practices may affect the reproducibility of our results across several cohorts. Subsequent research involving larger and more diverse populations, as well as multi-center collaborations, is essential to corroborate and expand our findings. We appreciate the reviewer's suggestion and have incorporated a discussion of these points in the revised manuscript. By acknowledging these factors, we aim to provide a balanced and transparent interpretation of our results, ultimately contributing to a more comprehensive understanding of "Monitoring the adverse implications of COVID-19-induced pulmonary complications on patients' respiratory capacity and physical abilities with moderate and severe signs during interval follow-up." We hope this response sufficiently addresses the reviewer's concerns, and we are happy to make further modifications if needed. Our analyses reveal that the substantial disparities in pulmonary function – demonstrated by spirometry and 6MWT results – and the radiological characteristics on HRCT are predominantly influenced by the degree of lung injury caused by COVID-19, rather than by the minor variations in biological demographics (e.g., age and BMI) observed between the moderate and severe groups. Despite the severe group exhibiting a marginally elevated average age (53.6 ± 14.7 years compared to 51.6 ± 15.5 years in the moderate group) and a higher BMI (27.6 ± 4.5 vs. 26.4 ± 5.3), the significant statistical disparities (frequently with $P < 0.001$) in our functional and imaging outcomes highlight that these endpoints possess enhanced discriminative capability regarding post-COVID-19 recovery. However, we recognize that subsequent research employing stratified sampling or multivariate analyses is necessary to further delineate and comprehend the independent effects of demographic variables.

Hui *et al.* indicate that similar outcomes have been seen in several postviral illnesses, including SARS and MERS.[30] The persistent difficulties in the severe group after 1 year have substantial therapeutic implications. These people may recover from long-term monitoring involves the systematic execution of imaging and pulmonary function assessments to detect and manage any chronic complications. The European Respiratory Society advocates for pulmonary rehabilitation programs designed to enhance patients' mobility and optimize their respiratory efficiency.[31] Approaches for the Management of Fibrosis Zhang *et al.* assert that the early initiation of antifibrotic therapies, such as pirfenidone, may prevent enduring damage in individuals exhibiting imaging indicators of progressive fibrosis.[24] A weakness of this study is its reliance on data from a singular site and the absence of spirometry data before COVID-19 infection, which would have elucidated the commonalities between the two groups. Furthermore, excluding persons with multiple health conditions may hinder the generalization of the results to broader groups.

The research has certain limitations that require consideration. The study was conducted at a single location, which may restrict the generalizability of the results to broader groups or contexts. The lack of pre-COVID-19 spirometry data is a significant drawback, as it hinders the ability to assess the degree of lung function deterioration directly attributable to the illness. The omission of patients with comorbidities limits the study's applicability since it fails to include individuals with more complex health issues who may exhibit various recovery trajectories. The limited sample size exacerbates these restrictions, potentially diminishing the statistical power of the findings. In addition, dependence on patient-reported histories poses a risk of recall bias. Future studies should address these deficiencies by utilizing multi-center data to enhance the generalizability of the results. Incorporating preinfection spirometry data would provide a more accurate understanding of the disease's impact on pulmonary

function. Recruiting larger cohorts that include patients from diverse backgrounds, including those with comorbidities, would yield a more comprehensive and representative dataset. Furthermore, research evaluating the effectiveness of early treatments such as pulmonary rehabilitation or antifibrotic medications may offer valuable insights for improving recovery outcomes. Ultimately, extending the follow-up duration beyond 1 year would provide deeper insights into chronic or long-term pulmonary sequelae and allow for the development of strategies to better assist patients throughout their recovery process.

Conclusion

This research emphasizes the intricate and extended recovery path of pulmonary function and exercise capacity in individuals with moderate to severe COVID-19. Patients with mild illness fully recovered at 12 months, but those with significant involvement had lingering deficits, such as persistent radiological abnormalities, obstructive patterns, and exercise-induced oxygen desaturation. These results highlight the essential need for personalized, extended follow-up treatment for severe patients. The findings underscore the need for a multidisciplinary strategy in addressing post-COVID-19 effects. Pulmonary rehabilitation therapies designed to improve exercise tolerance and optimize oxygen usage are vital for recovery. Moreover, regular pulmonary function assessments and imaging are essential for monitoring and managing persistent problems, especially in those with severe initial illness. The enduring nature of radiological abnormalities and functional impairments in severe instances suggests the potential benefit of early treatments, including antifibrotic medicines, to prevent permanent lung fibrosis development. Subsequent research should investigate the effectiveness of these therapies in alleviating chronic pulmonary problems. This study's results provide a framework for post-COVID-19 treatment, promoting focused, evidence-based ways to enhance rehabilitation and elevate the QoL for impacted individuals. This strategy mitigates the enduring effects of severe COVID-19 and equips the healthcare system with analogous issues in future pandemics.

Declarations statement

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Ethics approval and consent to participate

The author declared that the investigations were carried out following the rules of the Declaration of Helsinki of 1975, which was revised in 2013. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Shahrekord University of Medical Sciences (IR.SKUMS.REC.1399.254).

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

The study was planned with F.A, Z.H, F.A and E.Kh. The study was conducted with F.A, Z.H, and E.Kh. Moreover, Z.H, and E.Kh. approved the data collection. Interpretation of data was carried out by F.A, Z.H, F.A and E.Kh. The manuscript was drafted with F.A, Z.H, F.A and E.Kh. All authors have approved the final draft and agreed to submit the manuscript to this journal.

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Conflicts of interest

The authors have no conflicts of interest.

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