Pulmonary Function, Functional Capacity and Health Status in A Cohort of COVID-19 Survivors at 3 and 6 Months After Hospital Discharge

Original Article

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Abstract—Introduction. Coronavirus Disease 2019 is a multi-systemic disease and the lung is the organ most affected. Pulmonary function tests can help to determine the consequences of this disease. Our objective was to understand the impact of COVID-19 on pulmonary function, functional capacity and health status in a cohort of survivors. **Patients and methods.** A prospective longitudinal follow-up study of 53 COVID-19 patients was conducted at three and six months after discharge. The assessment included spirometry, lung volumes, pulmonary diffusion capacity, respiratory muscle strength, impulse oscillometry, 6-minute walk test and health-related quality-of-life ShortForm-36 questionnaire. **Results.** There were 35 male patients (66,0 %) with a mean age of 62,77 ± 14,03 years. Almost half of the patients (47,2 %) had persistent impaired pulmonary function. The most prevalent impairment was a combination of a restrictive pattern (30,2 % of the patients) and an impairment of diffusion capacity (28,3 % of the patients). Residual pulmonary function defects were still present at the 6-month evaluation, without significant improvement of lung function over this time, the exception was FVC mean which significantly improved at the 6-month evaluation. Considering the type of ventilatory support, there was no significant differences in lung function parameters, the exceptions were differences between groups regarding Rtot and R5 and R20 parameters. **Conclusions.** A significant proportion of COVID-19 survivors had impaired pulmonary function at 3-months after discharge and those residual defects were still present at the 6-month evaluation. Long term follow-up studies of lung function are important in COVID-19 survivors to evaluate whether these respiratory function sequelae persist over time. **Rev Med Clin 2021;5(2):e11052105023**

Keywords—COVID-19, lung function tests, non-invasive ventilation

Resumen—Función Pulmonar, Capacidad Funcional y Estado de Salud en Una Cohorte de Sobrevivientes de COVID-19 a los 3 y 6 Meses Después del Alta Hospitalaria

Introducción. La enfermedad por coronavirus 2019 es multisistémica y el pulmón es el órgano más afectado. El objetivo fue comprender el impacto del COVID-19 en la función pulmonar, la capacidad funcional y el estado de salud en una cohorte de sobrevivientes. **Pacientes y métodos.** Se realizó un estudio prospectivo longitudinal de 53 pacientes con COVID-19 a los tres y seis meses después del alta. La evaluación incluyó espirometría, volúmenes pulmonares, capacidad de difusión pulmonar, fuerza de los músculos respiratorios, oscilometría de impulsos, prueba de marcha de 6 minutos y cuestionario de calidad de vida. **Resultados.** Había 35 pacientes varones (66,0 %), edad media de 62,77 años. Casi la mitad de los pacientes (47,2 %) tenían una función pulmonar deteriorada persistente. El deterioro más prevalente fue una combinación de un patrón restrictivo (30,2 %) y um deterioro de la capacidad de difusión (28,3 %). Los defectos de la función pulmonar residual todavía estaban presentes en la evaluación de 6 meses, la excepción fue la media de FVC que mejoró significativamente. Considerando el tipo de soporte ventilatorio, no hubo diferencias significativas en los parámetros de función pulmonar, las excepciones fueron las diferencias entre grupos en cuanto a los parámetros Rtot y R5 y R20. **Conclusiones.** Una proporción significativa de los supervivientes de COVID-19 tenían una función pulmonar deteriorada a los 3 meses y esos defectos residuales todavia estaban presentes en la evaluación de los 6 meses. Los estudios de seguimiento a largo plazo de la función pulmonar son importantes para evaluar si estas secuelas de la función respiratoria persisten con el tiempo. **Rev Med Clin 2021;5(2):e11052105023**

Palabras clave—COVID-19, pruebas de función pulmonar, ventilación no invasiva

INTRODUCTION

Coronavirus Disease 2019 (COVID-19) is a highly contagious respiratory disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1–5] Is a multisystemic disease and the lung is the organ most affected.[4,6–8]

Data about pulmonary function following COVID-19 are scarce and it is imperative that long-terms studies of survivors be conducted in order to determine the persistence of abnormalities in pulmonary function and whether these abnormalities contribute to permanent functional sequelae.[7,9–14]

Pulmonary function tests can help to study the properties of the respiratory system and allow us to determine the consequences of the COVID-19 disease objectively.[4,7,15]

There are few reports in regard to pulmonary function in COVID-19 survivors, we decided to carry out a prospective follow-up study in order to better understand the impact of COVID-19 on pulmonary function, functional capacity and health status in a cohort of survivors, at 3 and 6 months after hospital discharge. We also want to know if there are differences between groups of COVID-19 patients in the different levels of care.

PATIENTS AND METHODS

Setting

This is a prospective longitudinal follow-up study of COVID-19 patients at three and six months after discharge from our hospital. The diagnosis of COVID-19 was based on the European Centre of Disease Prevention and Control (ECDC). All patients have had laboratory-confirmed SARS-CoV-2 infection by real-time reverse transcription polymerase chain reaction (RT-PCR) using nasal and pharyngeal swab specimens.

This study was approved by the institutional ethics committee of the Hospital Professor Doutor Fernando Fonseca, E.P.E. (register number 60/2020). Written informed consent was obtained from all patients prior to pulmonary function testing.

Patients and Study Design

From March 24, 2020 to July 30, 2020 a total of 158 COVID-19 patients were discharged from the Pulmonology ward. Patients were followed-up and evaluated at 3 and 6 months after hospital discharge.

During each visit, pulmonary function tests, respiratory muscle strength, impulse oscillometry, 6-minute walk test were performed. In addition, they completed a ShortForm-36 questionnaire (version 2, adapted) to measure health-related quality of life.

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Patients were eligible to participate in the study if they were over 18 years old with a confirmed diagnosis of COVID-19. Exclusion criteria were: previous mobility limitations, history of pulmonary resection; documented neurological or psychiatric disease; pregnancy; contraindications or inability to perform correctly the respiratory function tests included in the protocol; refusal to participate in the study.

Lung Function Tests and Respiratory Muscle Strength

Spirometry, lung volumes, pulmonary diffusion capacity and muscles measurements were conducted using MasterScreen Body^{TM} (CareFusion, Germany) system and impulse oscillometry was conducted using MasterScreen IOS^{TM} (CareFusion, Germany) system.

The pulmonary function tests were performed following the American Thoracic Society/European Respiratory Society (ATS-ERS) guidelines and measurements were expressed as percentages of predicted normal values.[16,17]

Recorded parameters were: Forced vital capacity (FVC), Forced expiratory volume in the first second (FEV1), FEV1/VCmax ratio, Total lung capacity (TLC), Residual volume (RV), Intrathoracic gas volume (ITGV), Total airway resistance (Rtot); Diffusing capacity of the lung for carbon monoxide measured by the single-breath method (DLco), Krogh factor (Kco). The hemoglobin value was also taken for correcting the DLco.

If obstruction was present, measurements were repeated 15 minutes after 400mcg of salbutamol administration. Impulse oscillometry system (IOS) was used to measure total airway resistance at an oscillation frequency of 5Hz (R5), central airway resistance at an oscillation of 5Hz(R20), Resonant frequency (Fres) and the reactance at 5Hz (X5). We considered a peripheral airway obstruction pattern if R5 >150 %pred, R20 <150 %pred, X5-X5pred >0,15KPa/L/s and a central airway obstruction pattern if R5 >150 %pred, R20 >150 %pred, X5-X5pred<0,15KPa/L/s.[18]

Measurements of the maximum static inspiratory pressure (PImax) and the maximum static expiratory pressure (PEmax) were performed by a mouth pressure meter via a flanged mouthpiece.

6-Minute Walk Test

We estimated the walking distance according to reference equations for the 6MWT in healthy Portuguese subjects. 19 We calculated the ratio of measured walking value of the patients to the predicted walking distance value of the healthy person in fair conditions. During the test we also measured the minimum peripheral oxygen saturation (SpO2min).

In our study we only performed the 6MWA at 3 months after discharge, because we no longer had the necessary safety conditions for its performance during the second wave of COVID-19 in October 2020.

Health-related quality of life questionnaire

Original SF-36 includes 8 multiple domains that globally assesses the self-reported health status. In our study only used the questions about general health perceptions (GH, 1 – great / 5 – weak), perceived change in health (CH, 1 – much better / 5 – much worse), physical functioning (PF, 10 – very limited / 30 – nothing limited), social functioning (SF, 1 – no interference / 5 – too much interference), vitality (VT, 4 – never / 20 - always) and mental health (MH, 5 – worse / 25 - best) domains.

Data Analysis

Statistical analysis was performed using Statistical Package for Social Science (SPSS) Version 27.0. Continuous variables were described using mean with standard deviation and categorical variables were described as percentage. For continuous variables of paired samples, paired-samples t-test was used to compare the mean difference of lung function parameters between 3 and 6-months evaluation; analysis of variance (ANOVA) was used for comparison of lung function parameters at 3-month visit, considering the type of ventilatory support (no mechanical ventilation support, non-invasive ventilation support and invasive ventilation support). All statistical tests were two tailed. Statistical significance was taken as p<0,05.

RESULTS

From March 24, 2020 to July 30, 2020 a total of 189 COVID-19 patients were admitted to the Pulmonology ward of our institution. Table 1 shows demographic and clinical characteristics of COVID-19 patients admitted. The mortality rate was 16,5 % (n=31). A total of 105 patients were excluded for reasons that are outlined in Figure 1.

Variable	Values
Age, years	64,7±15,7
Male sex, %	64,6
Lenght of hospitalization, days	20,7±14.1
Non-invasive ventilation, %	58,2
ICU admission (invasive ventilation), %	27,5
Length of mechanical ventilation, days	10,0±6,55
Mortality rate, %	16,4

TABLE 1: DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF COVID-19 PATIENTS ADMITTED FOR HOSPITALIZATION (N = 189). DATA ARE EXPRESSED AS MEAN (± SD) OR NUMBER, UNLESS OTHERWISE INDICATED.

At last, 53 patients completed both visits and the serial assessments in the study. There were 35 male patients (66,0 %) with a mean age of 62,77 ± 14,03 years (age range, 23 to 90 years). An overview of the serial lung function tests results for the group at 3 and 6-month evaluation is shown in Table 2.

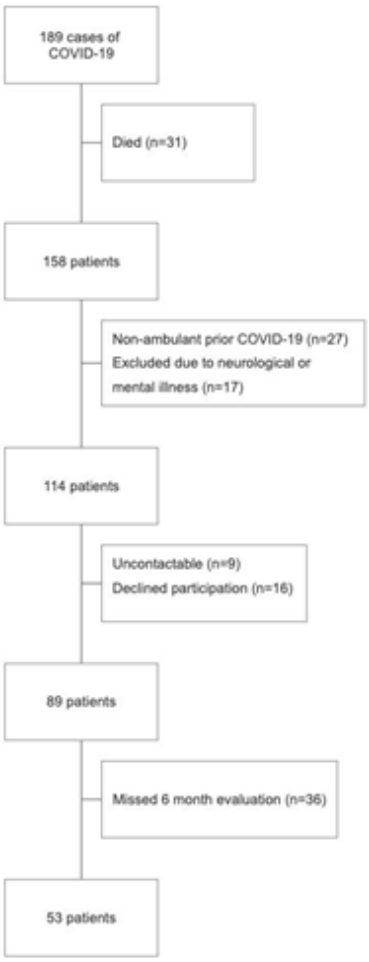

Figure 1: Enrollment of COVID-19 patients and follow up at 3 and 6 months after hospital discharge.

Lung Function Test

Lung function tests were uneventfully completed in all patients.

At 3-month visit, up to 47,2 % (n=25) patients had spirometry and lung volumes alterations. We found 16 patients (30,2 %) with restrictive pattern, 4 patients (7,5 %) with obstructive pattern, 1 patient (1,9 %) with mixed pattern and 4 patients (7,5 %) with elevated total airway resistance.

Of the four patients with obstructive pattern, one had history of poorly controlled asthma and the others three patients had a significant history of cigarette smoking. None of the obstructive patients had a positive bronchodilator test.

Impairment of DLco was found in 28,3 % of patients (n=15). According to ATS/ERS criteria of severity of DLco impairment, 10 patients (19 %) had mild, 4 patients (8 %) had moderate and 1 patient (2 %) had severe impairment.

Parameter	3 months	6 months	Mean difference
FVC (% predicted)	93,30 (16,37)	97,19 (18,21)	p-value=0,003*
FEV1 (% predicted)	94,89 (19,71)	97,91 (20,46)	p-value=0,06
FEV1/VCmax	78,53 (8,29)	78,15 (8,47)	p-value=0,564
TLC (% predicted)	88,58 (12,64)	89,53 (12,206)	p-value=0,250
RV (% predicted)	87,96 (21,67)	84,64 (22,88)	p-value=0,103
ITGV (% predicted)	91,15 (17,62)	90,40 (17,44)	p-value=0,458
RTot (kPa/L/seg)	0,25 (0,13)	0,26 (0,11)	p-value=0,602
DLco (% predicted)	79,74 (16,33)	81,74 (18,34)	p-value=0,120
DLco/VA (% predicted)	97,45 (20,14)	97,57 (19,51)	p-value=0,937
PImax (% predicted)	84,04 (32,66)	80,75 (28,35)	p-value=0,815
PEmax (% predicted)	83,43 (31,36)	75,06 (31,22)	p-value=0,098
R5 (% predicted)	127,75 (50,00)	130,44 (45,77)	p-value=0,859
R20 (% predicted)	99,30 (28,20)	99,08 (29,84)	p-value=0,794
X5(kPa/L/seg)	-0,137 (0,11)	-0,137 (0,09)	p-value=0,962
X5-X5predicted (kPa/L/seg)	0,108 (0,09)	0,104 (0,07)	p-value=0,509
Fres (Hz)	18,28 (5,36)	17,58 (5,03)	p-value=0,172

TABLE 2: RESULTS OF SERIAL PULMONARY FUNCTION TESTS FOR THE GROUP OF SURVIVORS AT 3 AND 6-MONTH EVALUATION. DATA ARE EXPRESSED AS MEAN (SD). FVC, FORCED VITAL CAPACITY; FEV1, FORCED EXPIRATORY VOLUME IN THE FIRST SECOND; TLC, TOTAL LUNG CAPACITY; RV, RESIDUAL VOLUME; ITGV, INTRATHORACIC GAS VOLUME; RTOT, TOTAL AIRWAY RESISTANCE; DLCO, DIFFUSING CAPACITY OF THE LUNG FOR CARBON MONOXIDE; KCO, CARBON MONOXIDE FACTOR ADJUSTED FOR HEMOGLOBIN; IOS, IMPULSE OSCILLOMETRY SYSTEM; R5, TOTAL AIRWAY RESISTANCE AT AN OSCILLATION FREQUENCY OF 5HZ; R20, CENTRAL AIRWAY RESISTANCE AT AN OSCILLATION OF 5HZ; FRES, RESONANT FREQUENCY; X5, REACTANCE AT 5HZ; PIMAX, MAXIMUM STATIC INSPIRATORY PRESSURE; PEMAX, MAXIMUM STATIC EXPIRATORY PRESSURE. * P-VALUE <0,05

Regarding respiratory muscle strength 20,8 % patients (n=11) had reduction in PImax and/or PEmax. Four patients (7,5 %) failed to perform the maneuver.

Normal impulse oscillometry parameters were found in 39 patients (73,6 %), 20,8 % of patients (n=11) showed a peripheral airway obstruction pattern, and 5,7 % of patients (n=3) showed a central airway obstruction pattern.

At 6-month evaluation we also found 47,2 % (n=25) patients with spirometry and lung volumes alterations. We found 13 patients (24,5 %) with restrictive pattern, 3 patients (5,7 %) with obstructive pattern, 1 patient (1,9 %) with mixed pattern and 8 patients (15,1 %) with elevated total airway resistance. None of the obstructive patients had a positive bronchodilator test.

Impairment of DLco was also found in 28,3 % of patients (n=15).

Regarding the severity of DLco impairment, 11 patients (21 %) had mild, 3 patients (6 %) had moderate and 1 patient (2 %) had severe impairment.

Regarding respiratory muscle strength 28,3 % patients (n=15) had reduction in maximal inspiratory pressure and/or maximal inspiratory pressure.

Normal impulse oscillometry parameters were found in 38 patients (73,1 %), 23,1 % of patients (n=12) showed a peripheral airway obstruction pattern, and 3,8 % of patients (n=2) showed a central airway obstruction pattern.

Table 2 shows the mean difference of lung function parameters between 3 and 6-months evaluation. Overall, no significant differences were found over this period in FEV1, FEV1/VCmax ratio, TLC, RV, ITGV, Rtot, DLco, Kco, PImax, PEmax, R5, R20, X5 and Fres. We did not find any significant improvement in lung function parameters, except for FVC, which significantly improved at the 6-month evaluation (p<0,05).

When considering only the patients with DLco impairment (28,3 %, n=15) or restrictive pattern (30,2 %, n=16) at 3-month evaluation, there was still no significant difference in those parameters in the 6-month evaluation (p =0,88 and p=0,10, respectively).

Among the 53 patients who completed both visits, 15 (28,3 %) did not need mechanical ventilation support, 22 patients (41,5 %) required non-invasive mechanical ventilation and 16 patients (30,2 %) required invasive mechanical ventilation.

When non-invasive ventilation was used, continuous positive airway pressure (CPAP) was the preferred mode (in 90,7 % of cases) and bilevel positive airway pressure was used in the remaining cases.

Table 3 shows the comparison of lung function parameters at 3-month visit, considering the type of ventilatory support. No significant differences between the three groups were found regarding to FVC, FEV1, FEV1/VCmax ratio, TLC, RV, ITGV, DLco, Kco, PImax, PEmax, X5 and Fres.

However, we found difference in Rtot between those who did not need mechanical ventilation and those who needed

Parameter	No ventilation support (28,3 %, n=15)	Non-invasive ventilation (41,5 %, n=22)	Invasive ventilation (30,2 %, n=16)	ANOVA (F)	P value
FVC (% predicted)	88,07 (18,95)	95,05 (17,69)	95,81 (10,83)	1,083	0,346
FEV1 (% predicted)	86,80 (16,37)	97,45 (21,43)	98,94 (19,72)	1,846	0,169
FEV1/VCmax	76,14 (9,59)	79,51 (7,49)	79,42 (8,11)	0,869	0,426
TLC (% predicted)	89,73 (15,24)	90,18 (13,52)	85,31 (8,07)	0,766	0,470
RV (% predicted)	95,80 (24,80)	90,00 (20,16)	77,81 (17,55)	3,056	0,056
ITGV (% predicted)	97,73 (20,28)	89,59 (18,53)	87,13 (12,13)	1,586	0,215
RTot (kPa/L/seg)	0,32 (0,18)	0,26 (0,10)	0,18 (0,06)	5,266	0,008*
DLco (% predicted)	77,73 (13,43)	84,68 (17,27)	74,82 (16,59)	1,914	0,158
DLco/VA (% predicted)	95,87 (17,93)	102,00 (16,62)	92,69 (25,73)	1,058	0,355
PImax (% predicted)	80,00 (33,72)	87,19 (31,51)	83,13 (35,12)	0,196	0,823
PEmax (% predicted)	80,23 (38,10)	87,76 (30,09)	80,13 (28,01)	0,341	0,713
R5 (% predicted)	128,93 (49,07)	147,18 (53,20)	99,94 (32,85)	4,734	0,013*
R20 (% predicted)	99,00 (23,29)	112,59 (27,98)	81,31 (23,48)	7,016	0,002*
X5(kPa/L/seg)	-0,129 (0,09)	-0,155 (0,147)	-0,119 (0,77)	0,501	0,609
X5-X5predicted (kPa/L/seg)	0,097 (0,078)	0,1282 (0,111)	0,091 (0,061)	0,962	0,389
Fres (Hz)	19,85 (6,45)	18,22 (5,55)	16,87 (3,64)	1,207	0,308

Table 3: Comparison of lung function parameters at 3-month evaluation of patients who did not need mechanical ventilation support versus those who had required non-invasive mechanical ventilation and those who needed mechanical ventilation. Data are expressed as mean (SD). FVC, Forced vital capacity; FEV1, Forced expiratory volume in the first second; TLC, Total lung capacity; RV, Residual volume; ITGV, Intrathoracic gas volume; RTot, Total airway resistance; DLco, Diffusing capacity of the lung for carbon monoxide; Kco, Carbon monoxide factor adjusted for hemoglobin; IOS, Impulse oscillometry system; R5, total airway resistance at an oscillation frequency of 5Hz; R20, central airway resistance at an oscillation of 5Hz; Fres, Resonant frequency; X5, Reactance at 5Hz; PImax, maximum static inspiratory pressure; PEmax, maximum static expiratory pressure. * P-value <0,05

invasive mechanical ventilation (p=0,008) and a difference in R5 and R20 between those requiring non-invasive mechanical ventilation and invasive mechanical ventilation (p=0,013 and p=0,002, respectively).

6MWT

6MWT was performed in 72 % of the patients (n=38) and the mean SpO2min measured was 94,5 %±2,1 %. Only one patient had significant hypoxemia (SpO2<88 %) after the test.

The mean of the predicted walking distance ratio in all subjects were 105,76 % ± 28,87 %.

Stratifying by different severity groups, there were no significant differences in mean SpO2min and mean of the predicted walking distance between those who did not need mechanical ventilation support and those who had required invasive or non-invasive mechanical ventilation support (p=0,795 and p=0,782, respectively).

Health-related quality of life among COVID-19 survivors

Health-related quality of life scores among COVID-19 survivors at 3 and 6 months after discharge are shown in Figure 2.

There were no significant differences between the 3 and 6-month evaluation regarding the means differences of the six SF-36 domain scores: GH (3,14 Vs 3,12; p=0,878), CH (2,90 Vs 2,83; p=0,520), PF (24,66 Vs 24,67; p=0,820), SF (1,64 Vs 1,54; p=0,411), VT (14,58 Vs 15,02; p=0,293) and MH (19,80 Vs 20,67; p=0,087).

Considering the type of ventilatory support, there were no significant differences in the scores regarding the six domains in study between these patients who did not need mechanical ventilation support and those who had required invasive or non-invasive mechanical ventilation support (p>0,05).

Discussion

The main findings of this prospective study are:

1. Almost half of the COVID-19 patients (47,2 %) had persistent impaired pulmonary function.
2. The most prevalent pulmonary function impairment was a combination of a restrictive pattern (observed in 30,2 % of the patients) and an impairment of diffusion

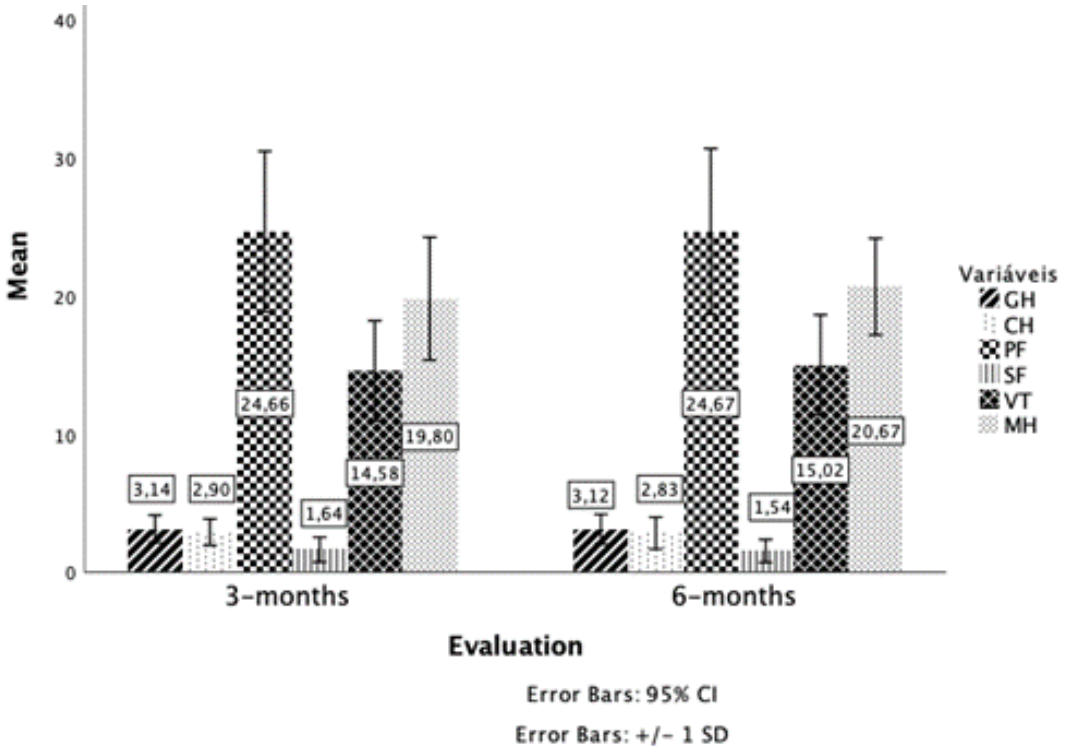

Figure 2: Health-related quality of life scores (Short Form General Health Survey-SF36, adapted) among COVID-19 survivors at 3 and 6 months after discharged. The vertical axis represents the mean SF domain score and the horizontal axis defines the 3 and 6-months evaluation. GH, general health; CH, perceived change in health; PF, physical functioning; SF, social functioning; VT, vitality; MH, mental health.

capacity (observed in 28,3 % of the patients). The impairment was mild in almost all cases.

3. Residual pulmonary function defects were still present at the 6-month evaluation, without significant improvement of lung function over this time (all the parameters remained static during the study period, the exception was FVC mean which significantly improved at the 6-month evaluation).

4. Besides some significant differences between groups regarding Rtot and R5 and R20 parameters, there was still no significant differences in others lung function parameters considering the type of ventilatory support.

The persistent impaired lung function in a significant proportion of COVID-19 survivors 6-months after discharge suggest that these abnormalities are more likely to persist in the long term. This is important, not only for the long-term follow-up of these patients, but also as a highlight of the permanent respiratory impairment that can result from the SARS-CoV-2 infection.

Preliminary evidence suggests impaired lung function in COVID-19 could last for several months or even years.[3,7] The literature on previous coronavirus infection, such as SARS and MERS, suggests that patients may experience persistent impairment lasting for months or even years after discharge.[1,4,10,20]

Nusair et al. recently suggested that low DLco in COVID-19 patients is caused mainly by reduced alveolar volume and not residual interstitial lung abnormalities or pulmonary vascular abnormalities, a finding that is consistent with the observation of a preserved Kco in our study.[12]

The result of autopsy of COVID-19 patients showed interstitial lung inflammation, alveolar inflammatory cell infiltration, fibrous hyperplasia, alveolar hyaline membrane formation and alveolar structure destruction. These pathological changes may result not only to impaired DLco but also in the decrease in lung compliance, which may explain the restrictive ventilatory dysfunction.[10,13,20,21]

Further studies are imperative in determining whether the abnormalities persist and contribute to permanent impairment and disability.[1,4,10,20]

Abnormal lung function tests raise concern regarding potential progression toward lung fibrosis. Isolated DLco impairment may also lead to the hypothesis of a vascular damage induced by the virus.[8,22,23] However, whether survivors of COVID-19 with pulmonary function impairment develop pulmonary fibrosis requires long-term follow-up.[3,17,24–26]

The restrictive abnormality of lung function of COVID-19 patients might have been partially due to respiratory muscle weakness, as reflected by persistent decreased PImax and PEmax values at 3 and 6 months after discharge (20,8 %

and 28,3 % respectively). Weakness of the expiratory muscles could lead to air trapping, whereas inspiratory muscle weakness may lead to atelectasis.[4,9–11]

Several reasons for muscle weakness were suggested, including viral-induced myositis, muscle wasting and deconditioning due to prolonged bed rest, steroid myopathy and critical illness associated poly-neuropathy or myopathy.[4,9–11]

The 6MWT was performed at 3-month assessment to evaluate the global responses to exercise. This test does not provide specific information on the function of individual organs and systems. The poor performance in 6MWT could be due to additional factor such as muscle wasting, steroid myopathy and possibly cardiac diastolic dysfunction.[10] Two previous studies have shown that 6MWT was substantially lower among ARDS survivors than controls 1-2 years after mechanical ventilation, but in our study only one patient had significant alterations in 6MWT.[10]

There are several limitations to this study: 1) only 60 % of the COVID-19 survivors completed the 6-months evaluation and there may be a bias towards selection of sicker patients with abnormal pulmonary function; 2) we had no patient's baseline pulmonary function results before COVID-19; 3) we assessed muscle strength by mouth pressure, low values might result from technical difficulties such as mouth leakage; 4) we did not perform cardiopulmonary exercise testing, as a result, the extra-pulmonary factors could not be measured; 5) we did not include length of invasive ventilation as a potential independent factor for lung function after COVID-19.

Conclusion

In summary, a significant proportion of COVID-19 survivors had impaired pulmonary function at 3-months after discharge and those residual defects were still present at the 6-month evaluation. The most prevalent pulmonary function impairment was a combination of a restrictive pattern and an impairment of diffusion capacity. Impaired respiratory muscle strength were detected in more than 20 % of the recovered COVID-19 patients.

Long term follow-up studies of lung function are important in COVID-19 survivors to evaluate whether these respiratory function sequelae persist over time. Our study helps to improve the characterization of COVID-19 patients and the respiratory function limitations generated by this disease over time.

Founding

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Conflicts of interest

The authors have no conflicts of interest to declare.

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