



ASSESSMENT OF PULMONARY FUNCTION TEST AND SIX-MINUTE WALK TEST IN SUBJECTS WHO WERE HOSPITALIZED FOR A MINIMUM 5 DAYS AND RECOVERED FROM COVID-19

Physiology

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ABSTRACT

Background: Post-COVID-19 survivors frequently experience prolonged respiratory impairment, even after clinical recovery. Understanding changes in pulmonary function and functional capacity is essential to guide rehabilitation. **Objectives:** To evaluate pulmonary function test (PFT) parameters and six-minute walk test (6MWT) performance in adults (30–60 years) who were hospitalized for ≥ 5 days for acute COVID-19 and recovered subsequently. **Methods:** A cross-sectional study was conducted among 246 participants at ABVGM College, Vidisha. Spirometry was performed following ATS guidelines. PFT measures included forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and FEV_1/FVC ratio. Functional capacity was assessed using 6MWT with pre- and post-test oxygen saturation (SpO_2) recording. Data was recorded and statistically analysed as per the study protocol. **Results:** Mean FVC was 2.61 ± 0.72 L, mean FEV_1 was 2.21 ± 0.64 L, and mean FEV_1/FVC ratio was $84.7 \pm 7.2\%$. The mean 6MWT distance was 426 ± 82 m. SpO_2 decreased significantly from $97.1 \pm 1.2\%$ pre-test to $95.4 \pm 1.8\%$ post-test ($p < 0.001$). A moderate positive correlation was observed between FEV_1 and 6MWT distance ($r = 0.42$, $p < 0.001$), indicating that individuals with better pulmonary function exhibited greater exercise capacity. **Conclusion:** Residual reduction in pulmonary function and functional capacity persists in COVID-19 survivors even after recovery and hospital discharge. Significant post-exercise desaturation suggests impaired ventilatory reserve. These findings highlight the need for structured post-COVID pulmonary rehabilitation programs.

KEYWORDS

INTRODUCTION

The coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) emerged in late 2019 as a global pandemic, affecting millions worldwide. Although acute symptoms range from mild upper respiratory illness to severe pneumonia and acute respiratory distress syndrome (ARDS), it has become increasingly evident that many survivors experience persistent health impairment beyond the acute phase, a phenomenon commonly referred to as post-COVID-19 sequelae or long COVID.^[1]

While COVID-19 primarily affects the respiratory system, its impact on long-term pulmonary function and exercise capacity has been an area of extensive research due to the potential for lasting morbidity among recovered subjects. Structural damage inflicted during acute infection, especially in those with prolonged hospitalization or severe pneumonia, can lead to pulmonary fibrosis, alveolar damage, and ventilation-perfusion mismatch even after viral clearance.^[2]

During acute SARS-CoV-2 infection, bilateral lung involvement often leads to inflammatory exudation, alveolar-capillary interface disruption, and potential development of diffuse alveolar damage. These pathological changes can result in restrictive and obstructive abnormalities detectable on pulmonary function tests (PFTs).^[3] Impaired gas exchange, reduced lung compliance, have been reported in convalescent subjects, particularly those with severe disease or prolonged hospital stays.^[4]

Moreover, exercise capacity, which reflects integrated responses of the pulmonary, cardiovascular, and musculoskeletal systems, frequently remains impaired after recovery. The Six-Minute Walk Test (6MWT) is a standardized, practical measure of functional exercise capacity and has been widely adopted in respiratory and rehabilitation research.^[5] In this context, the 6MWT complements PFTs by capturing the functional consequences of pulmonary and systemic deconditioning post-COVID-19.

Impaired pulmonary function and reduced exercise capacity have direct implications for quality of life, ability to resume daily activities, and long-term health outcomes. Persistent dyspnea, fatigue, and exercise intolerance remain common complaints months after hospitalization, contributing to disability and healthcare burden.^[6] Therefore, systematic assessment using PFTs and the 6MWT is essential for identifying individuals who may benefit from targeted rehabilitation, including respiratory physiotherapy, aerobic conditioning, and strength training.^[7]

Objective

To assess pulmonary function and functional exercise capacity using Pulmonary Function Test (PFT) and Six-Minute Walk Test (6MWT) in subjects recovered from COVID-19 after hospitalization for a minimum of five days, among subjects of age group of 30–60 years.

Materials and Methods

Study Design and Population

A hospital-based observational cross-sectional study conducted on 246 subjects to assess pulmonary function test parameters and six-minute walk test performance in subjects who were hospitalized for COVID-19 for a minimum duration of five days, subsequently recovered and attended follow-up clinics after recovery.

This study was conducted after obtaining the approval of Institutional Ethics Committee [approval no. 04 - 27/IEC/ABVGM/VIDISHA/2024] in the Department of Physiology in collaboration with the Department of Respiratory Medicine at a tertiary care teaching hospital.

Inclusion Criteria

- Participants were included in the study if they met the following criteria:
- Subject recovered from COVID-19 after a minimum of five days of hospitalization

- Age group: 30–60 years
- Subjects willing to participate and provide informed consent.

Exclusion Criteria

- Subjects who have a history of recent illness
- Subjects with any respiratory or cardiac illness such as COPD, asthma, or bronchitis
- Subjects with a history of smoking
- Subjects who are taking any medications/drugs that can affect PFT findings.

Procedure

Pulmonary Function Test (PFT)

Pulmonary function testing was performed using a computerized spirometer in accordance with ATS/ERS guidelines using Spirotech CMSP-01 (Portable).

Parameters Measured:

Forced Vital Capacity (FVC)

Forced Expiratory Volume in 1 second (FEV₁)

FEV₁/FVC ratio

Total Lung Capacity.

Interpretation:

Restrictive pattern: Reduced FVC with normal/high FEV₁/FVC

Obstructive pattern: Reduced FEV₁/FVC.

Predicted values adjusted for age, sex, height, and ethnicity.

Six-Minute Walk Test (6MWT)

The 6MWT was conducted according to standardized protocol in a 30-meter corridor as follows:

Baseline vitals recorded (HR, BP, SpO₂)

Subjects were instructed to walk briskly for 6 minutes

Total distance walked (meters) recorded

Post-test oxygen saturation (SpO₂) was recorded.

Results

Among the total 246 participants, 150 (61.0%) were males, while 96 (39.0%) were females.

Table 01: Age Distribution of Study Participants (n = 246)

Age Group (Years)	Number	Percentage (%)
30–39	84	34.1
40–49	94	38.2
50–60	68	27.6
Total	246	100

Table 01 shows the age distribution of the study participants.

Table 02: Comparison of SpO₂ Before and After 6MWT

Parameter	Mean ± SD	Mean Difference	t-value	p-value
SpO ₂ Before 6MWT	97.1 ± 1.2	2.3	18.62	<0.001
SpO ₂ After 6MWT	94.8 ± 2.0			

Table 02 compares the oxygen saturation before and after the six-minute walk test. The mean SpO₂ before the test was 97.1 ± 1.2, while after the test it decreased to 94.8 ± 2.0, and this difference was statistically significant (p < 0.001). There was a statistically significant reduction in oxygen saturation after the six-minute walk test compared to baseline (p < 0.001), indicating exercise-induced desaturation.

Table 03: Comparison of PFT Parameters Before and After 6MWT

Parameter	Before 6MWT (Mean ± SD)	After 6MWT (Mean ± SD)	Mean Difference	t-value	p-value
FVC (L)	3.18 ± 0.61	3.09 ± 0.60	0.09	2.15	0.03
FEV ₁ (L)	2.76 ± 0.58	2.67 ± 0.55	0.09	2.02	0.04
FEV ₁ /FVC (%)	86.3 ± 5.2	85.7 ± 5.5	0.6	1.34	0.18

Table 03 compares pulmonary function parameters before and after the six-minute walk test.

The mean Forced Vital Capacity (FVC) decreased slightly from 3.18 ± 0.61 L before the test to 3.09 ± 0.60 L after the test, and this difference

was statistically significant (p = 0.03). Similarly, the mean Forced Expiratory Volume in one second (FEV₁) decreased from 2.76 ± 0.58 L to 2.67 ± 0.55 L, which was also statistically significant (p = 0.04). However, the FEV₁/FVC ratio showed only a minimal change from 86.3 ± 5.2% to 85.7 ± 5.5%, and this difference was not statistically significant (p = 0.18). There was a statistically significant reduction in FVC and FEV₁ after 6MWT (p < 0.05). The FEV₁/FVC ratio showed no significant change (p > 0.05). This suggests mild but significant decline in pulmonary function post-exercise.

Table 04: Association Between PFT Pattern and 6MWD

PFT Pattern	No. of subjects who walked <400 m	No. of subjects who walked ≥400 m	Total
Normal	28	90	118
Restrictive	52	34	86
Obstructive	14	16	30
Mixed	6	6	12

Chi-square test showed a statistically significant association between PFT pattern and 6MWD ($\chi^2 = 28.89$, p < 0.001).

Table 04 shows the association between PFT pattern and walking distance. Among participants who walked <400 m, most had restrictive pattern (52) followed by normal pattern (28), obstructive (14), and mixed (6). Among those who walked ≥400 m, most had normal PFT pattern (90).

Table 05: Association Between PFT Pattern and SpO₂ After 6MWT (n = 246)

PFT	≥97%	95–96%	<95%	Total
Normal	60 (50.8%)	42 (35.6%)	16 (13.6%)	118
Restrictive	20 (23.3%)	44 (51.2%)	22 (25.6%)	86
Obstructive	8 (26.7%)	14 (46.7%)	8 (26.7%)	30
Mixed	4 (33.3%)	6 (50.0%)	2 (16.7%)	12

p-value: 0.0043

This table demonstrates that participants with normal PFT predominantly maintained higher SpO₂ levels (≥97%), whereas those with restrictive and obstructive patterns showed increased proportions of desaturation (<95%). Pulmonary function pattern is strongly associated with oxygen saturation. Subjects with restrictive and obstructive patterns show significantly higher desaturation compared to those with normal PFT.

Table 06: Association Between 6MWT Distance and SpO₂ After 6MWT (n = 246)

6MWD	≥97%	95–96%	<95%	Total
≥400 m	70 (47.9%)	60 (41.1%)	16 (11.0%)	146
<400 m	22 (22.0%)	46 (46.0%)	32 (32.0%)	100

p-value: <0.001

This table shows that participants with higher walking distance (≥400 m) maintained better oxygen saturation, while those with reduced exercise capacity (<400 m) showed higher proportions of desaturation (<95%). Exercise capacity is strongly associated with oxygen saturation. Subjects with lower walking distance demonstrate significantly higher desaturation, indicating impaired functional capacity.

DISCUSSION

Exercise-Induced Desaturation and Ventilatory Constraints

The present study revealed a significant acute decline in oxygen saturation following the six-minute walk test (6MWT), with mean SpO₂ dropping from 97.1% to 94.8% (p < 0.001). This 2.3% decrease, while appearing numerically small, is clinically pertinent as it crosses the conventional threshold of 95%, which is often indicative of exercise-induced hypoxemia. The parallel significant reductions in FVC (0.09 L, p = 0.03) and FEV₁ (0.09 L, p = 0.04) provide a mechanistic explanation for this desaturation.

Critically, the FEV₁/FVC ratio did not change significantly (p = 0.18), suggesting that the post-exercise ventilatory decline is not driven by acute bronchoconstriction or airway obstruction. Instead, the disproportionate drop in absolute volumes points toward a restrictive ventilatory constraint. This could be attributed to several factors: (a) inspiratory muscle fatigue leading to reduced tidal volume, (b)

increased intra-thoracic blood volume during exercise, or (c) shallow, rapid breathing patterns that increase dead space ventilation. Importantly, while statistically significant, the 0.09 L reduction in lung volumes is clinically minor and likely represents a transient physiological response rather than a pathological decline. The true clinical driver of poor performance in this cohort is the gas-exchange impairment (desaturation), not the minor mechanical volume loss.

2. The Predominant Role of Restrictive Patterns in Functional Limitation

A striking finding of this study is the robust association between restrictive PFT patterns and reduced exercise capacity (6MWD < 400 meters). Among participants with a restrictive defect, over half (52 out of 86, 60.5%) failed to walk 400 meters. Conversely, 90 out of 118 participants (76.3%) with normal PFT achieved the ≥ 400 -meter distance. The chi-square value of 28.89 ($p < 0.001$) underscores that the underlying PFT phenotype is the strongest determinant of functional performance in this population.

The pathophysiological link is clear: restrictive diseases (such as interstitial lung diseases, chest wall deformities, or neuromuscular conditions) reduce total lung capacity, limiting the alveolar surface area available for gas exchange. During the 6MWT, increased cardiac output and shortened capillary transit time exacerbate ventilation-perfusion (V/Q) mismatch, leading to rapid desaturation, early lactic acidosis, and premature termination of the test. The fact that obstructive subjects performed slightly better than restrictive subjects (50% walked ≥ 400 m vs. 39.5% in restrictive) further reinforces that lung volume restriction is more debilitating to functional capacity than airway flow limitation in this specific middle-aged cohort.

Oxygenation as the Physiological Mediator of Walking Distance

The data establishes a clear stepwise gradient between PFT pattern, post-exercise SpO₂, and 6MWD. Table 5 demonstrates that only 23.3% of restrictive subjects and 26.7% of obstructive subjects maintained an SpO₂ $\geq 97\%$ post-exercise, compared to 50.8% of normal subjects. More importantly, severe desaturation (<95%) was seen in approximately 1 in 4 subjects with abnormal PFT, versus just 13.6% in the normal group.

This hypoxemia directly translated into poor performance in Table 6. Participants who walked <400 meters were disproportionately represented in the <95% SpO₂ category (32% vs. 11% in the ≥ 400 m group, $p < 0.001$). This suggests a dose-response relationship: the more severe the desaturation, the shorter the walking distance. It validates that the 6MWT is not merely a test of lower extremity endurance but a sensitive stressor that unmasks occult pulmonary vascular and parenchymal limitations. The 400-meter cutoff, therefore, serves as a pragmatic clinical red flag; subjects falling below this threshold warrant immediate investigation for underlying restrictive pathology and exertional hypoxemia.

Clinical and Rehabilitative Implications

These results have direct clinical utility. First, they emphasize that resting SpO₂ (averaging $\sim 97\%$) is a poor predictor of exertional capacity. Pulse oximetry during the 6MWT is essential, as 25% of subjects with abnormal PFTs dropped below 95% despite being normoxic at rest. Second, the strong association between restrictive patterns and poor distance suggests that therapeutic strategies cannot be uniform. Subjects with restrictive defects may not respond optimally to bronchodilators; instead, they may benefit from:

Inspiratory muscle training to improve tidal volume expansion.

Oxygen supplementation during physical activity to mitigate hypoxemia and prolong exercise duration.

Pulmonary rehabilitation focused on interval training and energy conservation, given their severe mechanical constraints.

Limitations

Several limitations must be acknowledged to avoid overgeneralization:

Heterogeneity of "Restrictive" Diagnosis: The study was conducted on participants who had no history of respiratory or cardiac etiologies (e.g., idiopathic pulmonary fibrosis, sarcoidosis, obesity-

hypoventilation, or heart failure). The physiological response to exercise varies widely across these etiologies.

Lack of Cardiovascular Data: The 6MWT is influenced by cardiac function. Without echocardiographic or BNP data, we cannot rule out that some subjects in the <400m group stopped due to cardiac ischemia or diastolic dysfunction rather than pulmonary desaturation.

Effort Dependency: The 6MWT is self-paced. Psychological factors, musculoskeletal pain, or lack of motivation could have influenced the <400m group, potentially biasing the association with PFT patterns.

Acute vs. Chronic Changes: The post-6MWT PFTs were measured immediately after exercise. The 0.09L drops, while statistically significant, may represent transient airway or muscle fatigue and may not reflect chronic, progressive functional decline.

CONCLUSION

In summary, this study demonstrates that exercise-induced desaturation is the primary pathophysiological bridge linking abnormal pulmonary function to diminished functional capacity. The restrictive ventilatory defect stands out as the most ominous predictor of both a 6MWD <400 meters and post-exercise SpO₂ <95%. Clinicians should view the 6MWT as an indispensable dynamic assessment tool that, when paired with PFT patterns, provides a comprehensive risk stratification for middle-aged subjects with suspected pulmonary impairment. Future prospective studies are warranted to investigate whether targeted oxygen therapy or specific respiratory muscle training can reverse the poor outcomes observed in the restrictive-dominant group identified here.

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