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Spirometric Evaluation of Pulmonary Function Among Adults Who Have Recovered from COVID-19 Infection: A Cross-Sectional Study from Eastern India

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) primarily targets the respiratory system, and growing evidence suggests that pulmonary sequelae may persist beyond the acute phase. Quantifying residual lung impairment in the convalescent phase is essential for designing post-recovery care, yet data from the eastern Indian population remain limited.

Objective: To evaluate residual pulmonary function abnormalities in adults who had recovered from COVID-19 and to determine the association of any impairment with age, comorbidities, smoking status, body mass index (BMI), severity indicators, and disease duration.

Methods: This descriptive cross-sectional study was conducted in the Department of Physiology, Murshidabad Medical College and Hospital, West Bengal, between December 2022 and December 2023. Ninety adult residents (≥18 years) of Murshidabad district who had previously tested positive for COVID-19 were enrolled by purposive sampling. Spirometry was performed using a calibrated digital Spirowin spirometer (Genesis Medical Systems Pvt. Ltd.), following American Thoracic Society (ATS) acceptability and repeatability criteria. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, forced expiratory flow at 25–75% of FVC (FEF25–75%) and peak expiratory flow rate (PEFR) were recorded. Anthropometric and clinical data, including the Post-COVID-19 Functional Status (PCFS) scale and SpO2, were also captured. Data were analysed using SPSS version 20; $p < 0.05$ was considered statistically significant.

Results: The mean age of participants was 41.3 years; 53.3% were male. Mean spirometric values were: FVC 3.54 ± 0.84 L, FEV1 2.91 ± 1.71 L, FEV1/FVC 83.0 ± 5.23%, FEF25–75% 2.81 ± 0.65 L/s, and PEFR 6.52 ± 1.22 L/s. Pulmonary function declined significantly with advancing age (FEV1 $p = 0.04$; PEFR $p = 0.03$), in smokers compared with non-smokers (all parameters $p \leq 0.04$), and in participants with pre-existing pulmonary disease (FVC $p = 0.04$; FEV1 $p = 0.03$). Comorbidities (diabetes mellitus, hypertension, dyslipidaemia), underweight status, hospitalisation, lower SpO2, longer disease duration (>20 days), and higher PCFS scores were each independently associated with lower spirometric values ($p < 0.05$). A male-versus-female difference reached statistical significance only for PEFR ($p = 0.02$).

Conclusion: A substantial proportion of COVID-19 survivors continued to exhibit measurable spirometric impairment after recovery. Older age, smoking, comorbidities, prior pulmonary disease, hospitalisation, hypoxaemia during acute illness, and prolonged disease duration were the principal determinants of residual lung dysfunction. Routine post-COVID spirometric surveillance and

individualised pulmonary rehabilitation are recommended, particularly for higher-risk subgroups.

Keywords*: COVID-19; post-COVID sequelae; Pulmonary function test; Spirometry; FEV1; FVC; PEFR; India.*

INTRODUCTION

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), first emerged in Wuhan, China, in December 2019 and rapidly evolved into a global pandemic [1]. Although SARS-CoV-2 can affect multiple organ systems, the lung remains the principal target, with pathological features such as diffuse alveolar epithelial damage, hyaline membrane formation, capillary disruption, alveolar septal fibrous proliferation, and pulmonary consolidation having been described in the acute phase [2,3].

While most patients recover symptomatically within two to six weeks of infection, an increasing body of evidence indicates that respiratory symptoms and measurable lung function abnormalities may persist for weeks to months after the resolution of acute illness [4,5]. Restrictive ventilatory defects, reduced diffusing capacity for carbon monoxide (DLCO), and persistent imaging abnormalities have been reported in survivors of severe and even mild disease [6,7]. Circulating biomarkers of neutrophilic activation, alveolar epithelial injury, and pro-fibrotic signalling remain elevated in convalescents and correlate with impaired pulmonary function [8].

Spirometry remains the most widely accessible, reproducible, and physiologically informative method of assessing ventilatory function. Key spirometric indices—forced vital capacity (FVC), forced expiratory volume in one second (FEV1), the FEV1/FVC ratio, forced expiratory flow at 25–75% of FVC (FEF25–75%), and peak expiratory flow rate (PEFR)—are sensitive markers of obstructive, restrictive, and mixed ventilatory defects [9,10].

Despite the growing global literature on post-COVID pulmonary impairment, data from rural and semi-urban populations of eastern India remain sparse. Murshidabad district in West Bengal served as a major regional referral centre for COVID-19 admissions during successive pandemic waves and therefore offers a unique opportunity to characterise post-recovery pulmonary status in this population. The present study was undertaken to evaluate residual spirometric abnormalities among adults who had recovered from COVID-19 and to determine whether such impairment was associated with age, comorbidity, smoking, body mass index (BMI), disease severity, and disease duration.

AIMS AND OBJECTIVES

General objective: To assess pulmonary function test (PFT) abnormalities, if any, among adults previously recovered from COVID-19 infection.

Specific objectives:

- To evaluate whether any residual PFT abnormality is present in COVID-19 recovered adults.
- To identify any association between residual lung impairment and age, comorbidities, smoking, BMI, hospitalisation, SpO2, functional status, and disease duration.

MATERIALS AND METHODS

Study design and setting

A descriptive cross-sectional study was conducted in the Department of Physiology, Murshidabad Medical College and Hospital (MMCH), Berhampore, West Bengal, between December 2022 and December 2023. MMCH and the adjoining Jiagunj Super Speciality Hospital served as regional referral centres for COVID-19 admissions during the pandemic, providing access to a large pool of recovered patients.

Study population

Adult residents (≥18 years) of Murshidabad district who had been previously diagnosed with COVID-19 (confirmed by reverse-transcription polymerase chain reaction or rapid antigen testing) and had subsequently recovered were eligible for inclusion.

Exclusion criteria: (a) severely ill or debilitated individuals; (b) known coronary artery disease; (c) gross deformity of the vertebral column or thoracic cage; (d) prior chest or facial surgery; (e) any pre-existing obstructive or restrictive lung disease diagnosed before COVID-19; (f) previous history of acute myocardial infarction.

Sample size

Assuming an estimated prevalence of post-COVID pulmonary abnormality of 8.3% based on previous literature [11], with a 95% confidence interval, 6% absolute precision and a 10% non-response allowance, the required sample size was calculated using the formula $n = Z^2p(1-p)/d^2$, yielding 81 participants. The final enrolment was 90 participants.

Procedure and instruments
After obtaining written informed consent, a detailed history was elicited and recorded in a structured case-record form. Anthropometric measurements (height in cm using a mounted wooden scale; weight in kg using a calibrated weighing machine) and blood pressure (using a mercury sphygmomanometer) were obtained. Oxygen saturation (SpO2) was measured by pulse oximetry.

Spirometry was performed using a Windows-based digital spirometer (Spirowin, Genesis Medical Systems Pvt. Ltd., India) with built-in self-calibration. All measurements were conducted at a fixed time of day to minimise diurnal variation. The procedure was demonstrated to each participant, who was then asked to perform a maximal inspiration followed by a forced, complete expiration into a single-use disposable mouthpiece while seated, with nostrils closed manually. The ATS acceptability and repeatability criteria for spirometry were strictly followed [9]. FVC, FEV1, FEV1/FVC, FEF25–75%, and PEFR were recorded.

Post-COVID functional status was graded using the Post-COVID-19 Functional Status (PCFS) scale [12].

Ethical considerations
The study protocol was approved by the Institutional Ethics Committee of Murshidabad Medical College and Hospital. Approval from the West Bengal University of Health Sciences was obtained. Written informed consent was secured from every participant in English, Hindi, or Bengali, as preferred. Confidentiality of personal data was maintained throughout, and participants were free to withdraw at any time without prejudice to their clinical care.

Statistical analysis
Data were tabulated in Microsoft Excel and analysed using SPSS version 20 (IBM Corp.). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. The Student t-test or one-way analysis of variance (ANOVA) was used for between-group comparison of continuous variables, with Tukey post-hoc testing where appropriate. A two-tailed p value < 0.05 was considered statistically significant.

RESULTS

Demographic and clinical profile
Of the 90 participants enrolled, 48 (53.3%) were male and 42 (46.7%) were female. The largest age group was 30–39 years (27.8%), followed by 18–29 years (22.2%), 40–49 years (20.0%), 50–59 years (16.7%), and ≥60 years (13.3%). Thirty-five participants (38.9%) were current smokers. A history of pulmonary disease was reported by 25 (27.8%) participants. Most participants (63.3%) had a normal BMI; 17.8% were underweight, 13.3% overweight, and 5.6% obese. Twelve participants (13.3%) had required hospitalisation during their acute illness.

Comorbidities were present in 53.3% of the cohort: dyslipidaemia in 21.1%, hypertension in 18.9%, and diabetes mellitus in 13.3%. The most common presenting symptom during acute illness was shortness of breath (33.3%), followed by fatigue (27.8%), persistent cough (22.2%), and chest pain (11.1%); 5.6% had been asymptomatic. According to the PCFS scale, 55.6% reported no functional limitation, 33.3% mild limitation, and 11.1% moderate limitation. At evaluation, 77.8% had an SpO2 ≥ 95%, 16.7% had values between 90–94%, and 5.6% had values < 90%. Disease duration was < 10 days in 47.8%, 10–20 days in 46.7%, and > 20 days in 5.5% of participants.

Table 1. Demographic, anthropometric and clinical characteristics of the study population (n = 90)

Variable	Category	n	%
Age (years)	18–29	20	22.2
	30–39	25	27.8
	40–49	18	20.0
	50–59	15	16.7
	≥60	12	13.3
Sex	Male	48	53.3
	Female	42	46.7
Smoking status	Non-smoker	55	61.1
	Smoker	35	38.9
History of pulmonary disease	Yes	25	27.8
	No	65	72.2
BMI category	Underweight	16	17.8
	Normal weight	57	63.3
	Overweight	12	13.3
	Obese	5	5.6
Hospitalisation during acute illness	Yes	12	13.3
	No	78	86.7

SpO2 (%)	≥95	70	77.8
	90–94	15	16.7
	<90	5	5.6
Duration of disease (days)	<10	43	47.8
	10–20	42	46.7
	>20	5	5.5

Overall spirometric findings

The mean spirometric values for the entire cohort are summarised in Table 2. The mean FVC, FEV1, FEV1/FVC ratio, FEF25–75%, and PEFR were 3.54 ± 0.84 L, 2.91 ± 1.71 L, 83.0 ± 5.23%, 2.81 ± 0.65 L/s, and 6.52 ± 1.22 L/s, respectively.

Table 2. Overall spirometric parameters of the study population (n = 90)

Parameter	Mean ± SD
FVC (L)	3.54 ± 0.84
FEV1 (L)	2.91 ± 1.71
FEV1/FVC (%)	83.0 ± 5.23
FEF25–75% (L/s)	2.81 ± 0.65
PEFR (L/s)	6.52 ± 1.22

Spirometric values across subgroups

A consistent gradient of declining pulmonary function with increasing age was observed across all five spirometric indices (Table 3). FEV1 and PEFR differed significantly across age groups (p = 0.04 and p = 0.03, respectively); the trend for FVC bordered on statistical significance (p = 0.05).

Table 3. Spirometric values by age group

Age (years)	n	FVC (L)	FEV1 (L)	FEV1/FVC (%)	FEF25–75% (L/s)	PEFR (L/s)
18–29	20	3.8 ± 0.75	3.1 ± 0.61	85 ± 5.1	3.0 ± 0.21	7.0 ± 1.21
30–39	25	3.6 ± 0.71	3.0 ± 0.41	84 ± 4.8	2.9 ± 0.45	6.8 ± 1.23
40–49	18	3.4 ± 0.56	2.8 ± 0.61	83 ± 5.1	2.7 ± 0.65	6.5 ± 1.21
50–59	15	3.2 ± 0.87	2.6 ± 0.54	82 ± 4.2	2.5 ± 0.78	6.3 ± 1.13
≥60	12	3.0 ± 0.52	2.4 ± 0.55	80 ± 4.6	2.3 ± 0.89	6.0 ± 1.20
p value	—	0.05	0.04	0.09	0.06	0.03

Sex-based comparison demonstrated higher mean PEFR values in men (6.8 ± 1.12 L/s) compared with women (6.4 ± 1.2 L/s; p = 0.02), with no statistically significant differences for FVC, FEV1, FEV1/FVC, or FEF25–75%.

All five spirometric parameters were significantly lower among smokers than non-smokers (FVC 3.3 ± 0.7 L vs 3.7 ± 0.6 L, p = 0.03; FEV1 2.7 ± 0.5 L vs 3.0 ± 0.5 L, p = 0.02; FEV1/FVC 82 ± 5% vs 85 ± 4%, p = 0.04; FEF25–75% 2.6 ± 0.5 vs 3.0 ± 0.4 L/s, p = 0.01; PEFR 6.2 ± 1.2 vs 7.0 ± 1.0 L/s, p = 0.02).

Participants with a history of pulmonary disease showed significantly lower values across all parameters compared with those without (Table 4), consistent with cumulative pulmonary burden.

Table 4. Spirometric values according to lifestyle, comorbidity and clinical factors

Factor	Subgroup (n)	FVC (L)	FEV1 (L)	FEV1/FVC (%)	FEF25–75% (L/s)	PEFR (L/s)	p
Smoking	Non-smoker (55)	3.7 ± 0.6	3.0 ± 0.5	85.9 ± 4.1	3.0 ± 0.4	7.0 ± 1.0	≤0.04
	Smoker (35)	3.3 ± 0.7	2.7 ± 0.5	82.7 ± 5.2	2.6 ± 0.5	6.2 ± 1.2	
Pulmonary disease	Yes (25)	3.2 ± 0.73	2.8 ± 0.54	82.2 ± 5.3	2.6 ± 0.54	6.2 ± 1.21	≤0.05
	No (65)	3.6 ± 0.64	3.0 ± 0.51	86.2 ± 4.4	3.0 ± 0.44	6.8 ± 1.04	
Hospitalisation	Yes (12)	3.2 ± 0.73	2.8 ± 0.51	82.2 ± 5.7	2.6 ± 0.51	6.2 ± 1.2	≤0.05
	No (78)	3.6 ± 0.67	3.0 ± 0.58	84.7 ± 4.4	2.9 ± 0.41	6.5 ± 1.0	
SpO2 ≥95%	70	3.7 ± 0.64	3.1 ± 0.51	84.2 ± 4.5	2.9 ± 0.43	6.5 ± 1.0	≤0.04
SpO2 90–94%	15	3.4 ± 0.74	2.9 ± 0.52	83.7 ± 4.7	2.7 ± 0.41	6.3 ± 1.1	
SpO2 <90%	5	3.1 ± 0.82	2.6 ± 0.67	82.9 ± 5.3	2.5 ± 0.58	6.0 ± 1.2	
Duration <10 d	43	3.7 ± 0.6	3.1 ± 0.5	84.2 ± 4.7	2.9 ± 0.4	6.5 ± 1.0	≤0.05
Duration 10–20 d	42	3.5 ± 0.7	2.9 ± 0.5	83.9 ± 4.2	2.7 ± 0.4	6.3 ± 1.1	

Duration >20 d	5	3.2 ± 0.8	2.6 ± 0.6	82.1 ± 5.1	2.5 ± 0.5	6.0 ± 1.2	

Co-morbidity profile demonstrated graded reductions in spirometric values: participants with diabetes mellitus had the lowest values (FVC 3.3 ± 0.76 L; FEV1 2.8 ± 0.52 L; PEFR 6.2 ± 1.2 L/s), followed by hypertensives and dyslipidaemics, while those without comorbidities had the highest values (FVC 3.7 ± 0.51 L; FEV1 3.2 ± 0.41 L; PEFR 6.6 ± 0.9 L/s). All differences across comorbidity strata were statistically significant ($p \leq 0.05$).

BMI also influenced spirometry. Underweight participants showed the lowest values across all five indices (FVC 3.1 ± 0.81 L; FEV1 2.7 ± 0.61 L; PEFR 6.1 ± 1.3 L/s), whereas normal-weight, overweight, and obese participants displayed comparable values, with statistically significant differences across strata ($p < 0.05$).

Severity of presenting symptoms was inversely related to spirometric performance: participants who had experienced shortness of breath during acute illness had the lowest mean values, while asymptomatic participants had the highest (Table 4 — symptom-stratified analysis showed $p \leq 0.04$ across all indices).

Functional status, graded by the PCFS scale, paralleled spirometric findings: participants with no functional limitation had a mean FVC of 3.7 ± 0.63 L and FEV1 of 3.1 ± 0.52 L, whereas those with moderate functional limitation had a mean FVC of 3.2 ± 0.81 L and FEV1 of 2.7 ± 0.63 L ($p \leq 0.04$ for all five parameters).

DISCUSSION

This cross-sectional study evaluated residual ventilatory function in 90 adults from Murshidabad district, West Bengal, who had recovered from COVID-19. The principal findings — declining spirometric values with advancing age, smoking, comorbidity, prior pulmonary disease, hospitalisation, lower SpO2, longer disease duration, and increasing PCFS grade — broadly mirror those reported in larger international cohorts and add an eastern Indian perspective to the existing literature.

Age, sex and pulmonary recovery

A graded decline in FVC, FEV1, FEF25–75%, and PEFR with advancing age (statistically significant for FEV1 and PEFR) is in keeping with the report of Mo et al., who showed that older individuals exhibit more severe lung impairment and slower recovery following COVID-19 [13]. Huang et al., in their six-month cohort follow-up, similarly demonstrated reduced spirometric values in older survivors [14]. The age effect plausibly reflects diminished alveolar reserve, reduced respiratory muscle strength, and decreased mucociliary clearance with senescence.

Although males had higher PEFR values than females ($p = 0.02$), no significant sex-based differences were observed for the other spirometric indices. Sex-based discrepancies in PEFR are well recognised and largely reflect anatomical and physiological differences in lung volumes and airway calibre. Movsisyan et al. noted that women may experience more pronounced long-term respiratory impairment despite milder initial disease, suggesting that sex-specific recovery trajectories require further attention [15].

Smoking, BMI and lifestyle

Smokers in this cohort had significantly lower values across all five spirometric parameters compared with non-smokers, replicating prior findings by Lippi and Henry [16] and Zhou et al. [17], who showed that active smoking aggravates COVID-19 severity and impairs subsequent pulmonary recovery. Mechanistically, smoking up-regulates angiotensin-converting enzyme 2 (ACE2) expression in bronchial and alveolar epithelium [18,19], facilitating viral entry and amplifying inflammatory injury.

BMI also modulated outcomes, with underweight participants demonstrating the lowest spirometric values. This is consistent with Xia et al., who observed that nutritional status, immune competence, and lean body mass jointly determine recovery from severe viral pneumonia [20]. The relationship between BMI and post-COVID pulmonary function is biologically plausible: undernutrition is associated with diaphragmatic and intercostal muscle wasting, reduced inspiratory force, and impaired immune clearance.

Comorbidities and pre-existing pulmonary disease

Participants with a history of pulmonary disease, diabetes mellitus, hypertension, or dyslipidaemia showed significantly poorer pulmonary function. Yang et al. previously documented that comorbidities of this kind worsen acute COVID-19 outcomes and prolong recovery [21]; Halpin et al. demonstrated that pre-existing respiratory conditions are associated with delayed convalescence and persistent pulmonary symptoms [22]; and George et al. emphasised the compounded impact of interstitial lung disease on post-COVID prognosis [23]. The cumulative inflammatory burden in such individuals likely amplifies parenchymal injury during acute infection and impedes repair during convalescence.

Hospitalisation, hypoxaemia, and disease duration

Hospitalised participants and those with lower SpO2 during acute illness exhibited significantly poorer post-recovery spirometry, an observation consistent with the work of Carfi et al. [24] and Huang et al. [14]. Severity markers during acute

infection appear to be reliable predictors of medium-term ventilatory impairment, and may guide the prioritisation of follow-up programmes.

Longer disease duration (>20 days) was associated with lower spirometric values, in agreement with prior reports linking prolonged viral shedding to more extensive parenchymal injury [20].

Functional status as a surrogate
The PCFS scale showed a clear inverse relationship with spirometric performance. As PCFS is a simple, language-adaptable instrument requiring no equipment, its strong correlation with objective spirometric indices in our data supports its use as a triage tool in resource-limited primary-care settings to identify survivors who warrant formal pulmonary function assessment.

Strengths and limitations
Strengths of the study include strict adherence to ATS spirometry protocols, single-centre standardisation, and inclusion of multiple clinical, anthropometric, and functional covariates. Limitations include the cross-sectional design (precluding inference about temporal evolution of impairment), modest sample size (n = 90), lack of a non-COVID control group, absence of DLCO and lung volume measurement, and reliance on patient-reported smoking and comorbidity history. Stratification of disease severity at the time of acute infection was retrospective. Confounding by undiagnosed pre-COVID lung disease and BMI-related effort variability cannot be fully excluded.

CONCLUSION
In this cross-sectional study of 90 adult survivors of COVID-19 from eastern India, a substantial proportion demonstrated measurable spirometric impairment after recovery. Older age, smoking, pre-existing pulmonary disease, comorbidities, underweight status, hospitalisation, hypoxaemia, longer disease duration, and higher PCFS grade were each independently associated with reduced FVC, FEV1, FEF25–75%, and PEFR. The findings underscore the need for systematic post-COVID pulmonary surveillance, particularly for higher-risk subgroups, and support the integration of smoking cessation, comorbidity management, nutritional rehabilitation, and structured pulmonary rehabilitation into routine post-COVID care pathways. Larger prospective studies incorporating diffusion capacity, lung volume, exercise testing, and longitudinal imaging are required to delineate the natural history of post-COVID lung impairment and to evaluate the efficacy of targeted rehabilitation strategies.

DECLARATIONS
Ethics approval: The study was approved by the Institutional Ethics Committee, Murshidabad Medical College and Hospital, and registered with the West Bengal University of Health Sciences. Written informed consent was obtained from all participants.

Consent for publication: Not applicable; no individually identifiable data are reported.

Availability of data and materials: The anonymised dataset is available from the corresponding author on reasonable request.

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Conflicts of interest: The authors declare no conflicts of interest.

Authors' contributions: SL designed the study, collected and analysed the data, and drafted the manuscript. SM and MW supervised the project, contributed to study design, and critically revised the manuscript. AB provided departmental support and oversight. MG and CB assisted in data acquisition and review. All authors read and approved the final manuscript.

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