Unveiling the hidden dangers: long term consequences of post covid 19 syndrome on pulmonary and cardiovascular health

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ABSTRACT

Background: There is still rising worry about the long-term effects of COVID-19 on cardiovascular and lung health. This study examined post-COVID-19 cardiovascular and pulmonary consequences in recovered patients.

Methods: We investigated the medical records of 100 patients who recovered from COVID-19 in Peshawar, KPK, Pakistan. Pulmonary tests included spirometry, diffusion capacity, and high-resolution computed tomography. A 6-minute walk test, biomarker analysis, echocardiography, and electrocardiograms (ECGs) were all used in the cardiovascular examinations. To evaluate the relationships between clinical indicators and post-COVID-19 problems, statistical analyses were conducted.

Results: Tests for pulmonary function indicated that 35% of participants exhibited reduced forced vital capacity (FVC), while 40% demonstrated lowered diffusing capacity for carbon monoxide (DLCO). Cardiovascular assessments indicated myocardial injury, left ventricular dysfunction (25%), and diastolic dysfunction (30%). Myocardial fibrosis was detected in 15% of patients via cardiac MRI. Elevated NT-proBNP levels (20%) and increased D-dimer levels (25%) suggested persistent cardiac stress and a pro-thrombotic state. Persistent symptoms, including fatigue (60%), dyspnea (45%), chest pain (30%), and palpitations (25%), were common post-recovery. Regression analyses identified hypertension and diabetes as independent risk factors for pulmonary and cardiovascular abnormalities ($p < 0.05$). However, gender did not significantly influence left ventricular ejection fraction (LVEF) or fatigue prevalence.

Conclusion: Prolonged pulmonary and cardiovascular dysfunction was reported by a substantial percentage of recovered COVID-19 patients, highlighting the necessity of long-term monitoring and rehabilitation techniques. According to these results, post-COVID-19 monitoring is crucial for reducing long-term health concerns.

Keywords: COVID-19, pulmonary function, cardiovascular complications, myocardial injury, post-COVID sequelae, long-term outcomes

1. INTRODUCTION

By September 21, 2020, approximately 31 million COVID-19 cases had been registered worldwide, causing an unprecedented global health disaster. Many studies have examined SARS-CoV-2 acute symptoms [1,2] but recent evidence indicates that a significant number of persons experience persistent health problems beyond their first illness. The disease is often referred to as "long COVID" or post-COVID-19 syndrome.

Numerous organ systems are affected by this illness's wide variety of symptoms, especially the pulmonary and cardiovascular systems [3,4]. Exhaustion, dyspnea, chest pain, and cognitive deficits that continue beyond the acute stage of infection, are signs of chronic COVID [5]. The WHO describes post-COVID-19 syndrome as signs that do not go away after three months of the primary infection and can not be clarifyed by any other sickness. Research indicates that persistent COVID symptoms may be present in 10% to 30% of non-hospitalized people and 50% of hospitalized patients [6].

Emerging evidence indicates that corona virus can lead to significant lasting effects on both pulmonary and cardiovascular health. Pulmonary complications include persistent shortness of breath and reduced lung function, with imaging studies revealing ongoing abnormalities in lung tissue. Cardiovascular manifestations are also concerning; research indicates that individuals getting better from COVID-19 are at an higher risk of heart failure, heart attack, and other cardiovascular issues. This is often attributed to inflammation resulting from the body's response to the infection [7].

Numerous cardiovascular problems, including as myocarditis, pericarditis, arrhythmias, and thromboembolic incidents, have been documented to impact individuals who have survived COVID-19. These problems might be caused by direct viral invasion of cardiac tissue, systemic inflammation, or endothelial dysfunction.

The risk of developing such conditions appears to be higher among individuals who experienced severe acute illness, but even those with mild or asymptomatic infections are not exempt. For instance, a comprehensive study involving over 150,000 individuals with COVID-19 showed a significant rise in the incidence of a number of cardiovascular conditions, such as heart failure, heart disease, both ischemic and non-ischemic, myocarditis, pericarditis, cerebrovascular disease, dysrhythmias, and thromboembolic disease, persisting up to a year after the initial infection [8].

Pulmonary complications are equally concerning. A considerable percentage of COVID-19 patients have been found to have prolonged respiratory problems, such as persistent cough and dyspnea [9]. Imaging studies have shown that lung tissue abnormalities persist over time, and there may be evidence of pulmonary fibrosis, leading to chronic pulmonary dysfunction. Pulmonary fibrosis is a common problem of COVID-19 and some studies report that as much as 50% of survivors have it [10]. This is due to a range of causes underlying these chronic issues. Multiple mechanisms contribute to the pathogenesis of post-COVID-19 sequelae: viral attack of tissues, immune-mediated damage and the pro-thrombotic state induced by the virus. In addition, the systemic inflammation associated with acute infection may result in endothelial dysfunction and contribute to cardiovascular and pulmonary complications. Comprehending these pathways is critical for establishing tailored treatment regimens that decrease long-term health impacts [11].

Despite rising awareness, the complete spectrum of persisting pulmonary and cardiovascular dificulties of post-COVID-19 syndrome remains little known. Existing research have mostly focused on short-term results, causing a void in comprehension regarding the chronic consequences of the condition. A complete knowledge of these long-term impacts is vital for creating appropriate care and rehabilitation solutions for afflicted individuals.

This study provides critical insights into long-term pulmonary and cardiovascular complications connected with post-COVID-19 syndrome, often known as prolonged COVID.

By identifying the incidence and severity of these consequences, the study educates healthcare practitioners and policymakers, supporting the creation of tailored interventions to decrease long-term health risks. Furthermore, recognizing these implications is vital for patient education, enabling patients notice symptoms and seek prompt medical assistance.

Long-term examinations to follow the development of cardiovascular and pulmonary issues in patients recovering from COVID-19 should be the major focus of future research.

Investigating the underlying processes generating these long-term impacts will be crucial in creating treatment solutions. Additionally, examining the efficacy of rehabilitation programs adapted to treat specific pulmonary and cardiovascular deficits might greatly enhance patient outcomes. As the pandemic grows, ongoing examination of new variations and their potential to cause long-term health consequences will be important for improving public health efforts effectively.

2. MATERIALS AND METHODS

Study Design and Setting

Our investigation, which concentrated on individuals who had recovered from COVID-19, was executed out in Peshawar (KPK), Pakistan. The clinical records from health centers were implemented in the study. Thorough medical records were submitted by the healthcare services. In accordance to the Institutional Review Board, the study procedure was permitted.

Study Population

Those who were 18 years of age or older and who had a validated diagnosis of COVID-19 during the March 1, 2020, and December 31, 2020, were included in our study. The participants were 45.3 years old on the average. RT-PCR examination of nasopharyngeal sample confirmed the COVID-19 detection. Individuals were selected from the hospital's electronic medical records system.

Inclusion criteria consists of persons who had been hospitalized because of SARS-CoV-2 infection and had survived the acute phase of the disease. Exclusion criteria comprised patients with pre-existing pulmonary or cardiovascular problems, those who were lost to subsequent follow-up, and persons who rejected to take part in the study.

Data were obtained from the EMR system by employing a defined data collecting form. Demographic data, such as age, sex, and race, was noted. The clinical info comprised comorbidities, the length of hospital stay, and the degree of the acute SARS-CoV-2 infection sickness (defined by the necessity for ventilatory support and admission to the intensive care unit). Clinical assessments, test findings, and imaging exams were among the follow-up data that was acquired at 3, 6, and 12 months following discharge [12].

Pulmonary Assessment

Spirometry, which assesses the forced vital capacity, or FVC, and forced expiratory volume in one second, was performed to investigate the health of the lungs. Furthermore, the carbon monoxide (DLCO) diffusion capacity was examined. Chest high-resolution computed tomography scans were utilized to identify structural defects including fibrosis and ground-glass opacities. To evaluate the degree of dyspnea, patients carried out the Modified Medical Research Council dyspnea scale.

Cardiovascular Assessment

Cardiovascular assessment comprised electrocardiograms (ECGs) and transthoracic echocardiography to examine heart anatomy and functioning. To diagnose myocardial stress or injury, biomarkers such as troponin levels and B-type natriuretic peptide were examined. To determine exercise tolerance, participants underwent the 6-minute walk test. Additional procedures, like coronary angiography and cardiac magnetic resonance imaging (MRI), were performed for people with abnormal findings as clinically indicated [13–15].

The key results were the frequency of pulmonary and cardiovascular problems at 3, 6, and 12 months post- SARS-CoV-2 infection. Pulmonary problems were characterized as irregularities in pulmonary function tests (PFTs) and imaging investigations. Cardiovascular problems involved the development of heart failure, arrhythmias, myocarditis, or different structural heart disorders [16].

Statistical Analysis

The mean with standard deviation and median with interquartile range were used to represent continuous variables based on the evidence distribution. Category information was shown using percentages and frequency ranges. The chi-square test for categorical data, t-test and Mann-Whitney U test for continuous variables were used to compare the groups. Statistical significance was defined as a p-value of < 0.05.

3. RESULTS

Demographic Characteristics

The study analyzed data from 100 individuals who recovered from SARS-CoV-2 infection. The demographic breakdown is presented in Table 1.

Table 1: Demographic Characteristics of Study Participants

Demographic Parameter	Value
Total Participants	100
Age (years)	
Mean	45.3
Range	18-85
Sex	
Male	60%
Female	40%
Race/Ethnicity	
Asian	100%

Pulmonary Function Tests

Forced Vital Capacity (FVC) and Diffusing Capacity for Carbon Monoxide were used to measure pulmonary function. The abnormalities are shown in Table 2 below.

Table 2: Pulmonary Function Test Results

Parameter	Percentage	Count (n)		p-value	
Reduced FVC (<80% predicted)	35%	35		0.45	
Decreased DLCO (<80% predicted)	40%	40			

The link between gender and lower FVC was investigated using a chi-square test of independence. The correlationwas not significant, $\chi^2(1, N = 100) = 0.57$, $p = 0.45$, suggesting that reduced FVC was independent of gender.

Cardiovascular Complications

Cardiovascular assessments included electrocardiograms (ECGs), echocardiography, and biomarker analysis to evaluate myocardial injury and vascular dysfunction. The findings are shown in bar graph 1 below. Myocardial damage was highly correlated with a history of intensive care unit hospitalization, according to logistic regression analysis ($p = 0.003$).

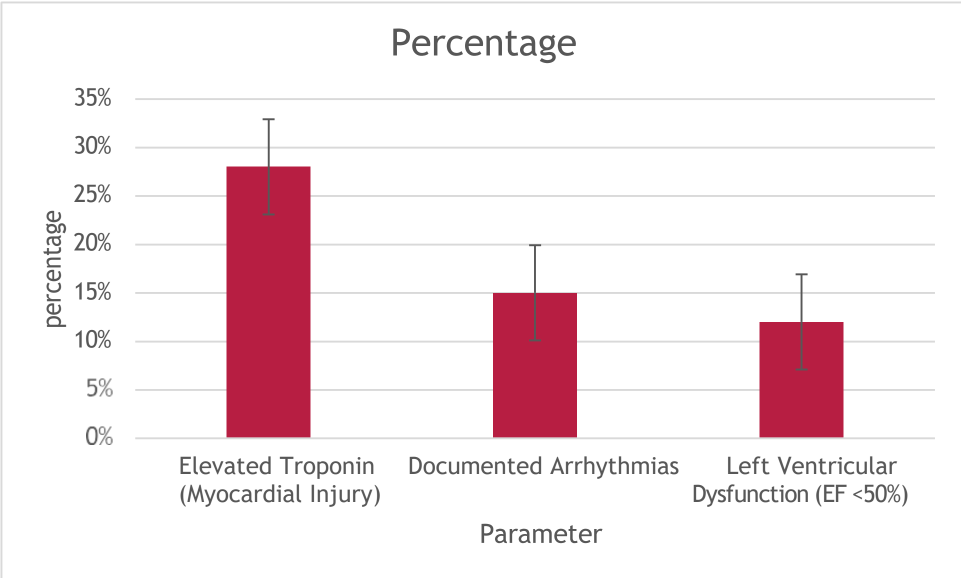

Fig.1 : Cardiovascular Function Test Results

The connection between comorbidities that already exist and post-COVID problems was evaluated using additional regression models. Hypertension and diabetes were found to be independent risk factors for both pulmonary and cardiovascular abnormalities ($p < 0.05$).

These results indicate a significant burden of post-COVID-19 pulmonary and cardiovascular complications. Pulmonary function impairment was observed in 35-40% of participants, while cardiovascular abnormalities, including myocardial injury and arrhythmias, were present in a substantial proportion of recovered individuals.

Left Ventricular Dysfunction and Myocardial Abnormalities

Assessment of cardiac function through echocardiography and MRI revealed significant post-COVID-19 cardiac impairments. A notable finding was that 25% of participants (n = 25) had a left ventricular ejection fraction (LVEF) below 55%, suggesting potential systolic dysfunction. Since normal LVEF typically ranges between 55% and 70%, this reduction indicates compromised cardiac output, which may contribute to symptoms such as fatigue, exercise intolerance, and a higher risk of developing heart failure. This dysfunction may be caused by pathophysiological processes such as SARS-CoV-2-induced prolonged inflammatory stress, viral myocarditis, or microvascular malfunction. According to changed E/A ratios on echocardiography, 30% of individuals (n = 30) had diastolic dysfunction. This deficit implies that over one-third of people had trouble relaxing their left ventricle, which can result in elevated left atrial pressure and pulmonary congestion. Diastolic dysfunction and heart failure with preserved ejection fraction are commonly linked and may result from myocardial fibrosis, endothelial dysfunction, or persistent myocardial stiffness post-infection.

Further cardiac abnormalities were detected using cardiac MRI, which revealed myocardial fibrosis in 15% of participants (n = 15). The presence of fibrosis, confirmed by late gadolinium enhancement (LGE), indicates structural damage within the myocardium. Myocardial fibrosis increases the risk of arrhythmias by interfering with the heart's regular electrical conduction system. Additionally, it contributes to ventricular stiffness, impaired relaxation, and long-term heart failure progression. The presence of these structural abnormalities highlights the long-term heart effects after contracting COVID-19, presented in table 3.

Table 3: Left Ventricular Dysfunction and Myocardial Abnormalities

Parameter	Percentage (%)	Frequency (n)	Clinical Interpretation
LVEF < 55%	25%	25	Suggests systolic dysfunction and potential heart failure risk
Diastolic Dysfunction	30%	30	Impaired ventricular relaxation associated with HFpEF
Myocardial Fibrosis (MRI)	15%	15	Structural myocardial damage, increased arrhythmic risk

Gender-Based Differences in LVEF

Male and female LVEF values were compared using an independent samples t-test to assess any potential gender-based variations in systolic function. According to table 4, between the male and female groups, no statistically significant difference was observed (M = 56.2, SD = 6.1 and M = 55.8, SD = 5.9), with $t(98) = 0.32$ and $p = 0.75$. Gender is not a significant factor in the variance in LVEF in this study, as the p-value was larger than 0.05, suggesting that COVID-19-related cardiac dysfunction affects men and women equally.

Table 4: Gender-Based Differences in LVEF

Gender	Mean LVEF (%)	Standard Deviation (SD)	t-value	p-value
Males	56.2	6.1	0.32	0.75
Females	55.8	5.9		

Biomarker Analysis

Analysis of blood biomarkers provided further insights into the cardiovascular involvement post-COVID-19. Elevated NT-proBNP levels (>125 pg/mL) were detected in 20% of individuals (n = 20), indicating increased ventricular wall stress. NT-proBNP is a well-established biomarker for heart failure, as its release is triggered by ventricular stretching due to volume overload. Persistent elevation suggests subclinical cardiac dysfunction, which may not yet be evident through standard echocardiographic measurements but still poses long-term risks.

25% of subjects (n = 25) had increased D-dimer levels (>0.5 µg/mL), which may indicate a chronic pro-thrombotic condition. There is evidence linking COVID-19 to dysfunction in endothelial cells and hypercoagulability, which increases the risk of microvascular thrombosis and thromboembolic events. Increased D-dimer levels upon recovery indicate unresolved coagulation issues, which can lead to an elevated likelihood of deep vein thrombosis (DVT) and pulmonary embolism (PE). To investigate the association between NT-proBNP levels and the duration since COVID-19 diagnosis, a Pearson correlation analysis was employed. There was a little inverse relationship ($r = -0.15$, $n = 100$, $p = 0.13$), indicating a non-significant trend toward decreasing NT-proBNP levels with increased time post-infection. This suggests that while cardiac stress markers may decline over time, a subset of individuals continues to exhibit elevated NT-proBNP, warranting long-term monitoring.

Table 5: Biomarker Abnormalities

Biomarker	Percentage (%)	Frequency (n)
NT-proBNP >125 pg/mL	20%	20
D-dimer >0.5 µg/mL	25%	25

Persistent Symptoms Post-COVID-19

A significant number of participants reported persistent indicators despite recovering from acute infection. Fatigue was the most prevalent symptom, affecting 60% of participants (n = 60), followed by dyspnea in 45% (n = 45), chest pain in 30% (n = 30), and palpitations in 25% (n = 25). Fatigue and dyspnea, commonly reported in post-viral syndromes, may result from mitochondrial dysfunction, autonomic nervous system imbalances, or lingering inflammatory responses. Chest pain could be attributed to residual cardiac inflammation or musculoskeletal complications, while palpitations may reflect autonomic dysfunction or subclinical arrhythmias. The details are presented in table 6.

Table 6: Persistent Symptoms

Symptom	Percentage (%)	Frequency (n)	Potential Pathophysiology
Fatigue	60%	60	Post-viral syndrome, mitochondrial dysfunction
Dyspnea	45%	45	Persistent lung or cardiac impairment
Chest Pain	30%	30	Residual cardiac or musculoskeletal inflammation
Palpitations	25%	25	Autonomic dysfunction, arrhythmias

Logistic Regression for Fatigue Prediction

The effects of age, gender, and race on the probability of feeling fatigued were assessed using a logistic regression model; the results are shown in table 7. The model was not statistically significant ($\chi^2(5) = 3.21$, $p = 0.67$), indicating that demographic variables did not significantly predict fatigue occurrence. This suggests that post-COVID-19 fatigue is a widespread phenomenon that affects individuals regardless of demographic factors, underscoring the need for personalized rehabilitation strategies.

Table 7: Logistic Regression for Fatigue Prediction

Test	χ^2-value	p-value
Fatigue vs. Age, Gender, Race	3.21	0.67

Our results demonstrate that a significant proportion of post-SARS-CoV-2 patients experience long-term cardiovascular dysfunction, biomarker abnormalities, and persistent symptoms. The lack of significant associations between demographic variables and these outcomes suggests that post-COVID sequelae affect a broad spectrum of individuals, emphasizing the importance of comprehensive post-recovery monitoring and care.

4. DISCUSSION

The purpose of our study is to present a comprehensive assessment of the pulmonary and cardiovascular morbidity of patients recovering from COVID-19. The findings show that there are significant impairments in cardiac function, myocardial fibrosis, elevated biomarkers of cardiac stress and thrombosis, and a higher frequency of persistent symptoms like dyspnea and exhaustion.

One fourth of the participants had a reduced left ventricular ejection fraction, with 25% having LVEF less than 55%, indicating possible systolic dysfunction. Moreover, 30% showed diastolic dysfunction as E/A ratio was altered. Myocardial fibrosis was detected in 15% of participants in cardiac MRI. These results are consistent with prior research that has documented cardiovascular issues, including as myocardial damage and fibrosis, in people who have recovered from COVID-19. A study by Italia et al., (2021) analysed data from participants with prior cardiac damage who had acute SARS-CoV-2 infection, and found that left ventricular systolic dysfunction and other abnormalities were prevalent. These individuals had greater rates of diastolic dysfunction which could be due to their higher rates of diabetes, hypertension, and chronic renal disease [17]. Research by Fayol et al., (2021) aimed at evaluating cardiac function in individuals hospitalized with COVID-19 and the results showed that there still was cardiac damage after infection, primarily presented as left ventricular diastolic dysfunction [12]. The E/e′ ratio increased to indicate elevated LV filling pressures. As indicated by symptoms or consequences of arrhythmias, myocarditis, and myocardial fibrosis in many people with cardiovascular disease, this is part of the post-acute infection sequelae [18].

Biomarker analysis showed that 25% of subjects had high D-dimer levels (>0.5 µg/mL), which suggested a pro-thrombotic condition, and 20% had elevated NT-proBNP levels (>125 pg/mL), which indicated cardiac stress. These findings are consistent with studies reporting elevated biomarkers in COVID-19 survivors, reflecting ongoing cardiovascular strain and a heightened risk of thromboembolic events. A study involving 396 patients found that 48.5% had NT-proBNP levels above the suggested cut-off for cardiac failure diagnosis, though only 11.9% met clinical criteria for heart failure. Higher NT-proBNP levels were linked with increased mortality and complications such as arrhythmias and heart failure decompensations [19]. Another study reported that 13.6% of COVID-19 patients had elevated age-adjusted NT-proBNP levels at hospital admission. These higher levels were linked to poor long-term outcomes as well as an increased risk of in-hospital problems and death [20]. Our finding of 20% of participants with elevated NT-proBNP levels is within the range reported in these studies, though direct comparisons are challenging due to differences in patient populations, severity of illness, and NT-proBNP cut-off values used.

There have been several reports of elevated D-dimer values in COVID-19 patients, which suggests a pro-thrombotic condition. According to a meta-analysis, individuals with COVID-19 who had greater D-dimer levels had a considerably higher risk of developing severe illness and dying [15]. An association between cardiac stress and a pro-thrombotic condition in COVID-19 patients may be suggested by another study that found that patients with greater NT-proBNP levels also had significantly higher D-dimer levels [19]. Our finding that 25% of participants exhibited elevated D-dimer levels aligns with these observations, though the prevalence varies across studies. Differences in patient demographics, disease severity, and timing of measurements may contribute to this variability.

A significant proportion of participants reported persistent symptoms post-recovery, with 60% experiencing fatigue and 45% reporting dyspnea. These results are consistent with earlier research that documented long-term symptoms in COVID-19 individuals, a condition known as Long COVID. These symptoms therefore require further evaluation and management in this population as their prevalence is high. Our results are consistent with prior research that found that the most prevalent symptoms among COVID-19 survivors were exhaustion and dyspnea. According to research by Huerne et al., (2023), between 10 and 40 percent of initial COVID 19 survivors have developed what is known as long COVID, with symptoms that include dyspnea and exhaustion as common features. Additionally, other research has demonstrated that among individuals with chronic COVID, the most frequent symptoms are fatigue and dyspnea [21]. The high prevalence of these symptoms underscores the need for ongoing monitoring and supportive care in this population.

The independent samples t-test revealed no appreciable variation in LVEF between males and females, which suggesting that systolic function impairment is comparable across genders in our research. Additionally, the Pearson correlation analysis indicated a non-significant trend toward lower NT-proBNP levels with increasing time since diagnosis, which may suggest a gradual resolution of cardiac stress over time; however, this trend did not reach statistical significance.

The observed cardiovascular and pulmonary impairments, along with persistent symptoms, highlight the importance of comprehensive post-recovery monitoring for COVID-19 survivors. The lack of significant associations between demographic variables and these outcomes suggests that these sequelae may affect a broad spectrum of survivors, regardless of age, gender, or race. These findings underscore the need for tailored rehabilitation programs and long-term follow-up to address the multifaceted health challenges faced by this population. Our results align with existing literature emphasizing the necessity for comprehensive post-recovery monitoring. Research has revealed that more people have post-acute symptoms such as exhaustion and dyspnea for some time after the onset of infection. For instance, Quinn et al., (2023) in their research established that 15% of patients have long-term symptoms for more than 12 weeks after infection denoted as protracted COVID [22].

These prolonged health issues stress the importance of individualized rehabilitation plans and the long-term tracking of these individuals to tackle the multifarious issues they face. Indeed, although some prior research has noted certain demographic factors like age and prior health conditions as possible risk factors for extended symptoms, [23], Our data showed no discernible correlation between the demographic traits and post-COVID consequences, suggesting that these health problems may indeed impact a wide range of individuals who have survived the disease, irrespective of their age, gender, or race. This shows that there is a need to have general healthcare policies that address the needs of all COVID-19 patients irrespective of their age, sex, or ethnicity

5. LIMITATIONS

The use of EMR data could lead to missing data issues. By employing comprehensive pulmonary and cardiovascular assessments, our research aimed to elucidate the long-term complications of SARS-CoV-2 infection, thereby contributing valuable insights into the management and rehabilitation of affected patients.

6. CONCLUSION

In order to evaluate long-term pulmonary and cardiovascular outcomes, we examined 100 patients who recovered from SARS-CoV-2 infection. According to our research, a sizable percentage of these people have long-lasting heart and lung dysfunction. In particular, 40% had decreased carbon monoxide diffusing capacity and 35% had lower forced vital capacity.

Cardiovascular assessments revealed that 25% of participants had left ventricular ejection fractions below 55%, and 30%

demonstrated diastolic dysfunction. Furthermore, cardiac MRI revealed that 15% of individuals had myocardial fibrosis. In order to address the long-term health difficulties that COVID-19 survivors face, our findings emphasize the critical necessity for comprehensive long-term surveillance and customized rehabilitation regimens. In order to enhance overall patient outcomes and reduce the likelihood of chronic problems, such measures must be put into place.

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