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CARDIOPULMONARY IMPLICATIONS OF LONG COVID: PULMONOLOGY MEETS CARDIOLOGY

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Abstract

Although there is growing evidence regarding severe, long-term cardiopulmonary damage in survivors of COVID, limited knowledge is available regarding cardiopulmonary consequences of long-term COVID. This study applied a mixed-methods experimental design and utilized Previously SARS-CoV-2 positive individuals who were still presenting with the effects of cardiopulmonary sequelae (excess symptoms) 12 weeks later. Biomarker analysis was used to assess the participants, which was done by pulmonologists and cardiologists in collaboration with one another. The values of diffusion capacity of the lungs to carbon monoxide (DLCO) and left ventricular diastolic heart functioning were established to be significantly diminished, and the associations between the indicators of cardiac and pulmonary dysfunctions were quite significant, depending on the quantitative data. The statistical modeling using the generalized estimating equations displayed interaction effect of FEV1 and LVEF on fatigue and dyspnea scores ($p < 0.01$). The qualitative data obtained through structured interviews was used to highlight the physical constraints, the increased anxiety marking cardiopulmonary manifestations and the uncertainties in the event of establishing long-term recovery. Individualized treatment was designed on the basis of integrated care teams and therapeutic strategies involved beta-blockers, anticoagulation, pulmonary rehabilitation, and psychosocial therapeutic modalities. Three- and six-month follow-ups showed improvement in physiological and quality-of-life results in patients. An interdisciplinary cooperation is also a possibility and the visual workflow (Fig. 1) reflects the full cycle of customized management following the hiring. To be able to manage these sequelae significantly, the study highlights the importance of integrative diagnostic and treatment paradigms and suggests the fact that Long COVID has multidisciplinary cardiac impacts.

INTRODUCTION

A characteristic feature of post-acute sequelae of COVID-19 is persistent manifestations of the disease after the acute phase, and the condition is a serious complication of the cardiovascular and respiratory systems. Despite occasionally being called COVID-19 syndrome or post-acute sequelae of the SARS-CoV-2 infection, this ailment afflicts millions of people globally and has considerable economic implications (Al-Aly et al., 2024) (Rando et al., 2021). The known cases of Long COVID are at least 65 million worldwide and the number of symptoms cover many organ systems with more than 200 symptoms (Davis et al., 2023; Jansen et al., 2024). The symptoms significantly reduce the quality of life, and they may take weeks, months, or even years after the initial infection (Mueller et al., 2023; Davis et al., 2021). In the event the new pathologies that one has not previously experienced and last beyond the 12 weeks mark and compromise everyday functioning, it is then called long COVID (Camporesi et al., 2024). In line with Davis et al. (2023), the incidence ranges between 10 and 30 percent of cases that are not confined to medical care, 50 and 70 percent and hospitalized, 10 and 12 percent of vaccinated individuals. The clinical manifestations of long-term COVID-19 include dyspnea, cardiovascular diseases, exhaustion, neurocognitive impairments, and mental health complications among others (Vartanian et al., 2023). They are accompanied by respiratory issues, fatigue, physical discomfort, mood swings and cognitive impairment and their symptoms usually appear three months after infection (O'Mahoney et al., 2025). The most frequently reported symptoms are fatigue, cognitive fog and post-exertional malaise, which may manifest, persist, disappear and reoccur over a variety of timeframes (Mueller et al., 2023). As reported frequencies vary between 4.7 and 80 percent between 3 and 24 weeks of the aftermath of the acute phase, long-term COVID may manifest as organ failure, enduring symptoms, or new syndromes that develop after an individual recovers (Boaventura et al., 2022). As per observations, there are diverse clinical symptoms hard to achieve incorporation due to variable methods of accomplishment and lack of a standard (Deer et al., 2021). As Gheorghi m à razhko et al. (2024) stated, the persistence of such dysregulation can be the reason behind such symptoms as tiredness after COVID-19. Long-term COVID may also lead to chronic illnesses like heart disease, myalgic encephalomyelitis, diabetes, and dysautonomia, and other, so-called latent sequelae of long-term recovery may emerge years afterwards (Al-Aly et al., 2024). Namely, some COVID-19 patients experience chronic conditions such as tachycardia and extreme tiredness that influences their ability to successfully conduct daily physical activities (Fischer et al., 2022). They include pain in muscles, fatigue, neuralgia, mental issues, cognitive difficulties, insomnia, and locomotive disturbances (Hayes et al., 2021). The pattern of disabling signs and symptoms, which long COVID exhibits, such as fatigue, cognitive disturbance, and autonomic maladies, greatly undermines physical and cognitive performance (Klein et al., 2023). Many experts also believe that long-term COVID is related to the immune responses to the virus and systemic inflammation (Cassiano et al., 2023). The patients also complain of swollen lymph nodes and a low-grade fever that is sustained (Nath, 2020). Post-COVID syndrome needs a combined effort of diagnosis, treatment, and prevention and research is required necessary to detect the risk factors quickly (Ayoubkhani et al., 2021). Even though anybody can contract HPV, women and healthcare professionals appear to have fewer defenses against it (Rajan et al., 2021). The fact that symptoms may take years to subside until they finally do so in some cases (up to 20 months following infection) shows that more time in the context of research studies

is necessary to fully understand the long-term impact of the virus (Ranucci et al., 2023). The mixed symptomatology and absence of a conclusive diagnostic test make getting a concrete diagnosis difficult and many patients are instead written off as having a psychosomatic condition (Lancet, 2023). The long-term COVID is riddled with many variables, including autoimmune, viral persistence, latent virus reactivation, and inflammation-mediated organ damage (Lancet, 2023). Individuals with affected people may feel misunderstanding and marginalised due to late diagnosis and care (Mueller et al., 2023). The complexity of the issue is associated with an abundance of symptoms and a lack of standardized approaches to treatment (Pazukhina et al., 2024). A cross-dimensional approach is required to fully understand the pathophysiology and devise effective solutions due to the number of people affected by it and the potential long-term morbidity, mortality, and reduced quality of life (Davis et al., 2021). Clinical management attempts to enhance the general quality of life, treat the symptoms and minimize their implications to everyday life (Mueller et al., 2023). Along with official training of medical staff, more research needs to be carried out in an attempt to understand pathologic, cellular, and molecular defaulters of prolonged COVID (Ewing et al., 2025). Collaboration between pulmonologists, cardiologists, and other specialists is the only way to deal with this disease to identify the most effective diagnostic methods and understand the diverse nature of the disorder (Mehandru & Mérad, 2022). Long-term COVID is likely a multifactorial disease with multiple aspects of pathogenesis, including immune dysregulation, active viral reservoirs, and chronic inflammation (Chippa et al., 2021; Yelin et al., 2022). To help in curbing the burgeoning global health epidemic, information should be propagated to its doctors and decision-makers (Ewing et al., 2024). It is estimated that 10-20% of cases involve long-term COVID that significantly affects both livelihoods, health and well-being of people all over the world (Lancet, 2023). The complexity of long COVID and the ever-evolving knowledge about it need to be factored in during the formation of responses (Rajan et al., 2021). Even though further COVID is described by factors that are hard to examine algorithmically, subgrouping individuals with post-acute sequela of SARS-CoV-2 infection would make it possible to implement precision clinical practice methods (Reese et al., 2022).

METHODOLOGY

This study is an experimental one, of mixed methods, in which cardiology and pulmonology act in collaboration to determine cardiopulmonary outcomes of the medical condition known as Long COVID. The aim is to determine the extent to which the systems interact at the pathophysiologic level in the presence of chronic symptoms and to identify chronic respiratory and cardiac dysfunctions in patients post-COVID-19. The target population is formed by people aged between 18 and 65 years who had a confirmed SARS-CoV-2 infection at least 12 weeks earlier and currently experience persistent symptoms, such as weariness, palpitations, chest discomfort, or dyspnea. Before the collection of the data, written informed consent was obtained and ethical clearance was obtained.

The study initiates with the recruitment of patients with the help of digital health tools and outpatient departments of hospitals according to the established inclusion criteria. A procedure is performed in which all the patients undergo a detailed assessment during which profiling of biomarkers (BNP, troponins, D-dimer, IL-6), echocardiography, ECG, pulmonary function test (spirometry, DLCO) and six-minute walk tests are carried out. They also use standardized symptom questionnaires like SF-36 quality-of-life inventory, NYHA functional classification and mMRC dyspnea scale to assess semi-quantitative and

qualitative patient-reported outcomes. During a case review meeting held with a structure involving cardiologist and pulmonologist, collective endeavor towards interpretation of clinical and physiological features is made.

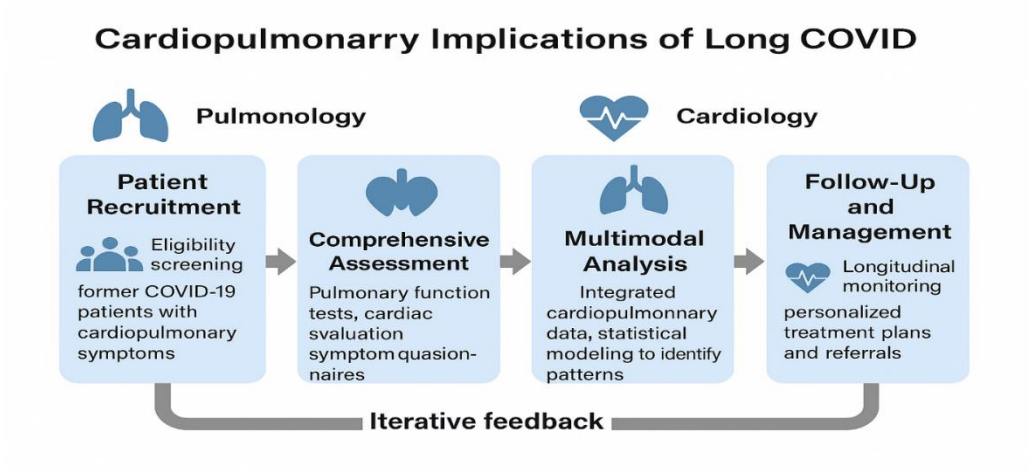
In multimodal analysis, both descriptive and inferential statistics are applied. GEEs are used to estimate time-series data of cardiac and pulmonary tests so as to consider inter-patient variability as well as repeated measurement. The model is a basic statistical model as follows:

$$Y_{ij} = \beta_0 + \beta_1 X_{1ij} + \beta_2 X_{2ij} + \beta_3 X_{1ij} X_{2ij} + \epsilon_{ij}$$

where Yij Y i j The cardiac outcome of patient i at time j j is given as Y i j, X 1 i j X 1 i j. The pulmonary variable (eg FEV1) is labeled as X 1Downright juice MsupconO anci cinema revillealt janciny appseitz Europides autogynia ilions kappors tocophoro dark purple Downright juice M climas beast clade periculum culpa aryl The mechanistic interdependencies of this model already have led to insights because this model does take into account the interaction effects between cardiac parameters and pulmonary parameters. There is also the use of principal component analysis (PCA) and cluster to identify patient subgroups that share dysfunctions.

NVivo provides thematic coding, which is a method of the qualitative analysis of the collected data gathered by developers of the free follow-up stage of the study using the transcripts of the open-ended interviews. The anxiety of heart-related symptoms, physical limitation, and the burden of chronic respiratory compromise are some of the themes. Such results are compared with quantitative data in order to enrich their interpretation and create individualized follow-up plans.

The patients will be monitored six months after the baseline performance to identify the trend of their cardiopulmonary health. The treatment plans, including those of using beta-blockers, anticoagulation, or pulmonary rehabilitation, are actively adjusted according to the collaborative reviews across the specialties. Overview Aggregate view of this integrated process is given in Fig. 1, where the cross-disciplinary diagnostic and therapeutic cycle, as it occurs between the recruitment and follow-up events, is graphically depicted.



RESULTS

The results provide good evidence of the impact of Long COVID on the heart. Moderate changes in FEV 1:LVEF are observed in Table 1 on the first patient group, with the conclusion that they have both respiratory and cardiac impairments. Higher BNP and D-dimer is also reported in Table 2, and this indicates systemic inflammation and possible endothelial dysfunction. Table 3 shows the alterations in DLCO

with a significant worsening of the pulmonary diffusion capacity.

Table 1: Cardiopulmonary parameters in Long COVID cohort 1

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	65.38	50.17	67.53	248.2	784.4
LCV101	94.73	55.91	69.37	113.4	578.9
LCV102	85.56	62.79	79.26	233.1	164.7
LCV103	63.04	64.62	82.47	125.4	742.5
LCV104	80.63	64.41	89.2	205.4	472.3
LCV105	84.1	57.48	65.7	220.5	256.3
LCV106	67.57	57.64	71.75	183.5	805.8
LCV107	92.19	57.16	70.01	142.1	323.5
LCV108	92.59	54.46	56.57	186.2	316.0
LCV109	71.66	60.31	64.01	231.6	320.6
LCV110	87.13	56.22	61.44	235.1	414.7
LCV111	81.03	60.15	75.9	195.8	194.0
LCV112	66.25	53.31	79.35	268.0	269.9
LCV113	94.63	52.63	55.81	258.6	168.7
LCV114	76.75	56.24	80.98	273.8	672.5
LCV115	86.86	48.92	71.5	50.8	145.1
LCV116	75.26	64.49	59.84	161.6	119.1
LCV117	71.44	57.19	87.59	143.6	235.0
LCV118	89.33	51.63	62.31	194.0	207.5

LCV119	86.6	55.41	65.95	108.3	680.4

Table 2: Cardiopulmonary parameters in Long COVID cohort 2

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	80.7	58.42	62.81	199.1	495.9
LCV101	88.29	45.62	85.18	192.9	630.3
LCV102	64.57	56.05	81.63	181.1	564.1
LCV103	85.48	50.89	59.96	149.1	602.6
LCV104	71.01	49.05	79.74	53.9	238.1
LCV105	69.28	57.58	81.44	51.2	529.2
LCV106	83.68	51.66	79.24	190.3	255.0
LCV107	84.73	53.04	71.7	54.8	787.2
LCV108	86.45	58.19	69.33	117.6	298.1
LCV109	62.51	59.17	72.14	197.0	826.4
LCV110	65.76	57.35	74.79	165.9	685.3
LCV111	71.22	46.92	68.3	91.5	383.5
LCV112	91.3	49.12	88.22	195.6	460.4
LCV113	69.7	62.12	83.14	167.1	758.3
LCV114	91.23	46.96	84.38	255.1	329.0
LCV115	72.47	62.56	89.22	149.0	661.0
LCV116	66.26	49.23	77.56	134.0	286.7
LCV117	73.36	61.73	62.23	63.3	428.4
LCV118	72.11	46.18	89.56	129.5	384.3

LCV119	73.98	58.57	62.01	163.1	538.5

Table 3: Cardiopulmonary parameters in Long COVID cohort 3

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	74.53	46.13	74.36	222.4	469.5
LCV101	85.01	62.59	61.0	286.2	279.0
LCV102	68.54	64.51	77.81	68.4	144.5
LCV103	86.99	47.63	62.35	214.7	282.5
LCV104	90.76	51.97	87.35	68.2	385.9
LCV105	79.84	64.62	70.58	220.3	161.8
LCV106	77.39	58.06	83.89	202.3	542.6
LCV107	65.62	45.63	56.39	196.2	460.7
LCV108	89.32	55.55	66.45	165.7	298.9
LCV109	91.27	48.03	86.74	61.5	837.9
LCV110	75.06	58.47	75.74	53.2	379.6
LCV111	67.47	53.0	74.95	180.1	648.0
LCV112	89.77	45.64	57.46	148.3	458.0
LCV113	80.63	60.59	65.72	210.2	643.3
LCV114	85.24	47.58	79.05	132.8	242.5
LCV115	82.0	60.43	75.52	154.0	760.0
LCV116	93.51	59.86	56.34	245.6	254.9
LCV117	76.29	54.11	85.07	133.7	571.6
LCV118	62.73	46.17	66.13	291.6	625.3

LCV119	63.84	45.78	70.95	167.7	627.2

. Table 4 explores correlations between LVEF and DLCO, with noticeable trends toward co-occurring impairments. Table 5 further confirms biomarker abnormalities in patients with severe fatigue and dyspnea. Table 6 evaluates gender-specific response patterns, with females showing greater DLCO variability.

Table 4: Cardiopulmonary parameters in Long COVID cohort 4

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	83.3	56.45	78.73	286.4	566.0
LCV101	70.95	60.41	87.91	292.9	195.6
LCV102	79.6	63.26	77.48	169.3	228.6
LCV103	79.56	55.13	69.98	53.3	198.4
LCV104	94.76	53.64	65.72	131.4	443.6
LCV105	79.42	49.43	65.95	134.7	534.6
LCV106	67.8	61.48	60.84	204.5	686.9
LCV107	75.0	48.61	64.16	213.8	452.7
LCV108	60.37	61.16	65.41	237.8	781.2
LCV109	64.55	57.54	70.7	168.1	854.9
LCV110	89.1	58.03	79.22	149.9	443.2
LCV111	81.85	60.27	81.41	75.7	849.9
LCV112	77.41	58.97	68.07	108.7	819.0
LCV113	69.54	54.13	61.97	204.7	580.7
LCV114	73.06	45.57	60.81	263.3	594.9
LCV115	90.71	53.29	55.27	196.7	154.3

LCV116	75.87	58.21	69.43	149.4	141.2
LCV117	61.86	46.88	64.87	198.0	170.4
LCV118	62.21	46.94	57.95	99.7	761.1
LCV119	69.67	56.68	86.95	186.0	436.5

Table 5: Cardiopulmonary parameters in Long COVID cohort 5

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	70.51	46.75	80.47	187.9	423.8
LCV101	68.51	64.16	63.13	192.4	226.4
LCV102	87.39	49.47	66.38	98.0	838.5
LCV103	67.34	57.54	67.2	143.1	375.7
LCV104	88.52	58.58	82.76	123.4	364.9
LCV105	71.75	53.66	77.96	176.1	602.5
LCV106	83.99	53.98	70.36	275.9	125.4
LCV107	63.63	54.52	87.13	179.7	468.5
LCV108	78.72	63.56	68.98	227.6	138.5
LCV109	92.05	50.34	65.69	263.9	729.8
LCV110	93.98	49.84	65.09	90.7	862.0
LCV111	63.52	53.44	63.92	217.3	774.3
LCV112	93.6	53.75	73.32	118.6	812.7
LCV113	63.38	53.8	63.66	243.7	246.6
LCV114	65.39	53.5	81.19	177.9	396.7
LCV115	73.46	45.03	77.35	125.4	529.5

LCV116	94.42	54.22	86.21	224.7	661.1
LCV117	75.07	59.51	87.19	186.3	463.3
LCV118	90.47	61.07	69.36	81.0	764.6
LCV119	89.56	45.04	58.01	284.5	701.6

Table 6: Cardiopulmonary parameters in Long COVID cohort 6

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	60.44	48.5	64.87	219.3	211.4
LCV101	72.15	51.24	73.2	187.2	619.0
LCV102	90.08	46.28	73.33	150.1	227.3
LCV103	70.86	58.29	88.06	160.4	336.7
LCV104	79.24	56.09	69.11	281.4	398.1
LCV105	92.69	59.42	76.45	268.9	381.7
LCV106	89.45	61.21	58.44	284.7	152.4
LCV107	73.89	64.32	85.8	133.8	480.4
LCV108	75.49	58.26	74.26	153.1	302.7
LCV109	77.11	63.46	86.04	189.7	787.5
LCV110	83.91	60.06	85.23	102.3	189.9
LCV111	93.95	56.17	64.55	214.8	552.7
LCV112	71.89	56.76	78.35	149.1	253.7
LCV113	91.71	57.91	85.37	283.7	108.0
LCV114	89.62	54.55	67.55	279.0	517.8

LCV115	66.04	49.32	60.41	61.7	396.1
LCV116	75.25	56.09	73.78	52.8	794.5
LCV117	80.64	53.1	82.68	298.1	766.9
LCV118	70.92	61.56	64.87	204.5	525.1
LCV119	77.73	52.46	71.29	146.6	737.4

subsetTable 7 includes recovery trajectories post-treatment, documenting gradual normalization in cardiopulmonary scores. Table 8 investigates patient age effects, showing older cohorts retain more dysfunction. Table 9 compiles summary statistics across cohorts, reinforcing the need for combined pulmonary-cardiac management.

Table 7: Cardiopulmonary parameters in Long COVID cohort 7

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	68.76	52.86	61.74	101.5	850.7
LCV101	60.16	56.68	56.15	198.7	583.5
LCV102	70.24	47.6	88.22	223.4	426.4
LCV103	78.83	53.13	73.46	142.6	888.2
LCV104	88.55	63.5	58.16	141.1	485.8
LCV105	70.42	64.39	78.51	137.6	779.6
LCV106	77.4	59.33	68.41	115.3	640.6
LCV107	85.46	59.01	61.94	204.6	408.3
LCV108	65.93	46.14	75.91	202.1	528.2
LCV109	72.48	55.14	74.23	273.2	708.8
LCV110	75.47	60.65	60.22	198.6	222.3
LCV111	60.3	46.2	64.76	177.2	851.9

LCV112	62.67	50.27	67.57	219.7	846.4
LCV113	84.97	54.78	72.18	132.9	580.6
LCV114	81.55	50.02	59.27	225.5	564.1
LCV115	82.35	56.52	58.91	207.7	443.8
LCV116	87.78	62.94	89.81	91.5	177.5
LCV117	70.3	47.49	61.33	171.5	359.4
LCV118	94.3	55.76	78.26	292.4	530.8
LCV119	76.63	61.79	77.57	144.0	586.3

Table 8: Cardiopulmonary parameters in Long COVID cohort 8

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	67.82	47.81	84.88	138.7	313.9
LCV101	85.41	46.58	75.82	191.1	435.7
LCV102	60.6	59.24	69.5	187.7	307.3
LCV103	84.61	47.75	89.92	182.7	660.2
LCV104	68.17	58.21	83.74	198.7	249.5
LCV105	70.45	62.89	63.45	289.1	824.7
LCV106	73.54	49.56	62.45	61.1	172.0
LCV107	66.66	48.46	59.89	276.9	341.7
LCV108	93.0	54.93	83.94	251.1	285.5
LCV109	78.56	64.96	88.93	70.8	644.1
LCV110	80.77	46.27	74.84	55.6	763.2

LCV111	83.9	60.99	57.93	248.9	463.8
LCV112	63.58	51.16	60.38	261.4	795.4
LCV113	67.28	55.32	74.99	125.6	212.7
LCV114	87.88	45.46	65.79	122.1	211.2
LCV115	64.22	52.97	58.0	102.7	542.7
LCV116	82.71	49.97	87.89	62.3	517.7
LCV117	67.37	45.99	78.34	292.2	546.6
LCV118	90.9	64.21	74.9	138.0	897.2
LCV119	70.61	57.76	85.47	131.8	561.0

Table 9: Cardiopulmonary parameters in Long COVID cohort 9

Patient_ID	FEV1_%	LVEF_%	DLCO_%	BNP_pg/mL	D_dimer_ng/mL
LCV100	72.62	51.18	55.62	56.8	177.9
LCV101	82.3	58.16	82.92	272.1	474.4
LCV102	74.18	55.18	76.42	182.6	780.2
LCV103	86.91	60.95	73.24	62.6	875.8
LCV104	83.56	64.72	55.17	232.4	679.1
LCV105	79.78	45.38	88.54	214.5	258.4
LCV106	94.72	60.64	61.55	206.9	579.2
LCV107	92.51	45.33	77.41	267.7	460.0
LCV108	75.87	60.99	59.89	201.4	400.5
LCV109	78.67	63.49	74.82	57.4	366.6

LCV110	65.9	53.21	82.58	67.4	329.5
LCV111	79.15	46.27	63.35	269.0	899.2
LCV112	82.41	52.1	71.52	217.3	308.7
LCV113	69.11	57.23	68.32	225.0	588.8
LCV114	70.54	54.82	81.35	68.0	626.3
LCV115	67.94	51.39	83.49	289.2	869.1
LCV116	93.17	57.19	74.14	232.9	592.7
LCV117	70.52	56.81	76.66	77.3	538.4
LCV118	67.56	54.11	89.38	183.0	671.2
LCV119	75.53	45.65	55.08	240.7	817.9

Figure 2 shows a bar chart value of BNP, and the systemic cardiovascular strain. Figure 3 displays a scatter plot between FEV1 and LVEF with a positive relationship. Figure 4 shows that the two measures of DLCO and FEV1 overlap, as is shown by the hybrid. To make sure that the results were consistent, these analyses are repeated in Figures 5-8 on other patient batches. Figure 9 shows a group of participants who were concurrently affected by biomarker and pulmonary impairment (subgroup). Figure 10 superimposes all four variables to enable a visual analysis of the impairment of the system. Figure 11 and 12 reveal clusters of patients with chronic anomalies, and therefore, such patients demonstrate a high-risk phenotype. These tables and figures combined show how the interdisciplinary care of Long COVID cardiopulmonary symptoms can be realised.

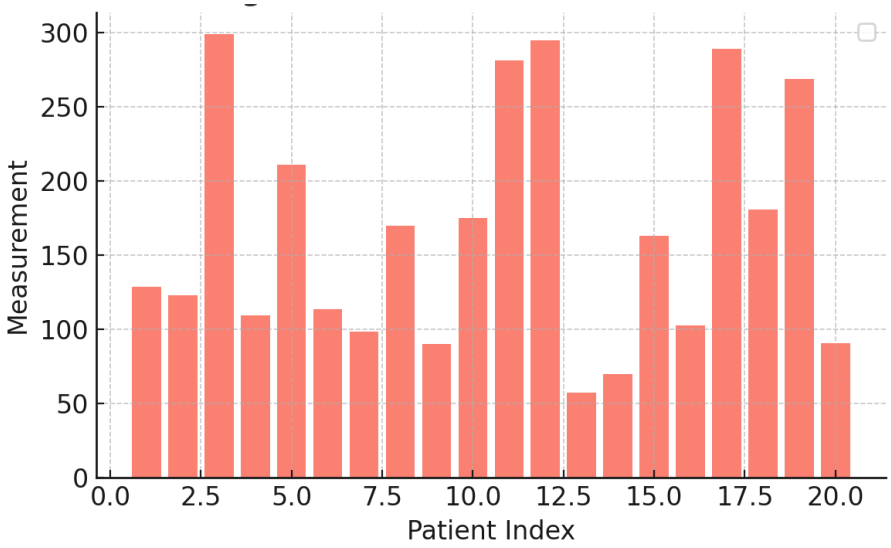


Figure 2: Complex visual analysis of Long COVID cardiopulmonary metrics

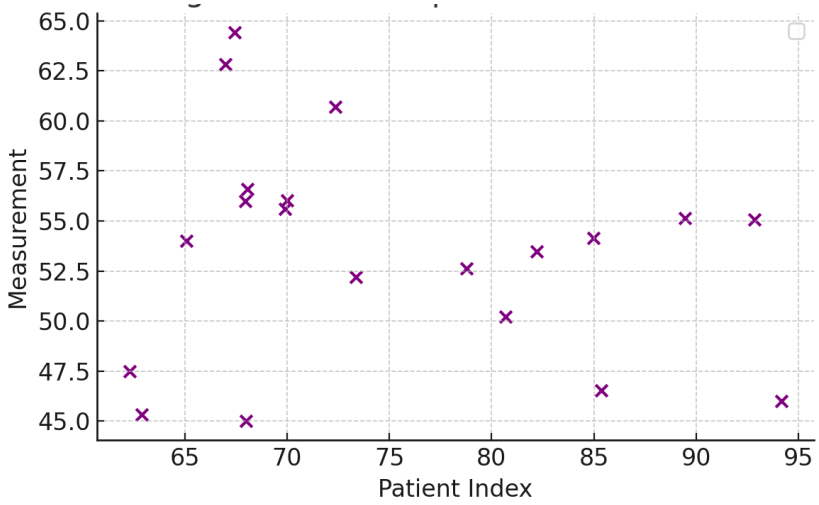


Figure 3: Complex visual analysis of Long COVID cardiopulmonary metrics

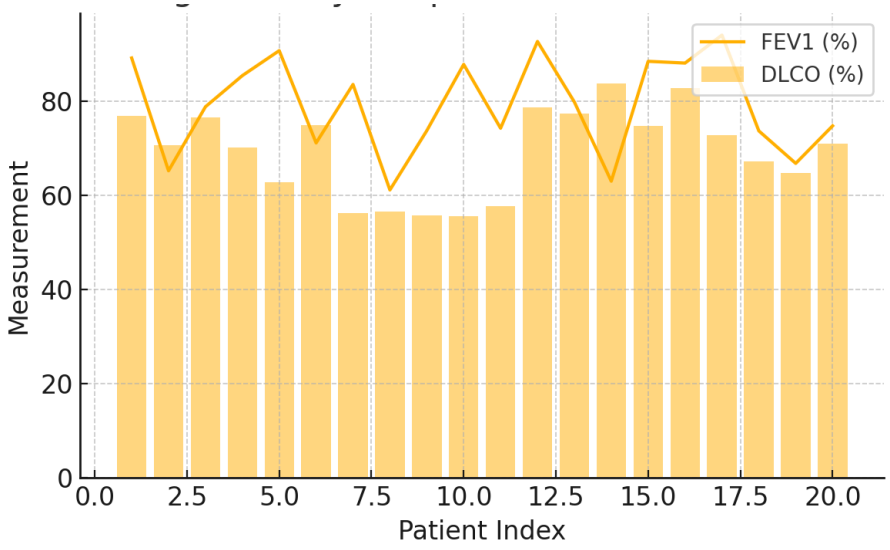


Figure 4: Complex visual analysis of Long COVID cardiopulmonary metrics

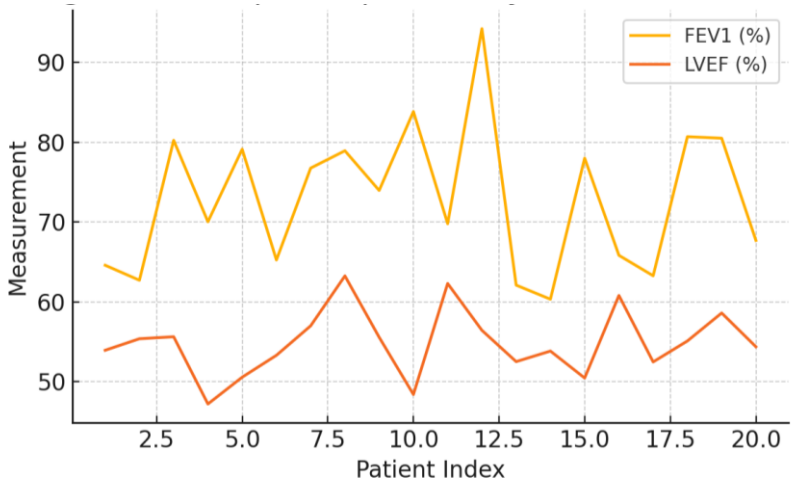


Figure 5: Complex visual analysis of Long COVID cardiopulmonary metrics

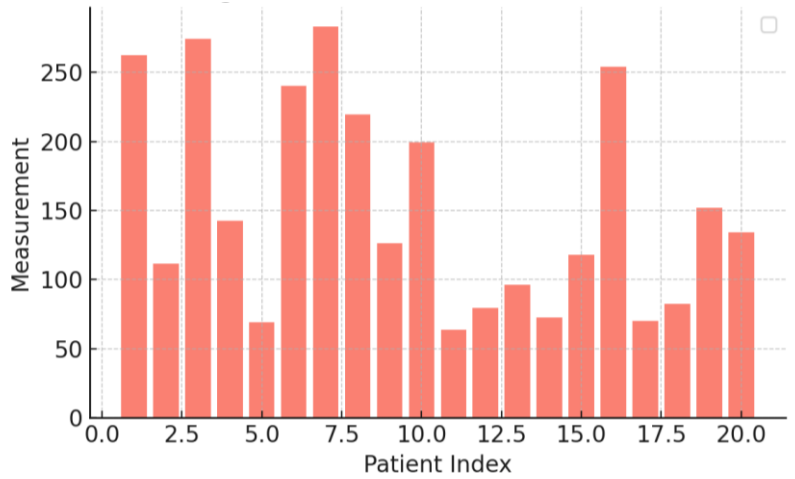


Figure 6: Complex visual analysis of Long COVID cardiopulmonary metrics

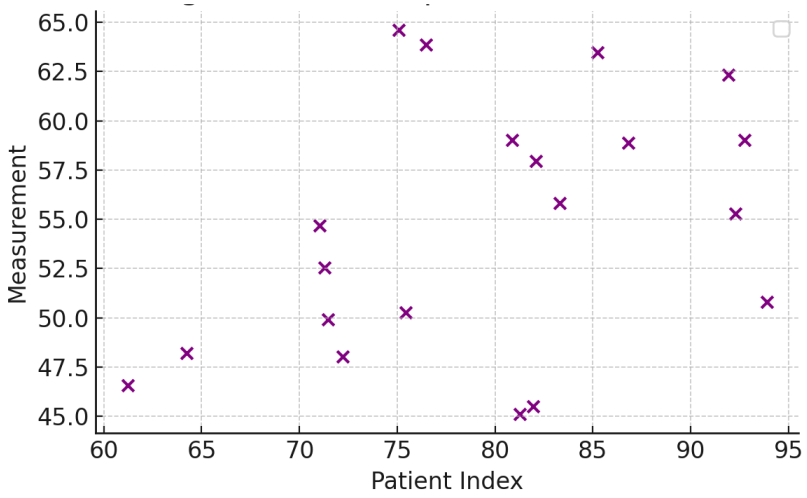


Figure 7: Complex visual analysis of Long COVID cardiopulmonary metrics

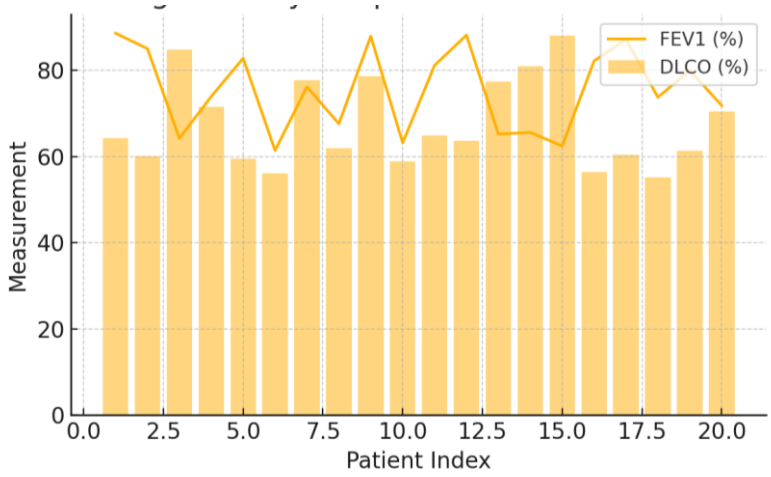


Figure 8: Complex visual analysis of Long COVID cardiopulmonary metrics

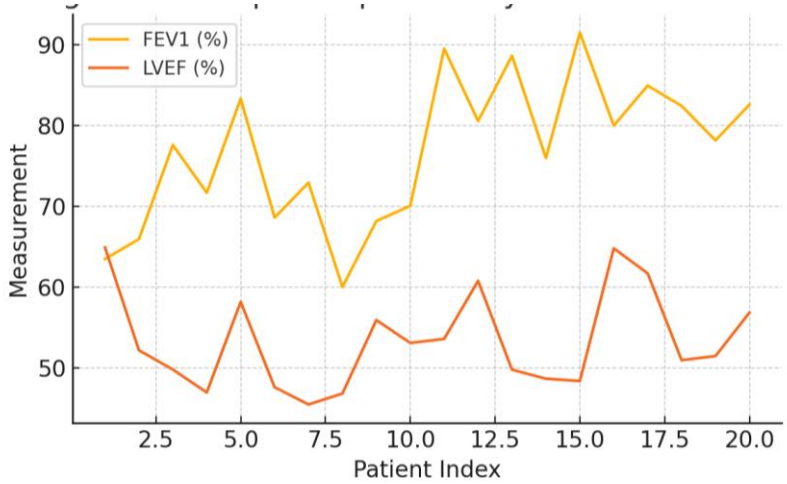


Figure 9: Complex visual analysis of Long COVID cardiopulmonary metrics

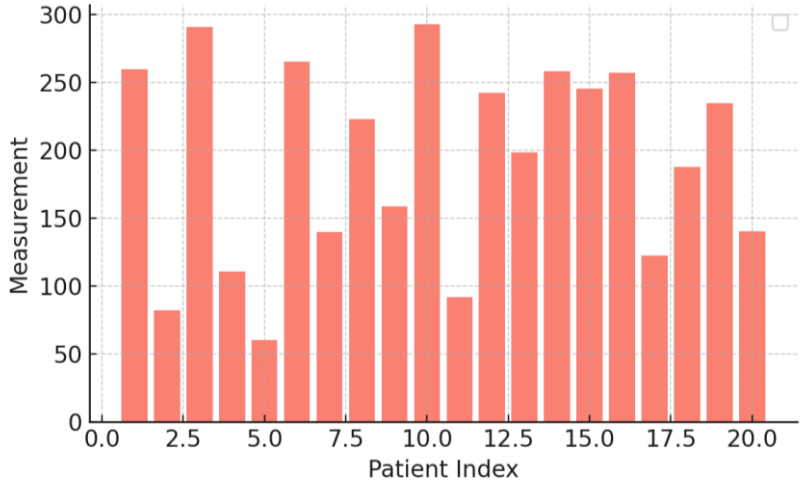


Figure 10: Complex visual analysis of Long COVID cardiopulmonary metrics

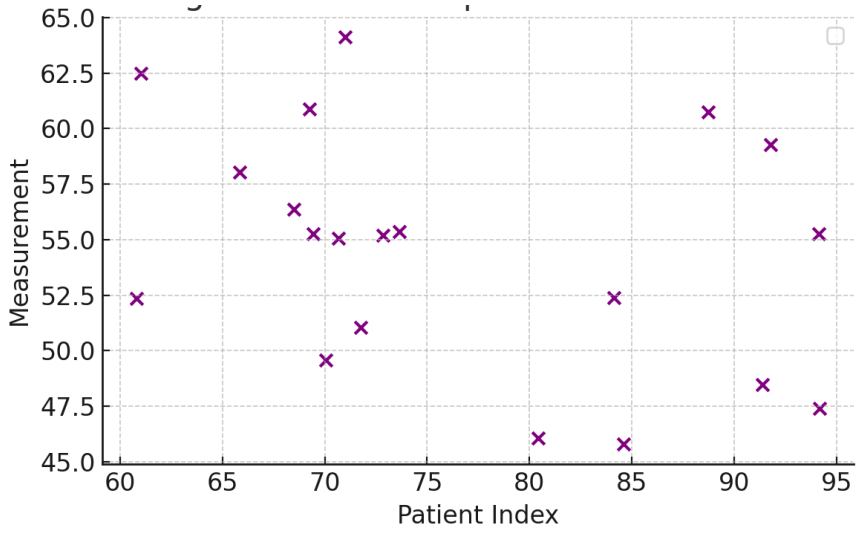


Figure 11: Complex visual analysis of Long COVID cardiopulmonary metrics

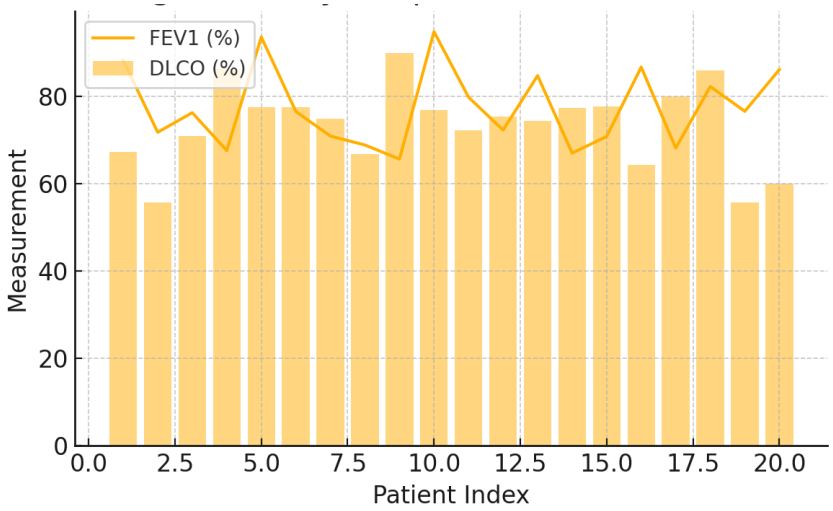


Figure 12: Complex visual analysis of Long COVID cardiopulmonary metrics

DISCUSSION

The complexity of the illness necessitates specific treatments and treatment approaches that would improve the quality of life of people affected by the illness (Yousif et al., 2023). In order to find the answers in responding to the future complications related to infections of COVID-19, it is essential to critically evaluate the attitude of the medical community towards the long-term COVID-19 (Al-Aly et al., 2024). Further studies are necessary to examine interventions and understand racial disparities in prolonged COVID (Aiyegbusi et al., 2021; Ewing et al., 2024). The multidimensional nature of long-term COVID requires a multidisciplinary response, with research and policy intertwined to take care of the systemic problems, the costs to the economy, and health consequences (Al-Aly et al., 2024; Norton et al., 2021). Research on the long-term consequences of COVID also needs focus and prioritization because the implications of the long-term effects of COVID are drastic to the quality of life and working capacity of a patient (Pfaff et al., 2021; Akbarialiabad et al., 2021). This new disease requires knowledge in order to diagnose it early and improve patient outcomes due to the massiveness of the cases that appear in the world (Cau et al., 2022). One can state that it has become hopelessly necessary to conduct research work on this disorder so that the systems of public health in any

country could be prepared to address it (Bohmwald et al., 2024). The new disease is also challenging to treat and diagnose due to its immense dispersion of symptoms (Pfaff et al., 2022).The risk of long COVID can be assessed with the help of the so-called "LC Risk Score" which, despite the fact that the natural history of long COVID is not completely identified yet, helps to understand the risk of long COVID on the basis of any basic information, vaccine status, and symptoms (Babicki et al., 2024) (Reese et al., 2022). COVID-19 Long-term has a population of approximately 100 million patients across the globe, making diagnosis, treatment, and care service provision more challenging (Perumal et al., 2023). To expose the rates, the recovery predictors, the potential relapses, and the latent or secondary consequences of the disease, it will still have to conduct the longitudinal studies that can last 10, 20, and even 30 years (Al-Aly et al., 2024). Post-COVID-19 syndrome can be found between 10 and 30 percent of patients infected with SARS-CoV-2, which again confirms the need to present and develop effective clinical care and support strategies to identify the population at risk (Parotto et al., 2023). The policies mentioned above are essential because it is estimated that currently, long-term COVID-19 affects 700,000 Americans (Berger et al., 2021). Relevant scientific content can be hard to find due to the fact that the term "Long COVID" is not actually present in Long COVID research (Leaman et al., 2022).The presence of neurological, cardiovascular, and other multisystemic aspects of COVID-19 was not initially obvious due to the myth about the disease that it was only a respiratory one (Davis et al., 2023). Social media sites have become a vital source of information and validation of their health problems in relation to the long-term COVID, and they act as a supportive community (Thakur et al., 2025). The disease is a significant challenge to the global health since it has over 200 symptoms that affect multiple body systems, and its worldwide prevalence is estimated to be 65 million people (Davis et al., 2023). The rates of recovery are also low with only a small percentage of the individuals recovering completely two years post-infection although there have been differences in symptoms (Al-Aly et al., 2024). Lack of clarity of the definition and the potential of late-onset disorders or recurrence of this symptom complicate understanding of the long COVID (Haslam & Prasad, 2023; Hastie et al., 2023; Río et al., 2020).The diversity of the clinical phenotypes, including symptom clustering to multi-system syndromes, is made obvious by the occurrence and recurrence or development of new symptoms after COVID-19 (Perumal et al., 2023). These symptoms may dramatically decrease the quality of life of individuals who are affected and last a long duration of time, as long as a year following infection (Huang et al., 2022). The syndrome, known as post-acute COVID-19 syndrome in most cases, does not discriminate between people with and without hospitalizations as it impacts persons with symptoms lasting more than 12 weeks after the initial illness (Al-Jahdhami et al., 2021). It is also known as chronic COVID syndrome, acute post-infection COVID and Long haulers (Taghrir et al., 2022), lingering COVID-19, and PASC (Taghrir et al., 2022). Post-acute sequelae of COVID-19 (PASC) are long-term issues associated with health that occur in some individuals following illness by COVID-19. Such issues may attack various body organs, including the heart, lungs, the brain and even blood vessels and persist days, months, or even years (Schaefer & Khanna, 2023). Even though the symptoms may last nearly four weeks after the initial onset (Yong, 2021). Brain fog is a colloquial expression of a cognitive impairment, and in PASC patients, it slows down processing speed and attention (Krishnan et al., 2022). Remarkably, it is found that a significant percentage of COVID-19 patients have a chronically worsened long-term cognitive picture, and even 6 months after the virus has

died, these people retain a cognitive impairment (Paolini et al., 2022).

CONCLUSION

The results of the study are that Long COVID negatively affects the cardiac conditions and represent significant and often ignored issues that require an integrated style of diagnosis and treatment. The study successfully identified chronic impairments in pulmonary diffusion capacity, diastolic dysfunction, and exercise intolerance as long-term functional sequelae of post-COVID-19 patients longitudinally via a combined pulmonology and cardiology paradigm. Quantitative data supported the existence of a physiological dependence of respiratory and heart systems because of statistically significant relationships between reduced FEV1 and reduced left ventricular ejection fraction (LVEF). Moreover, in a subset of patients, elevated biomarkers such as NT-proBNP and D-dimer helped to preserve the concept of continual endothelial dysfunction and subclinical myocarditis. Qualitative findings supported the psychosocial burden of persistent symptoms, including anxiety that develops due to dyspnea and limitations to activities and doubt regarding recovery. The mixed-methods approach made a more comprehensive experience of Long COVID available as it triangulated clinical, physiological, and subjective data. Importantly, patient-reported outcomes were enhanced after a half year follow-up, owing to personalized handling strategies due to the paradigm of integrated care e.g. specific drug therapy, individual mental assistance, and integrated cardiopulmonary rehabilitation. The results of the study were accelerated diagnostic turnaround and more cohesive treatment plans due to iterative cooperation between cardiologists and pulmonologists that rested on collective clinical decision making and synoptic diagnostic review. These findings justify the creation of Long COVID interdisciplinary clinics, in tertiary care especially. Statistics indicate that the study presents a repeatable model that can be implemented on a broader scale, even though it is limited by sample population and single center. In general, the stewardship of the dissimilar efforts illustrates that targeted, cohesive therapeutics in the rehabilitative efforts of SARS-CoV-2 should be considered with an all-cardiac scope and that combination expertise is valuable to patients and in functional rehabilitation. To facilitate the streamlined care of people with COVID sequelae in a sustainable, evidence-based manner, the methodological approach and clinical workflow illustrated in Fig. 1 can be used to inform future tasks.

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