ORIGINAL ARTICLE

Investigating Post-Covid Vital Signs: A Study of Physiological Parameters in Patients Recovering from COVID-19

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ABSTRACT

Introduction: The Severe Acute Respiratory Syndrome Coronavirus, which causes COVID-19, has a significant post-infection impact on affected persons. This study aimed to assess the long-term effects of COVID-19 on vital signs—respiratory rate, blood pressure, pulse rate, oxygen saturation, and forced expiratory rate. **Methods:** We surveyed 200 participants (aged 18-40) from MAHSA University, including 95 recovered COVID-19 patients and 105 non-infected individuals. Data collection involved spirometry, digital sphygmomanometer, pulse oximetry, and stopwatch recordings. Data analysis was done using SPSS software version 26 employing descriptive and analytical statistics. Independent t-test and a one-way ANOVA test were used for analysis. **Results:** Independent t-test revealed no significant differences between COVID and non-COVID groups in systolic/diastolic blood pressure, pulse rate, respiratory rate, and forced expiratory rate. However, oxygen saturation (p-value = 0.024) differed significantly. A comparison of the mean of the vital signs using the ANOVA test between the different post-recovery periods (0-6 months, 6-12 months, and more than 12 months) showed no significant changes. Yet, the oxygen saturation (p-value = 0.012) differed significantly. No associations were found between gender, ethnicity, blood group, and COVID status. **Conclusion:** Recovering COVID-19 patients exhibit decreased oxygen saturation post-infection. Other vital signs remain largely unaffected. This study emphasizes how crucial it is to comprehend how long-term COVID-19 affects lung function and vital signs to explore its consequences in daily life.
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INTRODUCTION

COVID-19 is a virus that has become prevalent and caused a worldwide pandemic. Individuals who were infected experienced symptoms related to the respiratory system and the cardiovascular system (1). This was later called Long COVID, which is defined as signs, symptoms, and conditions that continue or develop 4 weeks or more after initial COVID-19 infection (2). Some of the reported symptoms include headaches, myalgia, palpitations, chest and joint pains, cognitive and mental impairments, taste and smell dysfunctions, cough, and problems with the heart and gastrointestinal tract (3). Significant upper lung involvement has been found in 80% of the cases with onset of symptoms such as dyspnoea, cough, fever, and hypoxemia which have been demonstrated by abnormalities in pulmonary function tests (2). COVID-19 can also cause post-COVID cardiovascular sequelae such as acute ischemic injury (such as myocardial infarction), heart failure, stress cardiomyopathy, Postural Orthostatic Tachycardia Syndrome (POTS) and myocarditis (2). Palpitations, dizziness, elevated resting heart rate, and chest pain or tightness are the most prevalent cardiovascular (CV) symptoms seen in post-acute COVID-19 syndrome (PACS) patients. Despite increasing evidence regarding the long-term effects of COVID-19, there are still significant gaps in our understanding of its impact on younger, otherwise healthy adults. Most existing studies focus on older populations or those with pre-existing health conditions, which leaves the effects of COVID-19

on vital signs (such as respiratory rate, blood pressure, and pulse rate) in younger adults (ages 18–40) largely unexplored. Furthermore, there is a lack of longitudinal data that compares recovery periods (for instance, 0–6 months versus more than 12 months) to evaluate trends in oxygen saturation and other vital signs. This study aims to fill these gaps by investigating a uniform group of young, healthy adults without prior health issues, employing a cross-sectional design to compare those who have recovered from COVID-19 with non-infected individuals, and analyzing differences across various recovery phases to address inconsistencies found in the current literature. Our objectives of the study were to compare vital signs (systolic/diastolic blood pressure, pulse rate, respiratory rate, oxygen saturation) and peak expiratory flow rate (PEFR) between individuals who recovered from COVID-19 and non-infected controls, to assess variations in the vital signs among COVID-19-recovered participants across different post-recovery periods (0–6 months, 6–12 months, >12 months) and to evaluate the association between demographic factors (gender, ethnicity, blood group) and COVID-19 status to alterations in vital signs. The hypothesis of this study is individuals recovering from COVID-19 will show significant alterations in vital signs (blood pressure, pulse rate, respiratory rate, and oxygen saturation) and PEFR.

MATERIALS AND METHODS

Study design & sample size

The study design is a cross-sectional study involving 200 participants from MAHSA University, consisting of 95 people who have had COVID-19 before within the last year and 105 participants who never had COVID-19 as a control group. The sample size was determined based on prior research by Mohamed et al. (3). The calculation was done using an online tool https://www.stat.ubc.ca/~rollin/stats/ssize/n2a.html (4) based on the PEFR (μ1 = 6.05, μ2 = 6.58, sigma = 1.25 in the study. Utilizing these parameters, along with a power of 0.8 and a significant value of 0.05, the required sample size was calculated to be 88 participants per group. To account for potential dropouts, we increased the sample size to 95 participants in the COVID-19 recovered group and 105 in the non-COVID-19 group.

Inclusion criteria

The inclusion criteria for participants included in the study were, students and staff of MAHSA University aged 18-40, recovering from COVID-19 in the timespan of under a year, who were fully vaccinated against COVID-19 before infection.

Exclusion criteria

Participants were excluded from the study if they had pre-existing conditions affecting the cardio-respiratory system such as diabetes, hypertension, ischemic heart disease, cystic fibrosis, asthma, or any other related health issues. Figure 1 shows the flowchart of the participant recruitment.

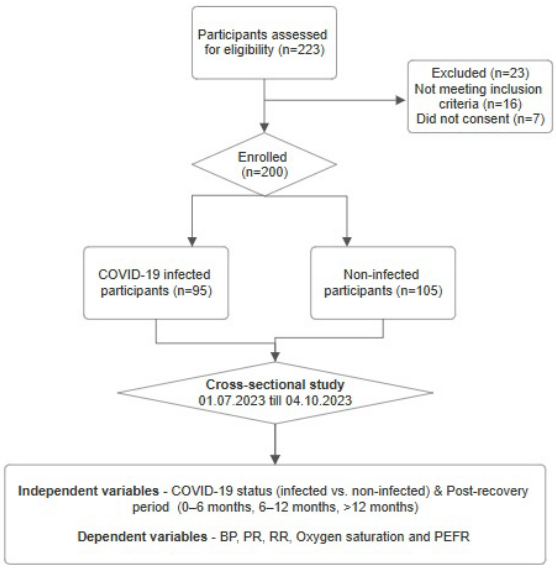

Figure 1: Flowchart of recruitment of participants

Procedure

Ethical approval for this study was obtained from MAHSA University (Ref. no. FOMBN/ EC/Feb 23/ 06). After obtaining informed consent, this study followed a structured process to collect participants' vital signs and demographic information. The procedure involved measuring key vital signs such as blood pressure, respiratory rate, heart rate, oxygen saturation, and peak expiratory flow rate. The tools used were a digital sphygmomanometer for blood pressure (5), a pulse oximeter for oxygen saturation and heart rate (6), a stopwatch for respiratory rate (7), and a peak flow meter for measuring peak expiratory flow rate (8). Data was systematically recorded using a Google Form and subsequently analyzed with SPSS version 26.

Before data collection, all participants were provided with an informed consent form. The form explained the study's objectives, procedures, and confidentiality measures to ensure voluntary participation. Participants were allowed to ask questions and were required to fill out the online consent form if they were willing to participate.

Blood pressure was measured using a digital sphygmomanometer with the participants sitting comfortably with their arm resting at heart level. Participants were asked to relax and remain still while the sphygmomanometer automatically measured systolic and diastolic blood pressure. Two readings were taken for accuracy, with an interval of a few minutes between readings. The average of the two readings was recorded.

The respiratory rate was measured by visually counting the number of breaths over one minute. To minimize

participant awareness, the observer discreetly observed chest movements during blood pressure and heart rate measurements.

Heart rate and oxygen saturation were measured using a pulse oximeter. Once the readings were stabilized on the oximeter screen, the values were recorded. The participant was asked to sit still during the measurement to avoid fluctuations in the readings.

A peak flow meter was used to measure the Peak Expiratory Flow Rate (PEFR). The participant was instructed to stand and hold the peak flow meter. They were asked to take a deep breath, and then exhale as forcefully as possible into the mouthpiece of the spirometer. This was repeated three times to ensure consistency, and the highest reading of the three was recorded as the participant's PEFR. The mouthpiece was changed between participants to maintain hygiene.

All data, including participants' demographic information (age, gender, etc.), along with their vital sign measurements (blood pressure, heart rate, respiratory rate, oxygen saturation, and PEFR), were recorded in real-time using a Google Form. The form was designed to capture all relevant variables, ensuring consistency in data entry.

Data Analysis

Once data collection was completed, responses from the Google Form were compiled into a spreadsheet. The data was then imported into SPSS version 26 for statistical analysis. Descriptive statistics were calculated for each variable (e.g., mean, median, and standard deviation). An independent t-test was done to compare the means of the systolic/diastolic blood pressure, pulse rate, respiratory rate, and PEFR between the non-COVID-19 and COVID-19 groups. A one-way ANOVA test was done to compare the means of the vital signs among the various recovery periods within the COVID and non-COVID groups.

Data integrity was maintained by cross-checking the values entered into the Google Form with the raw data collected from the devices, ensuring accuracy before analysis.

RESULTS

In this study, a total of 200 participants were randomly selected. 95 participants (47.5%) had been infected with COVID-19 before and 105 participants (52.5%) had never been exposed to COVID-19 (Table I). The association of the COVID status of the participants with gender (p-value = 0.596) and ethnicity (p-value = 0.462) was analyzed using the Chi-Square test indicating that there was no statistically significant association between developing COVID-19 infection with gender and ethnicity. An independent t-test showed a significant difference in oxygen saturation (p-value=0.024) between the infected and the non-infected participants. No significant difference was observed in the other variables in the two groups. The data were further categorized within their recovery months. Comparison of the means of systolic blood pressure (p-value = 0.418), diastolic blood pressure (p-value = 0.784), pulse rate (p-value = 0.185), respiratory rate (p-value = 0.382), PEFR (p-value = 0.522) and oxygen saturation (p-value = 0.012) were done using a one-way ANOVA test in non-COVID-infected participants and COVID-19 participants subgroups as per their recovery periods. (Table II & Table III). Further analysis using Games-Howell post-hoc tests compared oxygen saturation among the different recovery periods (e.g., 0–6 months, 6–12 months, and more than 12 months) for patients who had COVID-19. No significant difference was noted (p-value = 0.969) when comparing the oxygen saturation mean between 0–6 months and 6–12 months. However, there was a significant difference (p-value= 0.010) between the groups with the post-recovery period of 6-12 months and more than 12 months (Table IV).

Table I: Frequency of gender and ethnicity of participants with their Covid status

		Covid (n=95)	Non Covid (n=105)
Gender	Male	38 (40 %)	39 (37.14 %)
	Female	57 (60%)	66 (62.85%)
Ethnicity	Malay	34 (35.78%)	42 (40%)
	Chinese	22 (23.15%)	24 (22.85%)
	Indian	27 (28.42%)	21 (20%)
	Others	12 (12.63%)	18 (17.14%)

There was no statistically significant association between developing COVID-19 infection with gender and ethnicity.

DISCUSSION

The parameters investigated in our study encompassed blood pressure, oxygen concentration, respiratory rate, pulse rate, and peak expiratory flow rate (PEFR).

The blood pressure readings obtained from the participants did not exhibit any unusual patterns, as evidenced by the ANOVA One-way test. This could be possibly explained by the age and overall health status of the participants included in our study. However, in the study conducted by Caillon, significant associations were found between hypertension and systolic blood pressure (SBP) with mortality and respiratory distress indicators. To predict the likelihood of death, a penalized logistic regression model was utilized by Caillon and SBP emerged as a covariate in both the mortality and survival prediction models, indicating its significance in patient outcomes. It was observed that SBP was

Table II: Mean, standard deviation, and standard error of the mean of the vital signs recorded among the COVID-19 and non-COVID-19 participants

Variables	Had COVID infection?	Mean	Std. Deviation	Std. Error Mean
Systolic BP	Yes (n=95)	118.32	14.57	1.49
	No (n=105)	118.06	14.54	1.42
Diastolic BP	Yes (n=95)	74.51	10.76	1.10
	No (n=105)	74.13	9.17	0.89
Pulse rate	Yes (n=95)	84.64	16.35	1.68
	No (n=105)	83.97	15.35	1.50
Respiratory rate	Yes (n=95)	18.96	4.23	0.43
	No (n=105)	18.18	3.59	0.35
PEF rate	Yes (n=95)	441.00	116.36	11.94
	No (n=105)	419.33	121.26	11.83
Oxygen saturation	Yes (n=95)	97.64	2.06	0.21
	No (n=105)	98.24	1.64	0.16

elevated in deceased COVID-19 patients compared to those who were discharged, suggesting a potential link between higher blood pressure and the post-COVID-19 phase (9). Furthermore, the study reveals that there was no significant difference in the pulse rate between the COVID-19 and non-COVID-19 participants. This suggests that the cardiovascular impact of COVID-19 on these vital signs may be relatively transient or less pronounced during the post-acute phase of recovery. These results raise intriguing questions regarding the long-term effects of COVID-19 on cardiovascular health, warranting further exploration and follow-up research to elucidate the complex relationship between COVID-19 and cardiovascular parameters during the extended recovery period (10).

The reduction in oxygen saturation levels observed among individuals recovering from COVID-19 can be attributed to the harm inflicted upon alveolar cells during the COVID-19 infection. Alveolar cells are crucial components of the lung's air sacs responsible for facilitating the exchange of oxygen and carbon dioxide between the air and the bloodstream (11). The damage to these cells incurred during the infection can impair their ability to efficiently carry out this exchange process, leading to a decrease in oxygen saturation levels in the blood. Given the importance of oxygen levels in assessing respiratory health, further research focusing on this parameter could clarify whether patients continue to experience oxygen desaturation even after the acute

Table III: Comparison of the means of the vital signs recorded among the COVID-19 and non-COVID-19 participants using one-way ANOVA test

Variables	Post-COVID recovery period	N	Mean	Std. Deviation	p-value
Systolic BP	**0-6 months**	26	120.27	9.602	
	6-12 months	53	117.66	17.029	
	more than 12 months	16	117.31	12.726	.418
	never had covid	105	118.06	14.536	
	Total	200	118.18	14.516	
Diastolic BP	**0-6 months**	26	77.19	8.695	
	6-12 months	53	73.75	11.724	
	more than 12 months	16	72.63	10.223	.784
	never had covid	105	74.13	9.169	
	Total	200	74.31	9.932	
Pulse rate	**0-6 months**	26	86.15	14.737	
	6-12 months	53	84.92	16.951	
	more than 12 months	16	81.25	17.322	.185
	never had covid	105	83.97	15.351	
	Total	200	84.29	15.796	
Respiratory rate	**0-6 months**	26	20.00	4.040	
	6-12 months	53	18.42	4.478	
	more than 12 months	16	19.06	3.568	.382
	never had covid	105	18.18	3.586	
	Total	200	18.55	3.917	
PEF rate	**0-6 months**	26	438.46	145.236	
	6-12 months	53	435.85	94.063	
	more than 12 months	16	462.19	135.806	.522
	never had covid	105	419.33	121.260	
	Total	200	429.63	119.156	
Oxygen saturation	**0-6 months**	26	97.27	2.601	
	6-12 months	53	97.53	1.957	
	more than 12 months	16	98.63	.806	**.012**
	never had covid	105	98.24	1.644	
	Total	200	97.96	1.871	

Comparison of the means of systolic blood pressure (p-value = 0.418), diastolic blood pressure (p-value = 0.784), pulse rate (p-value = 0.185), respiratory rate (p-value = 0.382), PEFR (p-value = 0.522) and oxygen saturation (p-value = 0.012) were done using a one-way ANOVA test in non-COVID-infected participants and COVID-19 participants.

Table IV: Multiple comparisons of means of oxygen saturation among the different recovery periods using Games-Howell posthoc tests

Games Howell (I) post-covid recovery period	Games Howell (J) post-covid recovery period	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0-6 months	**6-12 months**	-.259	.577	.969	-1.81	1.29
	more than 12 months	-1.356	.548	.084	-2.84	.13
	never had covid	-.969	.535	.288	-2.42	.48
6-12 months	**0-6 months**	.259	.577	.969	-1.29	1.81
	more than 12 months	-1.097*	.336	**.010**	-1.98	-.21
	never had covid	-.710	.313	.114	-1.53	.11
more than 12 months	**0-6 months**	1.356	.548	.084	-.13	2.84
	6-12 months	1.097*	.336	**.010**	.21	1.98
	never had covid	.387	.258	.446	-.31	1.08
never had covid	**0-6 months**	.969	.535	.288	-.48	2.42
	6-12 months	.710	.313	.114	-.11	1.53
	more than 12 months	-.387	.258	.446	-1.08	.31

Games-Howell post-hoc tests showed no significant difference (p-value = 0.969) when comparing the oxygen saturation mean between 0–6 months, and 6–12 months. However, there was a significant difference (p-value= 0.010) between the groups with the post-recovery period of 6-12 months and more than 12 months.

phase of infection.

Our study did not show a statistically significant change in the respiratory rate of post-COVID patients. In contrast to our results, some studies have shown an increased respiratory rate observed in post-COVID patients. In the context of post-COVID syndrome, Mahmud et al found that approximately 46% of patients with tachypnoea developed post-COVID-19 syndrome (12). COVID-19 can cause long-term harm to lung tissue, potentially leading to decreased lung capacity. As a result, people may need to breathe more quickly to compensate for the reduced volume of air that can be accommodated in their lungs (13). Furthermore, the virus can disrupt the body's regular respiratory systems. This modification could involve disturbances in breathing muscle coordination, alterations in lung compliance, or other physiological adjustments that impact respiratory performance. These changes can result in an increased respiratory rate as the body seeks to improve the flow (12). The absence of a significant change in the respiratory rate in our study could be attributed to the relatively mild cases of COVID-19 among our participants or the timing of the assessment, which may have been after sufficient recovery of lung function. Additionally, variations in the methodologies used across studies, such as a lack of information on the severity of COVID-19 cases in our study, might explain the discrepancy in findings regarding respiratory rate changes.

These findings emphasize the vital significance of ongoing monitoring and respiratory assistance for persons in the post-COVID phase of recovery, particularly during physical exercise. The consequences of these findings are significant, as they show that continuing vigilance and tailored treatments are required to maintain the well-being of those who have battled COVID-19 and are now in the recovery phase. This is especially important at times of high physical activity, when the respiratory system may be under significant strain.

Finally, we turn our attention to the peak expiratory flow rate (PEFR). While this study represents the first exploration of PEFR in the context of post-COVID-19, it is crucial to recognize that this method has been successfully employed in other diseases like bronchial asthma and COPD to monitor the progression of the disease. It can help identify the patients who are more likely to experience worse clinical outcomes (14). A decrease in PEFR in post-COVID-19 patients is a marker of diminished respiratory function (15). However, there was no significant decrease in PEFR in our study group. This particular outcome presents intriguing questions that should be investigated further. To fully comprehend this phenomenon, it is necessary to investigate various contributing elements that may explain the absence of divergence. The possible reasons could be attributed to the younger age group of the participants (18-40) and the mild nature of the COVID-19 infection among our participants. Unfortunately, we did not collect data on the severity of the COVID-19 infection which limits the interpretation of this finding. Other considerations could also include the existence of comorbidities,

differences in baseline lung function, or other variables not adequately accounted for in the study design.

In conclusion, the study's findings emphasize the necessity of ongoing monitoring and support for individuals in the post-COVID phase, especially during physical exertion. This will enhance the quality of life (QoL) of individuals post-COVID. A study by Hawlader showed that QoL was lower in the post-COVID groups and it affected the physical, social, psychological, and environmental domains (16). Continued home monitoring of PEFR might help improve individuals' physical quality of life. The absence of significant differences in PEFR and vital signs between the COVID and non-COVID participants in our study prompts further investigation into the underlying factors and long-term cardiovascular effects of COVID-19. This research is pivotal in shaping our understanding of the comprehensive impact of the virus on the health of individuals in the post-acute phase of recovery.

Our research explores the lingering effects of COVID-19 in individuals after recovery, specifically honing in on respiratory issues. It highlights the decreased oxygen saturation due to alveolar cell damage and altered lung mechanics due to the virus (17). This study emphasizes the importance of continuous monitoring and respiratory support, especially during exertion, and interestingly notes the lack of significant differences in vital signs such as blood pressure, Peak Expiratory Flow Rate (PEFR), respiratory rate, and pulse rate between COVID and non-COVID participants during the post-acute phase.

Upon completion of this research project, several shortcomings must be taken into account. The first was the limited amount of time in which the study was conducted. This causes an inability to look for trends, follow up, or look back at participants' relevant medical history for a more in-depth study. Besides, the small demographic of participants solely from Mahsa University impacts the generalizability of this study across the board due to environmental factors that may impact findings. Apart from that, our study does not explore the underlying pathophysiological mechanisms of the findings and is predominantly focused on the observation of vital signs. The lack of funding and laboratory facilities also impact the accuracy of the estimation of participants' lung function as peak expiratory rate is not the most representative of lung function.

In the realm of future research, a proactive approach could tackle these constraints head-on. Firstly, a larger scale of research should be done on a large demographic of participants to improve the generalizability of the findings and study. Aside from that, by incorporating comprehensive physiological assessments, we might uncover intricate dynamics hidden beneath the surface. Furthermore, delving into the efficacy of targeted interventions offers a promising avenue for enhancing post-COVID vital signs. Through these endeavours, a more holistic understanding emerges, underpinning both the broader context and the underlying pathophysiological mechanisms at play. This multifaceted approach propels us closer to unraveling the intricacies of post-COVID recovery and Long COVID syndrome.

CONCLUSION

According to our study, COVID-19 may result in lasting effects on respiratory function. Such variations can be caused by a range of reasons, such as underlying comorbidities, persistent inflammation, or pathophysiological changes carried from the viral infection. The understanding of the post-COVID-19 situations can be improved by further investigations in this area, which will also help us build better treatment and care plans for post-COVID patients.

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