ORIGINAL ARTICLE

Covid-19 Aftermath: Spirometric and Ultrasonographic Insights into Pulmonary Health of IIUM Kuantan Female Undergraduate Students

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ABSTRACT

Background: COVID-19 has significantly impacted the public, leading to decreased pulmonary function, reduced quality of life, and increased mortality rates and healthcare burdens. The outbreak of COVID-19 has triggered a profound sense of fear and uncertainty regarding health status among individuals, communities, and nations. A specific public health concern related to COVID-19 is the potential for long-term respiratory complications that can affect pulmonary function. **Methods:** A cross-sectional study was conducted with 61 student volunteers from IIUM Kuantan, divided into COVID-19-virgin (n=32) and Post-COVID-19 (n=29) groups. Spirometry and ultrasound examinations were performed to evaluate pulmonary function and diaphragmatic mobility. Participants first underwent a spirometry test, followed by a diaphragmatic mobility assessment using ultrasound, with measurements taken on the right diaphragm during three respiratory actions;: quiet breathing, deep breathing, and voluntary sniffing. The data were analyzed using SPSS version 29.0 with Descriptive Analysis, Mann-Whitney U, and Spearman Correlation tests. **Result:** Among the participants, 51.6% were COVID-19-virgin (n=32), and 46.8% were Post-COVID-19 (n=29). All Post-COVID-19 participants were in Stage-2 of the disease. The Mann-Whitney U test revealed no statistically significant differences in FVC, FEV1, and FEV1/FVC between COVID-19-virgin and Post-COVID-19 participants. However, a statistically significant correlation in diaphragmatic mobility was found during deep breathing, with a moderate negative linear relationship (p = 0.006, r = -0.351). No statistically significant differences were found in diaphragmatic mobility during quiet breathing and voluntary sniffing. **Conclusion:** The findings suggest that Post-COVID-19 individuals may experience reduced diaphragmatic mobility during deep breathing despite normal spirometric parameters, indicating potential differences in pulmonary health between the groups. The decreased diaphragmatic mobility observed in Post-COVID-19 individuals warrants further investigation to understand the underlying mechanisms and long-term implications.

INTRODUCTION

A key concern regarding COVID-19 is the long-term respiratory sequelae that can impact public health and pulmonary function. Some individuals will experience long-term respiratory complications right after recovering from the acute phase of the disease. This syndrome is frequently referred to as "post-acute sequelae of SARS-CoV-2 infection" or "long COVID." While the majority of individuals who contract COVID-19 fully recover, approximately 10-20% of patients experience a range of medium- and long-term sequelae following their initial illness (Ahmad et al. 2021).

The long-term impact of COVID-19 is characterized by persistent symptoms beyond three months post-infection. The impact on lung function is substantial and has a wide range of effects, affecting many survivors. Studies have shown that even patients with non-severe COVID-19 experience long-term reductions in pulmonary function, functional capacities, and physical activities, necessitating extended healthcare and rehabilitative programs (Alshammari, Shanb, Alsubaiei & Youssef, 2024). Persistent symptoms such as fatigue, dyspnoea, and chest pain are common in prevalence of long-term COVID-19 even months after recovery from the initial infection regardless of the severity of the acute phase of COVID-19 (Tunçer et al, 2023; Patil et al., 2023).

The lungs are the most organ affected by COVID-19 (Mo et al. 2020), so there is no doubt it can affect the respiratory system in a person. Since the long-term consequences of COVID-19 infection on pulmonary function in young adults remain unclear, further studies are necessary to investigate the potential impact of the virus on lung capacity, respiratory efficiency, and overall pulmonary health in this population. While some patients show normal results on pulmonary function tests and echocardiography, they may still experience impaired volitional diaphragm function and control, which

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correlates with exertional dyspnea (Hadda et al., 2022). Despite the exponential increase in scientific publications and global collaboration on managing acute COVID-19 infection over the last two years, the long-term health effects on COVID-19 survivors remain unresolved. Thus, the present study aimed to investigate the impact of COVID-19 on pulmonary health among undergraduate students at the International Islamic University Malaysia (IIUM) Kuantan, Pahang.

MATERIALS AND METHODS

Ethical Approval

After obtaining ethical approval from the Kulliyyah Postgraduate and Research Committee (Reference no.: IIUM/310/14/11/2 ID No. KAHS 8/24) and IIUM Research Ethics Committee (IIUM/504/14/11/2/ IREC 2024-KAHS/DDIR), a cross-sectional study was conducted among the COVID-19-virgin and Post-COVID-19 who met the inclusion criteria from March 2024 until July 2024.

Participants Recruitment

A total of 32 participants were classified as COVID-19-virgin as they had not been infected with COVID-19. In contrast, 29 participants were classified as Post-COVID-19 being in Stage-2 of COVID-19 based on the COVID-19 Management Guidelines in Malaysia. Ministry of Health (MoH) stated that this group of people with Stage-2 were all symptomatic with no pneumonia detected. Most of them experienced the same common symptoms which are fever, cough, sore throat, fatigue, and headache. None of them were hospitalised during the infection, thus enough for them to fall under the mild level of the National Institute Health (NIH) classification. All 61 participants, including both the COVID-19-virgin (n=32) and Post-COVID-19 (n=29) groups, underwent spirometry and diaphragmatic mobility assessments.

Spirometry Assessment

The main outcome measurements for this assessment are forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and their ratio, FEV1/FVC. According to the American Thoracic Society, as mentioned and suggested by Jenkins et al. (2014), the highest values of FVC and FEV1 were selected as the most suitable values for analysing and representing pulmonary function. In addition, the FEV1/FVC ratio is also indicative of the volume of air that is expelled from the lungs within the initial second of a forced expiration (Lutfi, 2017). Prior to the assessment, participants were advised to wear comfortable, loose-fitting clothing and to loosen their belts if necessary, to facilitate optimal inhalation and exhalation during the procedure (Güçsav et al., 2023).

The participant was positioned in a sitting while a mouthpiece and a nose clip were given to ensure no air escaped through the nasal passages. The mouthpiece was put inside the designated hole or turbine and gently placed in the participant's mouth. Subsequently, the participant was instructed to perform a deep inhalation through the oral cavity to the fullest extent feasible, followed by forcibly exhaling the air into the designated tube. Following the spirometry assessment, the key parameters of FVC, FEV1, and FEV1/FVC were recorded for each participant. The test was performed a minimum of three times, and the average values were documented.

Diaphragmatic Mobility Assessment

Based on Sierra et al (2023), Diaphragmatic ultrasonography is a valuable, non-invasive, and readily available method for assessing the diaphragmatic mobility (DM). The scanning was conducted using 2 different modes; B-mode and M-mode with a 3.5 MHz curvilinear transducer to locate the position of the DM. A curvilinear transducer was used and placed on the area on anterior subcostal area, between the midclavicular and anterior axillary lines. Ideally, the liver can be utilized as the acoustic window to evaluate the right hemidiaphragm meanwhile the left hemidiaphragm can be evaluated using the spleen window.

The mode of scanning was in B mode and transverse scanning was carried out by looking across the liver for the gallbladder in the centre and the inferior vena cava on the right side of the monitor screen. The right hemidiaphragm was visually represented as a thick, curving, and hyperechoic line as shown in Figure 1. Once the right hemidiaphragm was located, the participant was instructed to take quiet breathing, deep breathing, and voluntary sniffing which were marked by the cursor (Boussuges et al, 2009). The mode of the scan was changed to M mode to identify the highest excursion of the hemidiaphragm. The callipers were placed at the bottom and top of the diaphragm's inspiratory slope to determine the excursion's amplitude. The scan was repeated at least 3 times, and the average measurement was taken. The mean of all the data for each group of variables (DM and spirometry assessment) was calculated. The Mann-Whitney U test was chosen to compare the means of DM of the COVID-19-virgin and Post-COVID-19, and the comparison of the means of spirometry assessment between the COVID-19-virgin and Post-COVID-19. Spearman Correlation was done to describe the relationship between COVID-19 status and DM assessment.

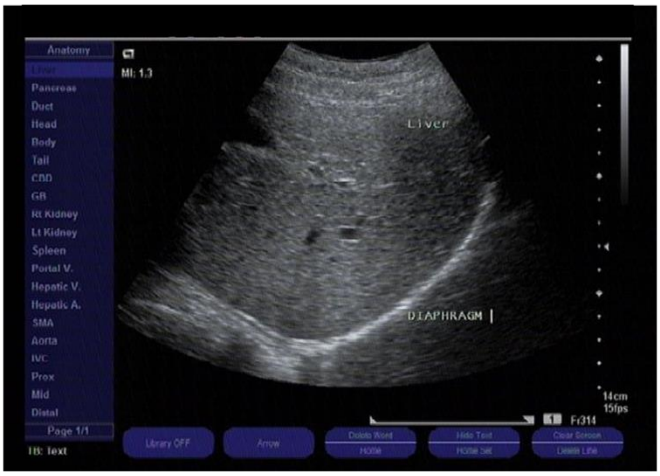

Figure 1: A thick, curved, and hyperechoic line represents the right hemidiaphragm

RESULTS

Descriptive Analysis

A total of 61 female participants from IIUM Kuantan undergraduate students participated in this study and all these participants were assigned to COVID-19-virgin and Post-COVID-19. A frequency analysis test was done to look for the demographic data for this study. Based on Table 1, the COVID-19-virgin (n=32) had the highest percentage of 51.6% meanwhile 46.8% of them were Post-COVID-19 (n=29).

Table 1: Demographic Data of Participants

Category	Frequency (n=61)	Percentage (%)
COVID-19 virgin	32	51.6
Post-COVID-19	29	46.6

Based on Table 2, the mean result from DM assessment using ultrasonography was divided into 3 different readings: Average Quiet Breathing Difference (AQBD), Average Deep Breathing Difference (ADBD), and Average Voluntary Sniffing Difference (AVSD). ADBD in COVID-19-virgin group recorded a higher mean of DM which was 4.88 ± 0.83 cm than the Post-COVID-19 group (4.21 ± 0.77 cm). Besides, the mean of AQBD in the COVID-19-virgin group is 1.19 ± 0.47 cm, and for the Post-COVID-19 group is 1.34 ± 0.48 cm. The mean of AVSD in the COVID-19-virgin group is 1.28 ± 0.46 cm while for the Post-COVID-19 group is 1.38 ± 0.49 cm.

Table 2: Mean of DM in COVID-19-virgin and Post-COVID-19

Assessment	COVID-19-virgin (n = 32)	Post-COVID-19 (n =29)
AQBD (cm)	1.19 ± 0.47	1.34 ± 0.48
ADBD (cm)	4.88 ± 0.83	4.21 ± 0.77
AVSD (cm)	1.28 ± 0.46	1.38 ± 0.49

On the other hand, the spirometry assessment in Table 3 showed the result of the mean FVC and FEV in the Post-COVID-19 group was 2.05 ± 0.47 L and 1.94 ± 0.45 L respectively were higher than the COVID-19-virgin group. The COVID-19-virgin group depicted a value of 2.03 ± 0.40 L and 1.94 ± 0.38 in the mean of FVC and FEV1. Meanwhile, the mean of FEV1/FVC in the COVID-19-virgin group was higher than the Post-COVID-19 group which was 95.30 ± 4.39 % and 94.41 ± 5.12 % respectively.

Table 3: Mean of Spirometry Tests in COVID-19-virgin and Post-COVID- 19

Assessment	COVID-19-virgin (n = 32)	Post-COVID-19 (n = 29)
FVC (L)	2.03 ± 0.40	2.05 ± 0.47
FEV1 (L)	1.94 ± 0.38	1.94 ± 0.45
FEV1/FVC (%)	95.30 ± 4.39	94.41 ± 5.12

Mann-Whitney U test: Spirometry Test

The statistical analysis using the Mann-Whitney U test in Table 4 showed no significant difference in the mean FVC between the COVID-19-virgin and Post-COVID-19 groups. The mean of FVC in the Post-COVID-19 group is higher than the COVID-19-virgin which is 2.05 ± 0.47 L and 2.03 ± 0.40 L respectively. Other than that, the mean of FEV1 between COVID-19-virgin and Post-COVID-19 groups also showed no significant difference. The mean of FEV1 in the Post-COVID-19 group is slightly higher than the COVID-19-virgin which is 1.94 ± 0.45 L and 1.94 ± 0.38 L respectively. There is no reduction in FVC and FEV1 measurements was noted in Post-COVID-19, suggesting that mild-to-moderate cases did not have a long-term negative impact on lung function in young adults (Mogansen et al, 2022)

Table 4: Mean of Spirometry Tests and DM in COVID-19-virgin and Post-COVID- 19

	Status	Mean rank	Mann- Whitney U	Z	p-value
FVC	COVID-19-virgin	29.20	406.50	-0.83	0.41
	Post-COVID-19	32.98			
FEV1	COVID-19-virgin	29.58	418.50	-0.65	0.51
	Post-COVID-19	32.57			
FEV1/FVC	COVID-19-virgin	32.59	413.00	-0.74	0.46
	Post-COVID-19	29.24			
AQBD	COVID-19-virgin	28.42	381.50	-1.59	0.11
	Post-COVID-19	33.84			
ADBD	COVID-19-virgin	36.50	288.00	-2.71	0.01
	Post-COVID-19	24.93			
AVSD	COVID-19-virgin	29.58	418.50	-0.81	0.42
	Post-COVID-19	32.57			

Mann-Whitney U Test: DM Assessment

A Mann-Whitney U test in Table 4 showed that there was no statistically significant difference in the distribution of AQBD and AVSD between COVID-19-virgin and Post-COVID-19, as assessed by DM assessment. Similarly, a study from Vetrugno et al, (2022) revealed that the is no significant difference in DM assessment between AQBD and AVSD. In contrast there is a significant difference in the mean for ADBD in the COVID-19-virgin and the Post-COVID-19 group which is 4.88 ± 0.83 cm and 4.21 ± 0.77 cm respectively. Deep breathing is the most significant for DM assessment in COVID-19 as it aids in allowing better visualization and evaluation of the diaphragm movement (Vetrugno et al, 2022). In addition, ADBD reading is very essential for the evaluation of diaphragmatic mobility and strength compared to the AQBD and AVSD (Boussuges et al, 2022).

Correlation between Covid-19 Status and Diaphragmatic Mobility

There was no significant correlation between COVID-19 status and AQBD and AVSD using Spearman's rank-order correlation with r = 0.206, p=0.112 and r = 0.104, p=0.424 respectively. Similar findings are found in the non-intubated COVID-19 patients, where they experienced a temporary decrease in diaphragm thickness but maintained normal diaphragm movement during quiet breathing, indicating that structural changes did not significantly impact functional capacity (Hadda et al., 2023). There was a moderate negative significant linear corelation r = -0.351, p=0.006 a between COVID-19 status and ADBD using Spearman's rank-order correlation. This is due to deep breathing puts a higher demand on the diaphragm forcing it to contract more forcefully, highlighting possible weakness or dysfunction present (Chandrakumar et al., 2023). In contrast, quiet breathing and voluntary sniffing may not stress the diaphragm as much, resulting in less pronounced differences between post covid-19 and covid-19 virgin.

CONCLUSION

In summary, this study concludes that Stage-2 of COVID-19 does not significantly affect quiet breathing diaphragm measurements (AQBD, AVSD) or lung function parameters (FVC, FEV1 and FEV1/FVC) in young adults. However, a significant reduction in ADBD was observed in the Post-COVID-19 group compared to COVID-19 virgin, indicating potential diaphragm weakness after infection. Additionally, a moderate negative correlation between COVID-19 status and ADBD highlights that deep breathing, which demands greater diaphragm strength, may expose subtle weaknesses in diaphragm function among Post-COVID-19 individuals. While overall lung function appears unaffected, these results suggest that COVID-19 may lead to minor but significant reductions in diaphragm strength and mobility under exertion.

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