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# LUNG FUNCTION AND FUNCTIONAL CAPACITY AFTER COVID-19

*Vinícius Spagnol Regasson*

*João Rafael Sauzem Machado*
http://lattes.cnpq.br/7402410174306137

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**Abstract: Objective:** To investigate the possibility of changes in lung function and/or functional capacity in the population after contamination with SARS-CoV-2. **Methodology:** This is an epidemiological cross-sectional observational study with a convenience sample where spirometry, manovacuometry and a six-minute walk test were performed. **Results:** The sample consisted of six individuals, with a mean age of 22.66 years, the mean number of symptoms in the acute phase was 4.6 and in the post-acute phase it was 2. 50% of those assessed reported that they were affected in terms of the activities and/or exercises carried out prior to the infection. The mean percentages of predicted and realized FVC were 101.16%, FEV1 98.5%, FEV1/FVC 100.66%, PEF 84%, FEF25-75% 87.66%, PIMax 105.59%, PEMax 78.70%, and DTC6 63.13%. **Conclusion:** The signs and symptoms affected the daily activities and/or physical exercise of half of the individuals assessed, the variables most affected were FEV1, PEF, FEF25-75, PEMax and DTC6, thus showing that there is an impairment, even if slight, in the pulmonary function and functional capacity of these individuals.

**Keywords:** Functional Status, Post-Acute COVID-19 Syndrome, Respiratory Function Tests.

## INTRODUCTION

On December 31, 2019, the World Health Organization (WHO) was alerted to several cases of pneumonia in the city of Wuhan, China. A week later, the Chinese authorities confirmed the identification of a new variant of a virus, named Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and causing coronavirus disease 19 (COVID-19). This was responsible for the decree of a Public Health Emergency of International Concern declared by the WHO and later characterized as a pandemic by the same according to the PAHO (2020) and Siordia (2020) websites.

On May 5, 2023, the WHO announced the end of the Public Health Emergency of International Concern caused by COVID-19, but emphasizes that it has not ceased to be a threat to global health (PAHO, 2023).

Studies suggest that COVID-19 is a multisystem disease and that there is both pulmonary and extrapulmonary involvement, related to its acute or long-term phase (Davis et al., 2021; Johnson et al., 2022).

The vast majority of those infected with SARS-CoV-2 had low and uncomplicated repercussions of the disease. However, the virus was still responsible for the hospitalization of approximately 14% of individuals who experienced the strongest repercussions of COVID-19. The most common symptom detected was pneumonia, characterized by fever, cough and shortness of breath. In addition to these, those infected may experience symptoms such as headache, fatigue, sore throat, rhinorrhea, anorexia, myalgia, diarrhea, altered sense of smell and taste, among others. In severe cases, acute respiratory distress syndrome (ARDS), septic shock and sepsis can develop (Rehman; Rehman; Yoo, 2021; Klein et al., 2021).

In the aftermath of the pandemic, there have been several cases of individuals whose physical and/or pulmonary function has been compromised, even weeks or months after the original infectious process, which has been considered long COVID. According to the National Institute for Health and Care Excellence (NICE) guidelines, these findings are described as post-COVID-19 syndrome, i.e. a range of signs and symptoms that develop during or after an infection and last for more than 12 weeks and are not attributable to another alternative diagnosis (Singh et al., 2023; NICE, 2020).

Long COVID is not an exclusive repercussion of a single stage of the disease. Regardless of the severity of symptoms, individuals are subject to developing it. Symptoms can appear after the mild form of the infection has occurred, since prevalence is identified in 10 to 35% of people treated in an outpatient setting and in up to 80% of those hospitalized with the most severe disease (Visca et al., 2023). According to data in the literature, 63.87% of COVID-19 patients had at least one long-term effect related to the disease 6 to 12 months after recovery or discharge, and 58.89% of patients still suffer these impacts at 12 months or after (Ma et al., 2023).

Based on the above information, the aim of this study was to investigate the possibility of changes in lung function and/or functional capacity in individuals from the city of Santa Maria - RS, after contamination with SARS-CoV-2.

## METHODOLOGY

This is an epidemiological, observational and cross-sectional study. Data was collected at the Physiotherapy Practical Teaching Laboratory (LEP) of the Franciscan University (UFN), in the city of Santa Maria - RS, from April to May 2024. The study was submitted to the UFN Research Ethics Committee (CEP) in accordance with the ethical criteria established by Resolution 466/12 of the National Health Council (CNS), and was approved under CAAE number: 76508423.9.0000.5306.

The sample was formed by convenience, i.e. any individual who met the inclusion criteria could take part in the survey. Dissemination took place via digital media through folders on social networks and via physical media, with the distribution of pamphlets and banners handed out in public and private healthcare facilities.

The inclusion criteria were age between 21 and 59 years, individuals who agreed to take part in the study and signed the Informed Consent Form (ICF), in addition to having had coronavirus infection proven by laboratory testing (RT-PCR report for SARS-CoV-2 positive/detected), individuals who did or did not require hospitalization (all those who had the disease in its mild, moderate or severe form were accepted, as well as asymptomatic individuals).

As for exclusion, the following criteria were established: individuals who did not have a laboratory test proving the infection or a negative/non-detected RT-PCR report, who did not accept or sign the informed consent form, who had pulmonary, cardiac and/or neurological disease diagnosed prior to the infection, who were unable to perform or understand any of the research assessment instruments correctly, who were undergoing cardiorespiratory rehabilitation at the time of the research and smokers.

Data was collected by performing spirometry, manovacuometry and the 6-minute walk test (6MWT). In addition, a form written by the researchers was applied, containing questions and sociodemographic information relevant to the research about the patients and their history before, after and during SARS-CoV-2 infection.

Spirometry was performed using a MIR MINISPIR device, manufactured in 2016, and the WinspiroPRO program version 7.2 was used to assess lung function. The ATS/ERS (2002) guidelines were followed, and the values obtained were compared to those predicted for the Brazilian population according to Pereira, Sato and Rodrigues (2007). After the test, the percentage of the values achieved in relation to the predicted values was used for analysis, taking into account the values of Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Tiffeneau Index (FEV1/FVC), Intermediate Forced Expiratory Flow (FEF25-75%) and Peak Expiratory Flow (PEF).

As for manovacuometry, the MDI model MVD300 digital device was used to assess respiratory muscle strength. The norms of

Evans and Whitelaw (2009) were followed, and the values obtained were compared to those predicted according to Neder et al. (1999). At the end, the percentage of the values achieved in relation to the predicted values was used for analysis, taking into account the values of Maximum Inspiratory Pressure (MIP) and Maximum Expiratory Pressure (MEP).

As for the 6MWT, the norms of the ATS (2002) were followed, and the values obtained were compared to the predicted values according to Soares and Pereira (2011). The percentage of the values achieved in relation to the predicted values was used for analysis, taking into account the distance covered (6MWD) and the Borg values at rest, Borg after exercise, oxygen saturation (SpO )$_2$ at rest and the lowest SpO value$_2$ during the run.

For data analysis, the results obtained were tabulated in an Excel spreadsheet and then analyzed descriptively, since the number of individuals selected was small in relation to the researchers' expectations, which did not allow for a quantitative analysis.

## RESULTS

Initially, 34 individuals showed an interest in taking part in the research, however, data was only collected from eight people and analyzed from six of them. Two individuals were disqualified for omitting information that fit the exclusion criteria. The final sample consisted of six individuals (17.67% of those who showed interest), and their characterization is shown in Table 1.

| | |
|---|---|
| Age | Average of 22.66 years |
| Sex | Female (83.33%)<br>Male (16.67%) |
| Ethnicity | White (100%) |
| Body mass index (BMI) | Average 24.4<br>BMI below 25 (83.33%)<br>BMI over 25 (overweight) (16.67%) |
| Number of SARS-CoV-2 infections. | 1 (100%) |
| Number of doses taken/ administered of CO-VID-19 vaccine | Average of 3.5 doses<br>2 (33,33%)<br>4 (50%)<br>5 (16,67%) |
| Number of symptoms in the acute phase of COVID-19 | Average of 4.6 symptoms in the sample<br>3 (33,32%)<br>4 (16,67%)<br>5 (16,67%)<br>6 (16,67%)<br>7 (16,67%) |
| Most reported symptoms in the acute phase of COVID-19 | Fatigue (83.33%)<br>Cough (66.66%)<br>Myalgia (50%) |
| Type of treatment/in-tervention carried out during the acute phase of COVID-19 | Outpatient (100%) |
| Number of symptoms after the acute phase of COVID-19 | Average of 2 symptoms<br>0 (16,67%)<br>1 (16,67%)<br>2 (50%)<br>3 (16,66%) |
| Most reported symptoms after the acute phase of COVID-19 | Memory deficit (80%)<br>Dyspnea (40%)<br>Fatigue (40%) |
| Carried out rehabilitation for COVID-19 | Not done (100%) |
| Symptoms have affected physical activity and/or exercise | Yes (50%)<br>No (50%) |

Table 1 - Characterization of the sample

**Caption:** Descriptive table characterizing the sample. **Source:** Author's construction.

As for the spirometry data, 66.67% of the subjects had results below 100% for FVC and FEV1, 33.33% had results below 100% for FEV1/FVC; 83.33% had results below 100% for PEF, two of which had results below 70% (64% and 69% of predicted); and 66.67% had results below 100% for FEF25-75%, two of which had results equal to or below 70% (65% and 70% of predicted).

| Given | Average and range |
|---|---|
| FVC % predicted | 101,16% (90-118) |
| FEV1 % predicted | 98,5% (88-116) |
| FEV1/FVC % predicted | 100,66% (94-107) |
| PEF % expected | 84% (69-111) |
| FEF25-75% % predicted | 87,66% (65-107) |

Table 2 - Spirometry values

**Legend:** Table with means and ranges of the data obtained from spirometry. **Source:** Author's construction.

As for the manovacuometry data, 50% of the individuals had results below 100% for PIMax performed as predicted, with all of these individuals having a result below 65% of predicted; and 83.33% had results below 100% for PEMax performed as predicted, with all of these individuals having a result equal to or below 75%.

| Given | Average and range |
|---|---|
| MIPax % predicted | 105,59% (57,78-152,32) |
| PEMax % predicted | 78,70% (59,34-121,35) |

Table 3 - Manovacuometry values

**Caption:** Table with averages and ranges of the data obtained from manovacuometry. **Source:** Author's construction.

As for the 6MWT data, 100% of the individuals had results below 80% for the 6MWT performed as predicted; as for Borg at rest, there was a variation of 0 to 3, and a variation of 1 to 8 for Borg after exercise, while as for $SpO_2$ at rest there was a variation of 98% to 99%, and for the lowest value of $SpO_2$ during running it was 91% to 96%.

| Given | Average and range |
|---|---|
| DTC6 % forecast | 63,13% (54,39-75,43) |
| Borg at rest | 0,6 (0-3) |
| Borg after exercise | 3,5 (1-8) |
| SpO2 at rest | 98,66% (98-99) |
| Lower SpO value2 during the run | 94,16% (91-97) |

Table 4 - 6MWT values

**Legend:** Table with means and ranges of the data obtained in the 6MWT. **Source:** Author's construction.

## DISCUSSION

In COVID-19, infected patients may experience a variety of signs and symptoms, including fever, cough, fatigue, pneumonia, headache, diarrhea, hemoptysis and dyspnea (Adhikari et al., 2020). In our research, we found that people who had been infected with SARS-CoV-2 had an average of 4.6 symptoms during the acute phase of the disease, the most cited being fatigue (83.33%), cough (66.66%) and myalgia (50%). These findings are in line with those of Pullen et al. (2020), where the most reported symptoms were cough (82%), fever (67%), fatigue (62%) and headache (60%) or in the study by Huang et al. (2020), where the most common findings were fever (98%), cough (76%), dyspnea (55%) and myalgia/fatigue (44%).

Other similar findings can be found in individuals hospitalized for COVID-19, such as those described by Goulart et al. (2021), with the most frequent clinical symptoms being dyspnea (48.29%), cough (30.73%) and myalgia (24.39%), while for Liu et al. (2020), the most common symptoms were fever (79.6%), cough (48.0%), sputum (25.8%), sore throat (8.6%) and diarrhea (5.4%), or Guan et al. (2020), who reported cough (67%), fever (44%) and fatigue (38%) as the most common symptoms in patients admitted to hospitals.

Although the repercussions of long COVID are multifactorial, two examples of factors can be cited as influencing this phase, both the triple vaccination against COVID-19, which seems to reduce the likelihood of persistent sequelae, but does not prevent the development of long COVID, and the low severity of the disease in the acute phase (Singh et al., 2023).

In this study, the average number of doses of vaccine for each individual was 3.5 and the symptoms reported by the sample fall within the presentation of the mild form of the disease, that is, individuals treated on an outpatient basis without the need or severity that would indicate hospitalization for treatment, and this description is in line with that described by Siddiqi and Mehra (2020) and by Kłos et al. (2024). Thus, we can assume that both the fact of triple vaccination and the severity of the disease in the acute phase may have been factors that benefited our subjects, as they had a low repercussion of the symptoms reported after the acute phase.

As for the symptoms present in long COVID, these are nonspecific, being defined as a range of signs and symptoms that develop during or after infection with COVID-19, and are not attributable to other alternative diagnoses (Singh et al., 2023; Soriano et al., 2022). In this study, it was found that individuals can present an average of two symptoms of this phase, however not always after contamination by the virus will the individual present repercussions of long COVID. Among the findings, 83.33% of individuals reported at least one symptom after the acute phase of COVID-19, while one individual felt no long-term repercussions and another felt up to three symptoms. During this period, the three symptoms most reported by the sample were memory deficit (80%), dyspnea (40%) and fatigue (40%). Even so, although 50% of the individuals said they had not felt any repercussions on their activities and/or physical exercise due to the long-term symptoms, none of those assessed had undergone intervention/rehabilitation for COVID-19.

From the data obtained from spirometry, when we analyzed the mean results, we saw that the percentage of predicted FEV1 (98.5%), PEF (84%) and FEF25-75% (87.66%) showed results below 100%, while FVC (101.16%) and FVC/FEV1 (100.66%) showed results above 100%. In the study by Suppini et al. (2023), in which spirometry and lung diffusion capacity were assessed in individuals infected with SARS-CoV-2 in the different severities of the disease, 40 days after infection and after 1 year, it was found that in the 40 days after the acute phase of COVID-19, individuals with mild disease had all the predicted percentage averages below 100% for FVC (97.8%), FEV1 (95.4%), FVC/FEV1 (83.0%) and FEF25-75% (81.0%) and, after 1 year, they continued with these same values below 100%, FVC (98.2%), FEV1 (96.6%), FVC/FEV1 (78.9%) and FEF25-75% (89.3%). In the study, the authors also point out that there were significant average increases in FVC, FEV1, carbon monoxide diffusion, total lung capacity and residual volume in all forms of disease severity over one year. This finding was more evident in severe cases of COVID-19 compared to mild and moderate patients, whose lung function almost normalized. Also in this sense, the study by Huang et al. (2020) points out that pre- and post-intervention spirometry of 8 weeks in a study group and a control group, the mean percentages of predicted FVC (88.7%), FEV1 (87.7%), FEV1/FVC (84.1%) and FEF25-75% (92.8%) were below 100%, so it can be seen that both studies corroborate, in part, the findings of our study.

Manovacuometry was used as a form of pre- and post-intervention assessment in individuals with COVID-19 by Hockele et al. (2022) and they reported that the average percentage of predicted MIP was 120% and MEP was 104.3% before the rehabilitation protocol was applied. Satar et al. (2023), on the other hand, reported values of 101.83% for MIP max and 123.56% for MEP max before the intervention. In the present study, the mean values for the percentage of MIPmax and MEPmax were 105.59% and 78.70% respectively. When considering the MIP max values, both previous studies provide data that corroborates ours, since the average percentage of MIP max performed was above 100%, however, this data goes against the grain when considering the MEP max values, since these showed a large discrepancy in values when compared to those cited in the literature.

In the 6MWT, the mean predicted percentage of 6MWD was 63.13%, while the mean Borg score at rest and Borg score after exercise were 0.6 and 3.5 respectively. $SpO_2$ at rest and the lowest value of $SpO_2$ during the run were 98.66% and 94.16% respectively. For Hockele et al. (2022), the average predicted 6MWD percentage was 59.7%, when analyzing post-COVID-19 individuals in the various pre-intervention disease severities, and as for the two-month post-intervention data, the participants had an average predicted 6MWD percentage of 82.6%. Thus, the 6MWD values in this study were between the pre-intervention and post-intervention values in the comparative literature. However, when comparing the 6MWD data with the study by Campos et al. (2024), it was observed that in the present study, a lower value was found, and for these authors the average predicted percentage was 77.6% pre-rehabilitation in the compared study. The mean SpO values$_2$ at baseline and $SpO_2$ at the end of the test were 97% and 96% respectively, which may suggest corroboration with the data in the present study, since there was a drop in the mean $SpO_2$ at baseline and at the end of the test in both studies, although in the present study, $SpO_2$ had a greater drop when compared to the values in the literature.

## CONCLUSION

It can be seen that varied and multisystemic repercussions can affect the various areas of individuals infected with the SARS-CoV-2 virus, both in the acute phase of the disease and after infection. In this study, it can be seen that the signs and symptoms affected the activities and/or physical exercise of half of the people assessed after infection, with the variables showing reperfusion being FEV1, PEF, FEF25-75%, PEMáx and DTC6, thus showing that there is an impairment, even if slight, in the pulmonary function and functional capacity of the people investigated.

Further longitudinal cross-sectional observational research is suggested before and after the COVID-19 pandemic with individuals infected with SARS-CoV-2 at all stages of the disease, including symptomatic and asymptomatic individuals, as a way of drawing up a profile for the global population, in order to identify whether the disease has affected the world/general population in its lung function and functional capacity, but not only restricted to these variables, but also covering all the biopsychosocial aspects that may be involved. A more numerically significant and heterogeneous sample is important in this study, in order to understand the effects and impacts caused in the various populations affected by this disease.

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