

Functional performance analysis in individuals recovered from COVID-19: assessment through the six-minute walk test

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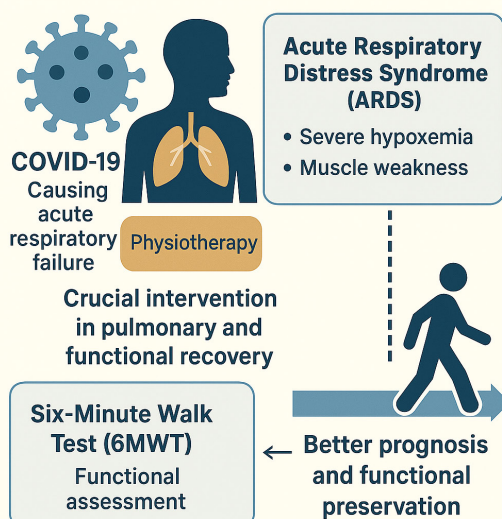
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Graphical Abstract

Highlights

- Impact of COVID-19 on pulmonary and muscular function.
- Six-Minute Walk Test (6MWT) – an essential tool.
- Below-expected performance in the 6MWT.
- Physiological responses to exertion.
- Importance of post-COVID pulmonary rehabilitation.

REHABILITATION OF POST-COVID-19 PATIENTS



Abstract

The COVID-19 pandemic has posed significant challenges to healthcare systems, with physiotherapy playing a crucial role in the management of post-infection patients. This descriptive study investigated the Six-Minute Walk Test (6MWT) as an assessment tool to monitor physiological and functional changes in post-COVID patients. Conducted at the Outpatient Clinic of Physiotherapy in Cardiology and Pulmonology at Universidade São Francisco, Bragança Paulista/SP, the study included 18 individuals referred for pulmonary rehabilitation, with a median age of 47 years (± 13.40), body mass of 74.50 kg (± 20.48), and mean height of 1.65 m (± 0.09). The median distance covered in the 6MWT was 481 meters (± 106.20), corresponding to 78.9% of the predicted value according to the guidelines of the American Thoracic Society and the European Respiratory Society, indicating reduced tolerance to submaximal aerobic exercise. Statistically significant differences were observed between initial and final values of systolic blood pressure ($p < 0.005$), heart rate ($p < 0.002$), rate-pressure product ($p < 0.001$), and Borg's Rating of Perceived Exertion scale, both respiratory ($p < 0.006$) and muscular ($p < 0.007$). However, no significant differences were found in oxygen saturation ($p > 0.34$) or diastolic blood pressure ($p > 1.00$). The results suggest that cardiovascular and hemodynamic adjustments occurred physiologically, reinforcing the use of the 6MWT as a valuable tool for assessing submaximal functional capacity and physiological responses to exercise. The 6MWT proved to be useful in evaluating exercise tolerance in post-COVID individuals.

Keywords: COVID-19. Physiotherapy. Exercise Test.

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INTRODUCTION

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, posed significant challenges to healthcare systems worldwide. In addition to efforts to contain viral spread, ensuring appropriate treatment for infected patients was essential. Physiotherapy emerged as a crucial intervention in the management of these patients, who developed acute respiratory failure (ARF), playing a key role in pulmonary and functional recovery, particularly in those with severe respiratory symptoms¹.

Most COVID-19 infections resolved naturally without severe sequelae². However, a subset of patients who developed severe disease progressed to a hyperinflammatory state, leading to severe hypoxemia and reduced pulmonary compliance, culminating in Acute Respiratory Distress Syndrome (ARDS)^{2,3}. Following ARDS, a proportion of patients exhibited impaired functional capacity of the respiratory muscles and generalized neuromuscular weakness⁴.

Thus, the functional rehabilitation of these individuals, through strategies to improve functional performance—usually implemented by physiotherapy—became not only essential but indispensable. Clinical experience with rehabilitated COVID-19 patients who were discharged demonstrated that timely respiratory and musculoskeletal rehabilitation was effective in improving prognosis, maximizing functional preservation, and enhancing quality of life⁵.

Once the rehabilitation process begins, the need arises for tests that provide objective quantifiable parameters capable of demonstrating pathophysiological changes, thereby allowing quantitative monitoring of patient progress. According to the American Thoracic Society (2002), the Six-Minute Walk Test (6MWT) stands out as an excellent option, with its strongest indication being the measurement of therapeutic intervention responses in patients with moderate-to-severe cardiac or pulmonary disease. The 6MWT has also been used as a single measure of patients' functional status, as well as a predictor of morbidity and mortality⁶.

The applicability of this test is particularly feasible in clinical settings, as it requires minimal equipment, limited space, and low cost. Therefore, in this study, the 6MWT was employed as a tool to collect quantitative data and to evaluate measured variables in individuals with post-COVID-19 sequelae. This study sought to address the following question: Is the 6MWT safe and clinically useful for assessing the functional capacity and physiological responses of individuals with post-COVID-19 sequelae undergoing pulmonary rehabilitation?

Accordingly, the objective of this study was to evaluate the applicability of the 6MWT in individuals with post-COVID-19 sequelae, comparing predicted values with those obtained, and analyzing physiological and perceptual responses to exertion.

MATERIALS AND METHODS

Study design: This was an observational and retrospective study, comprising a data collection phase.

Participants: The sample was obtained through the sequential inclusion of all eligible patients who were treated at the research site during the established data collection period, following approval by the Institutional Research Ethics Committee.

Research setting: All assessments were conducted at the Outpatient Clinic of Physiotherapy in Cardiology and Pulmonology, School of Physiotherapy, Universidade São Francisco, in the city of Bragança Paulista, located in the interior of the State of São

Paulo, Brazil. The study was approved by the Research Ethics Committee (REC) of Universidade São Francisco (CAEE: 53287021.60000.5514), in accordance with the ethical and legal recommendations set forth in Resolution 466/2012 of the Brazilian National Health Council for research involving human subjects.

Inclusion criteria: The sample consisted of individuals over 18 years of age, of both sexes, referred by a physician for participation in pulmonary rehabilitation (PR), and presenting low risk for physical training according to the criteria established by the American Heart Association (Figure 1).

CLASS A:

Men ≥ 45 years and women ≥ 55 years without symptoms or diagnosis of cardiovascular disease (CVD), presenting with two or more major risk factors for CVD.

CLASS B:

Individuals with stable CVD and at low risk of complications during vigorous exercise. This classification includes patients with CAD (myocardial infarction, stable angina, myocardial revascularization, angioplasty), valvular heart disease, heart disease with LVEF $\leq 30\%$ without hypertrophic cardiomyopathy or recent myocarditis, and congenital heart disease, who present at least one of the following characteristics:

1. New York Heart Association (NYHA) functional class I or II.
2. Exercise capacity ≤ 6 METs.
3. Absence of heart failure symptoms.
4. Absence of myocardial ischemia or angina at rest or during exercise testing at or below 6 METs.
5. Expected increase in systolic blood pressure during exercise.
6. Absence of sustained or non-sustained ventricular tachycardia at rest or during exercise.
7. Ability to self-monitor physical activity intensity through heart rate monitoring.

Source: adapted from FLETCHER, BALADY, AMSTERDAM, *et al.* 2011. Exercise Standards for Testing and Training: A Statement for Healthcare Professionals from the American Heart Association. *Circulation*, vol. 104, p.1694–1740, 2011⁷.

Figure 1 - American Heart Association criteria for a Cardiovascular Rehabilitation program in low-risk patients. Universidade São Francisco, Bragança Paulista, 2024.

Exclusion criteria: Patients with musculoskeletal disorders, peripheral neuropathy, and/or Parkinson's disease; moderate and high risk (Classes C and D) for physical training, according to the criteria of the American Heart Association⁸. Participants who did not attend the evaluations, those who presented increased blood pressure levels, exertional angina and/or any symptoms during the evaluation, and those with incomplete data were also discontinued from the study, as well as participants who had to interrupt the test, even during its six-minute execution.

Procedures: After agreeing to participate in the study, sociodemographic and clinical data were collected, as well as anthropometric data such as body weight, height, and body mass index (BMI)⁹, in addition to cardiac and pulmonary auscultation¹⁰. Participants were evaluated on a single occasion, during which the following parameters were assessed: heart rate (HR), oxygen saturation (SpO₂), Borg's Rating of Perceived Exertion scale, systolic blood pressure (SBP) and diastolic blood pressure

(DBP), rate-pressure product (RPP), predicted and actual distance in the 6MWT.

Assessment instruments

Systemic blood pressure (BP) measurement: BP values were obtained using a previously tested and calibrated sphygmomanometer. Measurement was performed in accordance with the recommendations of the Brazilian Guidelines on Arterial Hypertension (2020)¹¹. The values obtained supported the classification of subjects according to the Brazilian Society of Hypertension (2020): optimal BP (SBP <120 and DBP <80 mmHg); normal (SBP <130 and DBP <85 mmHg); borderline (SBP 130–139 and DBP 85–89 mmHg); Stage 1 hypertension (SBP 140–159 mmHg and DBP 90–99 mmHg); Stage 2 hypertension (SBP 160–179 mmHg and DBP 100–109 mmHg); Stage 3 hypertension (SBP ≥ 180 mmHg and DBP ≥ 110 mmHg); isolated systolic hypertension (SBP ≥ 140 mmHg and DBP <90 mmHg). BP was measured using a Premium[®] sphygmomanometer and a Littmann[®] Classic III stethoscope.

RPP assessment: The rate-pressure product (RPP) is a measure used to evaluate cardiovascular demand during physical activities, particularly in the context of submaximal exercise such as the 6MWT. RPP is calculated by multiplying HR by SBP, reflecting cardiac workload, since the simultaneous increase of these two parameters indicates greater myocardial effort to deliver oxygen to the tissues. This parameter is an important hemodynamic indicator as it indirectly reflects cardiac work¹².

Oxygenation assessment: Measured using pulse oximetry with a portable Oled Graph G-TECH® pulse oximeter authorized by ANVISA. Reference values of 95% to 98% were adopted.

Heart rate assessment: Measured as beats per minute (bpm). Reference values for healthy adults at rest range from 60 to 100 bpm. HR was measured using a Polar® heart rate monitor.

Body mass and height measurement: Body mass was obtained using a calibrated anthropometric scale (Marte®) verified by INMETRO, with a capacity of up to 150 kg. Patients were asked to remove footwear during measurement. Height was measured in the standing position using a stadiometer fixed to the scale platform and resting on the head, with the patient standing upright, back against the stadiometer, and gaze directed at the horizon. Based on body mass and height, BMI was calculated according to the World Health Organization (2000)⁹ recommendations.

Exercise tolerance measurement: Participants underwent the 6MWT to compare predicted distance with the distance achieved, as well as to verify and document cardiovascular responses to physical exertion through RPP, and to assess dyspnea levels during the test. The 6MWT is considered the most representative test of activities of daily living compared with other walking tests. The test was conducted according to the guidelines of the Ame-

rican Thoracic Society and European Respiratory Society⁶. Participants were instructed to walk as far as possible for six minutes in a flat, straight, indoor corridor 30 m in length. Two traffic cones marked the turning points, and the corridor was marked every 3 meters. Standardized instructions and verbal encouragement were provided at each minute. Distances covered in the 6MWT were recorded in meters, as well as the percentage of predicted values¹³. Predicted distance for each participant was calculated prior to the test using the formulas: Women = $(7.57 \times \text{height in cm}) - (5.02 \times \text{age in years}) - (1.76 \times \text{weight in kg}) - 309$, Men = $(2.11 \times \text{height in cm}) - (2.29 \times \text{weight in kg}) - (5.78 \times \text{age in years}) + 667$ as described by Enright & Sherrill (1998)¹⁴. At the beginning and end of the test, subjective perception of respiratory exertion and lower limb fatigue were assessed using the adapted Borg scale¹⁵.

Data collection: Data collection was carried out by one of the researchers at the research site.

Data analysis: Statistical analyses were performed using SPSS software, version 27 (IBM Statistics). The Shapiro-Wilk test was applied to assess data normality. Descriptive statistics were used to characterize the sample, and the non-parametric Wilcoxon test was applied for comparisons between time points regarding the studied variables. Differences were considered significant at $p < 0.05$.

Ethical considerations: In compliance with ethical standards for research involving human subjects (Resolution 466/2012 of the Brazilian National Health Council), this study was submitted to and approved by the Research Ethics Committee (REC) of Universidade São Francisco [Opinion no. 5.952.479] (CAEE: 53287021.6.0000.5514). Volunteers were included in the study only after providing informed consent by signing the Free and Informed Consent Form (FICF).

RESULTS

The anthropometric characterization of the final sample is presented in the table 1 below:

Table 1 - Anthropometric characterization of the sample (n = 18), Bragança Paulista, Universidade São Francisco, 2024.

	Median	Standard Deviation
Age (years)	47	13.40
Body mass (kg)	74.50	20.48
Height (m)	1.65	0.09
BMI (kg/m ²)	27.52	6.13

Legend: kg: kilograms; m: meters; BMI: body mass index; kg/m²: body weight in kilograms divided by squared height.

The study sample consisted of 23 individuals; however, three were excluded due to non-attendance, and two were excluded for not presenting a referral letter for pulmonary rehabilitation (Figure 2).

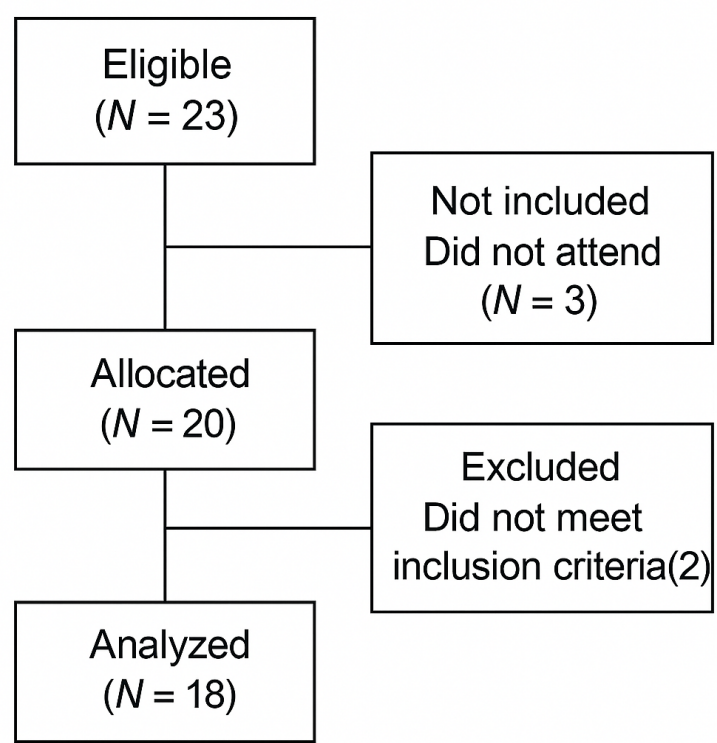


Figure 2 - Study Flowchart.

As shown in Table 2, regarding the predicted and achieved distance in the 6MWT, a significant difference was observed between initial and final values. Significant differences were also identified between initial and final values for SBP, HR, RPP, and Borg’s Rating of Perceived Exertion scale after the test. No significant differences were observed between initial and final values for oxygen saturation and DBP.

Table 2 - Distribution and comparison of variables assessed in the 6MWT (n = 18). Bragança Paulista, Universidade São Francisco, 2024.

		p-value
Predicted distance (m)	Achieved distance (m)	
608,98	481	<0.001*
SpO ₂ inicial (%)	SpO ₂ final (%)	
97	95	0.34
SBP initial (mmHg)	SBP final (mmHg)	
120	130	0.005*
SBP initial (mmHg)	SBP final (mmHg)	
80	80	1
HR initial (bpm)	HR final (bpm)	
86	95	0,002*
HR initial (bpm)	HR final (bpm)	
Borg perceived exertion – respiration (initial)	Borg perceived exertion – respiration (final)	
2	4	0.006*
Borg perceived exertion – lower limbs (initial)	Borg perceived exertion – lower limbs (final)	
0	2	0.007*

Legend: SpO₂: oxygen saturation; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; RPP: rate-pressure product; LL: lower limbs.

DISCUSSION

The present study aimed to evaluate and compare the predicted and achieved distances in the 6MWT, as well as to analyze initial and final test values for SpO₂, SBP, DBP, HR, RPP, and Borg's Rating of Perceived Exertion (respiratory and muscular) in post-COVID-19 patients referred for pulmonary rehabilitation.

The 6MWT provides quantitative data on submaximal exercise tolerance and allows comparison with predicted values¹³. The median distance covered by the participants was 481 meters, indicating a possible reduction in exercise tolerance, corresponding to approximately 78.9% of the predicted value according to the literature¹³. Thus, it can be observed that following COVID-19-related dysfunction, there is a reduction in tolerance to physical exertion, as evidenced at the time of assessment. In the study conducted by Mantha *et al.* (2020)¹⁶, the authors demonstrated the usefulness of the 6MWT in the initial diagnosis of COVID-19, enabling early discrimination between mild and severe cases. Similarly, in a cross-sectional study involving 34 post-COVID-19 patients and 33 healthy individuals, assessed one month after a non-severe infection using the six-minute step test (6MST), the 6MWT, and pulmonary function tests, the authors found that, regarding 6MWT performance, the distance covered by the post-COVID-19 group (423 ± 7 m) was 94 m shorter than that of the healthy group¹⁶. Although the present study did not include a healthy control group for comparison, its findings are consistent with those of Omar *et al.* (2023)¹⁷, as the participants presented distances 21.10% below predicted values.

With respect to HR behavior, a physiological response was observed when comparing initial and final 6MWT values ($p < 0.002$). Similar responses were also observed for SBP ($p < 0.005$), RPP ($p < 0.001$), and Borg's perceived exertion for both respiration ($p < 0.006$) and lower limbs ($p < 0.007$). These findings indicate that participants, when subjected to the 6MWT, exhibited physiological adjustments resulting from exposure to submaximal aerobic effort. The study by Alonso *et al.* (2002)¹⁸ reported that exposure of healthy patients to aerobic exercise is a direct predictor of increased HR, reinforcing the results of the present study, in which such physiological adjustments occurred in response to exertion, even in individuals with sequelae from SARS-CoV-2 infection.

The results of this study regarding BP, HR, and

RPP demonstrated that cardiovascular and hemodynamic adjustments occurred physiologically, which are essential to ensure adequate tissue perfusion and maintain BP within acceptable limits in response to exercise intensity. These adjustments involve sensory receptor input and efferent responses that modulate HR, venous return, and redistribution of blood flow to working muscles, generating a series of physiological responses arising from autonomic and hemodynamic adaptations that influence the cardiovascular system^{19,20}. Furthermore, it should be emphasized that the increase in RPP provides an indirect estimate of cardiac workload and myocardial oxygen consumption²¹, reflecting once again the expected adjustment to exertion, even when submaximal. Fletcher *et al.* (2001)⁷ noted that RPP is an important tool for assessing cardiovascular responses to exercise, since the combination of HR and SBP reflects the total hemodynamic load on the heart. Stewart *et al.* (2016)²² also highlighted that RPP is an effective parameter for identifying patients with heart failure, as elevated RPP values are associated with increased cardiovascular morbidity and mortality. In addition, RPP has been used in studies assessing functional recovery in postoperative patients and in the rehabilitation of respiratory diseases such as chronic obstructive pulmonary disease (COPD) and in post-COVID patients. Regarding subjective perception of effort, assessed using Borg's Rating of Perceived Exertion scale, an increase was observed in response to exertion, demonstrating that exercise produced dyspnea and muscular fatigue in the lower limbs. Data from a meta-analysis conducted by Pouliopoulou *et al.* (2023)²³, which synthesized 14 studies, showed that dyspnea was assessed in eight of them, highlighting the importance of this variable as a key parameter of analysis in this population, as was carried out in the present investigation. This variable was also similarly emphasized in the classic study published by Enright *et al.* (1998)¹⁴. The adapted Borg scale (0–10 version) used in this study is an effective and widely employed tool to assess exercise intensity, particularly in clinical and rehabilitation settings, due to its simplicity, versatility, and low cost, making it an excellent option to monitor workload in patients with different health conditions, such as chronic respiratory diseases. Despite its limitations, including subjectivity and the possibility of psychological influences, the scale remains a valuable method to tailor exercise programs and

ensure patient safety and comfort¹⁴.

In the studied sample, no differences were observed between initial and final values of oxygen saturation and DBP. In the study by Mazza *et al.* (2020)²⁴, involving a sample of 402 subjects with post-COVID-19 psychiatric symptoms, the authors found oxygen saturation values within reference ranges, consistent with the findings of the present investigation, although the populations presented distinct dysfunctions. It is also noteworthy that, even during the 6MWT, oxygen saturation behavior reflected the continuous delivery of oxygen to active tissues, demonstrating the adequacy between exertion and oxygen consumption²¹. Similarly, DBP behavior in response to submaximal exertion is known to physiologically decrease or remain unchanged, and its increase may indicate diastolic impairment, which can reduce myocardial oxygen supply¹⁹. In the present study, no significant differences were observed between initial and

final DBP values, which may have contributed to the stability of SpO₂. In line with these results, Zile *et al.* (2022)²⁵ also reported no significant changes in DBP among individuals affected by COVID-19. The literature indicates that survivors of COVID-19 pneumonia may present persistent multisystem involvement (lungs, pulmonary vessels, heart, muscles, red blood cells), which can negatively impact exercise capacity²⁵. In this context, it is necessary to employ a tool capable of measuring variables related to exercise tolerance and monitoring treatment progression, which may also serve as a therapeutic discharge criterion²⁶, as is the case with evaluation through the 6MWT.

Although the results of the present study are relevant, some limitations must be acknowledged, including the small sample size and the absence of a healthy control group. Additionally, it was not possible to conduct follow-up assessments after a potential intervention through pulmonary rehabilitation.

CONCLUSION

In conclusion, the 6MWT results indicate that the dysfunction present in the studied population negatively impacted performance, as the distance covered was below predicted values. Nevertheless, SpO₂ and DBP did not show significant variation between the initial and final test moments, suggesting that, despite residual dysfunction, the cardiovascular system was able to adjust adequately, maintaining effective ventricular relaxation. On the other hand, the changes observed in SBP, HR,

RPP, and Borg's Rating of Perceived Exertion demonstrate that the body responded physiologically to submaximal exertion, promoting the necessary adjustments in cardiovascular and hemodynamic parameters.

These findings suggest that, despite performance limitations, cardiovascular function was able to adapt during submaximal testing, underscoring the importance of monitoring physiological parameters during the 6MWT in this population.

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All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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