

Post-COVID-19 functional capacity assessed with ring and walk tests: cross-sectional study

Capacidade funcional pós-COVID-19 com teste de argola e de caminhada: estudo transversal

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Abstract

Introduction: COVID-19 can cause persistent symptoms even in mild cases, such as fatigue and dyspnea, which can reduce functional capacity and make it difficult to perform activities of daily living. **Objective:** To compare functional capacity using the pegboard and ring test and the six-minute walk test responses in post-COVID-19 patients according to the ventilatory support used. **Methods:** Cross-sectional study including 40 adults of both sexes after SARS-CoV2 infection between June 2020 and June 2021, with assessment of functional capacity using the pegboard and ring test (upper limbs) and the six-minute walk (lower limbs). Those who reported comprehension deficit or neuromuscular disease were excluded. All participants were evaluated between 15 and 90 days after the onset of symptoms, diagnosed by nasal swab and classified according to the ventilatory support used during the infection. **Results:** The mean age of the participants (n = 40) was 54.30 (± 12.76) years, with BMI 28.39 (± 4.70) kg/m² and pulmonary involvement in 51.49 (± 17.47)%. A total of 37 participants were hospitalized with a stay of 14.33 (± 15.44) days, and 30% were previously immunized, while 7.5% reached the predicted distance covered. The average achieved was 46.44% (398.63 \pm 130.58 m) in the distance covered and 39.31% (237.58 \pm 85.51) in the movement of rings. Participants who had invasive mechanical ventilation (n = 10) had the worst functional capacity in both tests 265.85 \pm 125.11 m and 181.00 \pm 90.03 rings, compared to 472.94 \pm 88.02 m and 273.25 \pm 66.09 rings in non-invasive ventilation (n = 8), 410.32 \pm 90.39 m and 257.68 \pm 62.84 rings in oxygen therapy (n = 19), 569.00 \pm 79.50 m and 203.00 \pm 169.00 rings when there was no hospitalization (n = 3). **Conclusion:** Participants who required invasive mechanical ventilation had worse functional capacity, 46% of what was expected in the walk test and 39% of what was expected in the pegboard and ring test.

Keywords: COVID-19. Physical endurance. Physical functional performance. Upper extremity. Walk test.

Resumo

Introdução: A COVID-19 pode causar sintomas persistentes mesmo nos casos leves, como fadiga e dispneia, que podem reduzir a capacidade funcional e a realização das atividades de vida diária. **Objetivo:** Comparar a avaliação da capacidade funcional a partir do teste da argola e caminhada dos 6 minutos pós-COVID-19 conforme o suporte ventilatório utilizado.

Métodos: Estudo transversal com 40 adultos, de ambos os sexos, pós-infecção por SARS-CoV2 entre julho/2020 e julho 2021, com avaliação da capacidade funcional pelos testes da argola (membros superiores) e caminhada (membros inferiores) de 6 minutos. Todos os participantes foram avaliados entre 15 e 90 dias do princípio dos sintomas, diagnosticados por swab nasal, e classificados conforme o suporte ventilatório utilizado durante a infecção. **Resultados:** A média de idade dos participantes ($n = 40$) foi 54,30 ($\pm 12,76$) anos, índice de massa corporal 28,39 ($\pm 4,70$) kg/m² e acometimento pulmonar em vidro fosco 51,49 ($\pm 17,47$)%. Trinta e sete participantes foram hospitalizados com permanência de 14,33 ($\pm 15,44$) dias, 30% previamente imunizados; 7,5% atingiram o predito da distância percorrida. A média alcançada foi de 46,44% (398,63 \pm 130,58 m) na distância percorrida e 39,31% (237,58 \pm 85,51) em movimento de argolas. Os participantes que utilizaram ventilação mecânica invasiva ($n = 10$) apresentaram pior capacidade funcional em ambos os testes: 265,85 \pm 125,11 m e 181,00 \pm 90,03 argolas comparado a 472,94 \pm 88,02 m e 273,25 \pm 66,09 argolas em ventilação não invasiva ($n = 8$), 410,32 \pm 90,39 m e 257,68 \pm 62,84 argolas em oxigenoterapia ($n = 19$), 569,00 \pm 79,50 m e 203,00 \pm 169,00 argolas sem internação ($n = 3$). **Conclusão:** Os participantes que necessitaram de ventilação mecânica invasiva apresentaram pior capacidade funcional, com 46% do esperado no teste de caminhada e 39% no teste de argola de 6 minutos.

Palavras-chave: COVID-19. Resistência física. Desempenho físico funcional. Extremidade superior. Teste de caminhada.

Introduction

There are numerous reports that COVID-19 can affect functional capacity after infection, with secondary pulmonary, cardiovascular, neurological and musculoskeletal complications as a result of the infectious process. In the case of individuals who required hospitalization, the need and duration of

mechanical ventilation, in addition to the intensity of pulmonary impairment, combined with social isolation, appear to be factors that can reduce exercise tolerance and negatively impact the performance of activities daily living (ADLs).¹⁻⁷

Numerous stress tests can be used to evaluate functionality. The six-minute walk test (6MWT) is one of these, being classified as submaximal. The 6MWT is considered safe, simple and reproducible, which makes it easier to use widely in various health services. The measurement of the distance covered, with analysis of perceived exertion (Borg Scale) and observation of the cardiovascular and respiratory response to effort, allows the interpretation of the test to guide treatments and guide the rehabilitation process.⁸ In COVID-19, the decrease in the distance covered in the test may be associated with limitations in daily activities, and the signs and symptoms of this impairment may occur for months or even years after infection.¹⁻⁷

The six-minute ring test (6MRT), which was developed by Celli et al.,⁹ allows the assessment of functional capacity based on constant movement of the upper limbs. The test was first used in patients with chronic obstructive pulmonary disease, whose physical limitations in this lung disease can impact and/or make walking impossible.⁹⁻¹¹ There are also promising studies with the 6MRT in patients with asthma¹² and pulmonary hypertension.¹³

Although observational studies have shown a reduction in the distance covered associated with disability assessed in the 6MWT,¹⁻⁷ no studies have been found that evaluate patients with the 6MRT, even with frequent complaints of dyspnea and pain in the shoulder girdle after COVID-19 infection.¹⁻⁷ Therefore, the objective of this study was to compare the responses of 6MRT and 6MWT in post-COVID-19 patients according to the ventilatory support received throughout the infection.

Methods

We carried out a prospective cross-sectional study after recruiting a convenience sample composed of adults following SARS-CoV2 infection. These individuals had been referred to a public cardiorespiratory physiotherapy service in the city of São Paulo, Brazil for cardiopulmonary rehabilitation because of persisting symptoms of COVID-19.

Data collection was carried out between July 2020 and July 2021 at the Physiotherapy Outpatient Clinic of the Irmandade da Santa Casa de Misericórdia de São Paulo, after approval by the Research Ethics Committee (CAAE: 33118220.8.0000.5479, Approval No. 5.718.067), and after all participants who agreed to take part in the study signed an informed consent form.

The criteria for inclusion in the study were: having tested positive for COVID-19 (inclusion after 15 days of onset of symptoms); age ≥ 18 years; both sexes; and medical indication for follow-up with physiotherapy. Participants should not have had a history of previous physical limitations in the lower and/or upper limbs, neuromuscular disease, need for oxygen support and/or use of upper and lower limb orthoses that could alter performance in the tests. Participants with more than 90 days of medical/hospital discharge and those who reported a lack of understanding or difficulty in understanding the study and/or the proposed tests were excluded.

Before starting the tests, all participants were interviewed and collection of anthropometric measurements, history of comorbidities, date of RT-PCR (reverse transcriptase reaction followed by polymerase chain reaction) showing a positive nasal swab, length of hospital stay in days (if any), ground-glass lung involvement by computed tomography (CT), need for ventilatory support and type of support (oxygen, high-flow nasal cannula, invasive or non-invasive mechanical ventilation). All participants were classified according to the ventilatory support used in the treatment of COVID-19,¹⁴ and they were assessed by one of the two physiotherapists involved in the study, who were previously trained for the proposed study. At the end of the evaluation, participants who were indicated for follow-up were included in one of the cardiorespiratory rehabilitation programs offered at the service.

The physical tests were carried out on the same day, according to the guidelines of the American Thoracic Society (ATS).^{8,15} The 6MWT was the first and followed the guidance of walking at the highest possible speed sustained for six minutes. Measurements of blood pressure (BP, mmHg), heart rate (HR, bpm), oxygen saturation (SpO_2 , %), dyspnea and lower limb fatigue (Modified Borg 0-10) were determined before and in the sixth minute. The completion of the test. HR was monitored for one minute after the end of the tests to observe the return to baseline HR.⁸ The 6MRT was

performed after resting for 30 minutes. Accordingly, the participant remained seated with posterior support of the chest, hips and knees at 90° in front of a wooden panel with four pegs (two upper and two lower) containing 20 rings. The lower pegs were positioned at shoulder height for each participant and the upper pins were positioned 20 cm above. Participants were instructed to move the rings with both hands simultaneously, from lower to upper and upper to lower pegs, continuously and as fast as possible for six minutes. BP, HR, SpO_2 , dyspnea and fatigue (upper limbs) were determined before, in the third and sixth minutes and after one minute of each test, according to guidelines.¹⁵

Clinical tests were carried out as an evaluation and indication and/or prescription for cardiorespiratory and metabolic rehabilitation. The predicted value for the total movement of the rings and the distance covered in six minutes, for each patient, were calculated according to the equations by Lima et al.¹⁵ and Iwama et al.,¹⁶ respectively, with the following equations used for calculation of predicted values: $6MRT^8$: $676.34 - (4.223 \times \text{age in years})$; $6MWT^{16}$: $622.461 - (\text{age in years}) + (61.503 \times \text{sex: men} = 1; \text{women} = 0)$. The maximum heart rate (HRmax) was calculated using the Karvonen et al.¹⁷ formula, considering the submaximal value 85% of this value: $HR_{max} = 220 - \text{age (years)}$. The double product was calculated from the multiplication of HR and systolic BP measured in the sixth minute of each test.

The data collected were tabulated and analyzed using the SPSS program (Statistical Package for the Social Sciences-IBM®, version 13.0, 2013). For data analysis, participants were grouped according to severity, known as the Ordinal Scale for COVID-19, which subdivides into groups according to symptoms, need for hospitalization and types of ventilation resources used. The results were described as mean and standard deviation. Normality distribution was assessed using the Shapiro-Wilk test. When comparing the 6MWT and 6MWT variables, the Student t-test (parametric measurements) and the Wilcoxon test (non-parametric measurements) were used. When comparing variables according to ventilatory support, we used the Kruskal-Wallis test for independent samples. After analyzing normality, Spearman's bivariate correlation was performed between the variables age, body mass index (BMI), ground-glass lung involvement on CT and length of hospital stay with the values achieved in each test and the difference between predicted and achieved for each test.

Results

Forty participants were evaluated, with only three not being hospitalized. The proportion of men was 62.50% in the sample, with a mean age of 54.30 (± 12.76) years, BMI of 28.39 (± 4.70) kg/m² and pulmonary involvement of 51.49 (± 17.47)%. Twelve participants (30%) had previously been immunized, with at least one dose of vaccine. Table 1 presents the description of the participants, with the stratification of cases according to the ventilatory support they needed during hospitalization.

In the sample, 48% (n = 13) reported having hypertension, 40% (n = 9) had type 2 diabetes; 35% (n = 5) were classified as obese (BMI ≥ 30 kg/m²), 31% (n = 4)

had a history of cancer with treatment and 23% (n = 2) dyslipidemia, while 16% (n = 1) had human immunodeficiency virus. None of the participants declared having obstructive or restrictive lung disease, but one of the participants started using a bronchodilator after the hospitalization period.

Of the 37 hospitalized participants, 47.5% used continuous oxygen, 20% (n = 8) required a high-flow nasal cannula and/or non-invasive ventilation and 25% (n = 10) required invasive mechanical ventilation, four of which were tracheostomized for a long period of mechanical ventilation. The mean overall length of stay was 14.32 \pm 15.43 (0 to 89) days and the period between discharge and the evaluation carried out was 39.40 (± 23.26) days.

Table 1 - Characteristics of participants according to ventilatory support received in the treatment of COVID-19

Ventilation support	NNS	Oxygen	IMV and/or HFNC	IMV	Total	p
n (%)	3 (7.5)	19 (47.5)	8 (20.0)	10 (25.0)	40 (100)	-
Age (years)	56.33 \pm 14.36	56.05 \pm 12.80	54.25 \pm 5.47	50.40 \pm 16.85	54.30 \pm 12.76	0.273
BMI (kg/m ²)	26.73 \pm 0.84	27.70 \pm 5.15	29.85 \pm 3.27	29.05 \pm 5.46	28.39 \pm 4.70	0.546
Days of hospitalization	-	8.47 \pm 4.43	12.88 \pm 4.42	30.90 \pm 23.03	14.33 \pm 15.44	0.001
Lung involvement on tomography (%)	-	46.58 \pm 18.86	58.75 \pm 19.23	55.00 \pm 10.54	51.49 \pm 17.47	0.016
6MWT value predicted (m)	559.47 \pm 10.47	557.83 \pm 33.61	568.44 \pm 25.87	572.47 \pm 32.98	563.74 \pm 30.67	0.533
6MWT value achieved (m)	569.00 \pm 79.50	410.32 \pm 90.39	472.94 \pm 88.02	265.85 \pm 125.11	398.63 \pm 130.58	0.002
6MRT value predicted (rings moved)	435.44 \pm 79.50	436.63 \pm 62.84	444.24 \pm 23.10	460.50 \pm 71.14	444.00 \pm 53.89	0.273
6MRT value achieved (rings moved)	203.00 \pm 169.00	257.68 \pm 62.84	273.25 \pm 66.09	181.00 \pm 90.03	237.58 \pm 85.51	0.253
Test interrupted (n)	6MRT (01)	6MRT (02)	6MRT (01)	6MRT (05) 6MWT (02)	6MRT (09) 6MWT (02)	-

Note: NNS = no need for support; IMV = invasive mechanical ventilation; HFNC = high-flow nasal cannula; BMI = body mass index; 6MWT = six-minute walk test; 6MRT = six-minute ring test. Bold values indicate statistical significance.

The average maximum HR values, calculated from the Karvonen et al.¹⁷ formula was 165.70 (± 12.76) bpm, considering the entire sample. Clinical measurements and values predicted and achieved in the tests are described in Table 2, considering all participants included.

The double product evaluated from the variables of the sixth minute of the 6MWT was significantly higher compared to the 6MRT, as was perceived exertion using the Borg scale for dyspnea. There was a greater drop in SpO₂ in the sixth minute of 6MWT compared to 6MRT

at the end of the tests. The values achieved in 6MWT were on average 70.71% predicted, while 6MRT showed a mean of 53.51% predicted. However, the difference between predicted and achieved, compared between tests, did not demonstrate a significant difference.

In relation to the variables analyzed according to ventilatory support, length of stay and lung involvement were greater in the group that had invasive mechanical ventilation during hospitalization, just as the value achieved in 6MWT was lower for these patients (Table 1).

Table 2 - Comparison of the variables assessed in the six-minute walk test (6MWT) and the six-minute ring test (6MRT) in the total sample (n = 40)

	VP	VA	VP versus VA p	HR 6th min	SpO ₂ 6th min	BP 6th min	PD 6th min	PE 6th min (LL)	DP 6th min
6MWT	563.74 ± 30.67	398.63 ± 130.58	0.001	113.05 ± 6.47	94.45 ± 2.96	129.65 ± 12.18	4.00 ± 2.77	3.44 ± 2.85	14,738.68 ± 2,741.21
6MRT	444.03 ± 53.89	237.58 ± 85.51	0.001	90.55 ± 5.52	96.63 ± 1.72	124.30 ± 11.73	2.39 ± 2.46	4.18 ± 2.43	11,292.85 ± 2,416.74
p	0.001	0.001	0.104	0.001	0.001	0.001	0.009	0.209	0.001

Note: VP = value predicted; VA = value achieved; HR = heart rate ; SpO₂ = oxygen saturation; BP = blood pressure; PD = Perceived dyspnea; PE = perceived exertion; LL = lower limbs; DP = double product; min = minute. Bold values indicate statistical significance.

In the Spearman correlation analysis applied between the variables independently, no correlation was identified between BMI and the result achieved in the 6MWT ($r = -0.074$; $p = 0.324$) and 6MRT ($r = 0.129$; $p = 0.213$) or with the difference between what was predicted and achieved in the tests (6MWT: $r = 0.132$; $p = 0.208$; 6MRT: $r = 0.144$; $p = 0.188$). Lung involvement did not show a correlation between results achieved in 6MWT ($r = -0.106$; $p = 0.257$) and 6MRT ($r = -0.263$; $p = 0.051$) or with the difference between what was predicted and achieved in the tests (6MWT: $r = 0.173$; $p = 0.143$; 6MRT: $r = 0.164$; $p = 0.155$). Age showed a negative and weak correlation in the 6MRT and the achieved result ($r = -0.267$; $p = 0.048$) and a weak negative correlation between the predicted and achieved values ($r = -0.374$; $p = 0.009$), with no correlations with the 6MWT (achieved: $r = -0.174$, $p = 0.141$; difference: $r = 0.125$; $p = 0.221$). The length of stay showed a correlation with both tests, a weak negative correlation with the value achieved in the 6MWT ($r = -0.436$; $p = 0.002$) and in the 6MRT ($r = -0.372$; $p = 0.009$) and a moderate correlation in the 6MWT between predicted and achieved values ($r = 0.536$; $p = 0.001$), which was not confirmed in 6MRT ($r = 0.116$; $p = 0.238$). The value achieved was 46.44% of that predicted for 6MWT and 39.31% for 6MRT. Only non-hospitalized patients reached the predicted value of the 6MWT, but no patient, regardless of severity, reached the predicted value of the 6MRT.

Discussion

Throughout the COVID-19 pandemic, clinicians have been gathering and publishing a series of observations

on patients who recently had the infection with varying severity. Complaints of generalized fatigue, chronic tiredness without apparent improvement after rest, memory changes, difficulty in resuming ADLs and frequent complaints of reduced physical capacity²⁻⁷ currently generate a series of new questions regarding the potential of stress tests in evaluation of post-COVID-19 patients, as envisioned in this study.

The characterization of the participants in this study corresponded to the profile that continues to be reported throughout clinical studies on COVID-19. There are studies, carried out mainly before immunization, which indicate that the majority of patients with greater severity are men, aged between 50 and 60 years, with a history of hypertension, diabetes and overweight or obesity. These same characteristics are recurrent in patients who require hospitalization and some type of ventilatory support.¹⁸⁻²⁰ This same profile was observed in the sample followed in this study.

In the evaluation of clinical variables measured in the tests proposed in our study, cardiovascular measurements reached higher values and SpO₂ showed a greater reduction in the 6MWT than in the 6MRT. We can infer this observation that the 6MWT enabled a better assessment of the cardiovascular and respiratory response due to the greater range of values of these variables during effort. Furthermore, it is observed in the data collected that patients who required invasive mechanical ventilation showed greater loss in the distance covered compared to other types of ventilatory support. Despite this, it is necessary to note that the 6MRT is a test performed only with the upper limbs, different from the gesture of walking, a more routine act that recruits a greater number of muscle groups.

The 6MWT is aimed at carrying out a test at the highest possible walking speed, which requires a large blood supply and oxygen consumption.⁸ In the 6MRT, there is the hypothesis that the ring test requires less cardiovascular supply by recruiting a smaller isolated muscle group in the upper limbs.^{21,22} This may explain the greater double product and increase in the sensation of dyspnea, related to 6MWT. The inability to meet the greater cardiovascular, respiratory and metabolic demand during exertion may explain the reduction in distance covered in the 6MWT by the sample in the present study and corroborates other research,¹⁻⁷ but clinical tests measuring direct oxygen consumption variables need be developed in the post-COVID-19 population to better evaluate this observation made in this cross-sectional study.

It is noteworthy that the comorbidities and the profile of the participants prior to the infection could be associated with the results achieved in relation to the values predicted in the tests. The sample presented in this study, however, did not have a diagnosis of previous heart or lung disease, and the participants who did not require hospitalization and ventilatory support managed to reach the predicted value of 6MWT, although this observation is limited by the small sample without hospitalization described here.

The drop in SpO₂ during 6MWT has been studied as a predictor of morbidity and mortality in pneumopathies,²³ as it has been described with interest after COVID-19.²⁴ In cases after COVID-19, 6MWT has been described not only for the assessment of silent hypoxemia but also for the perception of a thromboembolic event at hospital discharge.²⁵ In the present study, the reduction in SpO₂ was greater in the 6MWT than in the 6MRT, allowing better respiratory assessment in the 6MWT due to the proximity of the measurement to the oxygen supply to the tissues in the face of increased demand during exertion, without clinical signs that would raise the suspicion of a thromboembolic event.

All these observations must be critically considered in COVID-19, as it is an inflammatory microvascular disease, which can reduce metabolic and oxygen supply, which in exertion does not meet the demand, explaining the reduction in the distance covered in the 6MWT and in the number of ring movements in 6MRT.²⁶⁻²⁸ The infection must lead to systemic microvascular complications with the inflammatory process and lead to cardiovascular, neurological and musculoskeletal dysfunctions, which

would reduce the metabolic capacity necessary for exertion and ADLs.^{4,5,7,26-28}

There are studies that demonstrate similar cardiovascular and respiratory responses of 6MRT and 6MWT; however they are designed with a sample of patients with chronic diseases.^{9-13,29,30} It is necessary to consider the possibility that our sample here is the presentation of a number of cases with consequences of a viral disease. With this in mind, it appears that there is still much to expand on the complications and limitations caused by this virus, despite the results of the present study, demonstrating that the 6MWT presents itself as a more appropriate method for assessing functional capacity.

There was no difference in perceived exertion of the upper limbs (6MRT) compared to the lower limbs (6MWT). Nine patients discontinued 6MRT, compared to two with 6MWT, achieving the number of ring movements in half of the cases versus two-thirds of the total sample. These data must be interpreted with caution because of the small-sized sample involved and the tests used here being indirect in terms of assessing the clinical variables that were described. Only a test that allows direct measurement of oxygen consumption could be viewed as the gold standard for the ring test or the walk test.

The movements performed in the upper limbs during 6MRT potentially recruit the muscles of the upper limbs with anaerobic predominance, which may not increase cardiovascular demand in a prevalent way, and show less resistance to fatigue for maintaining the elevated position of the upper limbs.^{29,30} During the 6MRT, there were reports of pain in the shoulder girdle and a greater number of interruptions throughout the test. Studies on individuals with lung disease highlight that the 6MRT is influenced by the continuous use of accessory breathing muscles, with dynamic hyperinflation,³¹ and that they have lower vital and inspiratory capacity, showing worse results on the 6MRT.¹¹ In the present study, however, it was not possible to observe these indices.

The 6MWT, in the present study sample, demonstrated greater potential for evaluating functional capacity and cardiovascular and respiratory variables, reaching values closer to the maximum heart rate and greater double product, as well as a greater reduction in SpO₂ than the 6MRT. The subjective assessment of upper and lower limb exertion was similar in the tests, but not in the assessment of dyspnea and functional capacity.

These results require larger studies, with analysis of energy demand, dynamometry of the muscles of the upper and lower limbs and profile of the participants' lung function, which are pointed out as limitations in the present study. Therefore, it is necessary to improve clinical and functional assessment with analysis of oxygen consumption in an objective manner and with a greater number of participants.

Conclusion

Participants who required invasive mechanical ventilation had worse functional capacity, with 46% of what was expected in 6MWT and 39% of what was expected in 6MRT. There was, with greater inference for the assessment of functional capacity with the 6MWT after COVID-19 infection. The sample studied showed a reduction in functional capacity in the assessment carried out in both 6MRT and 6MWT.

Authors' contributions

CT and BFCF were responsible for data collection, and CVM and VBX were responsible for data analysis and writing the manuscript. All authors participated in the conception and design of the study, critical review of the manuscript and approval of the final version.

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