






# Efficacy of pulmonary telerehabilitation on exercise tolerance, fatigue, perceived exertion, depression, and quality of life in COVID-19 survivors

## Eficácia da telereabilitação pulmonar na tolerância ao exercício, fadiga, percepção de esforço, depressão e qualidade de vida em sobreviventes de COVID-19

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**ABSTRACT | INTRODUCTION:** Telerehabilitation advanced significantly with the emergence of COVID-19 and the recommendation of limiting physiotherapist-patient contact time whenever practicable. The effectiveness of telerehabilitation on those who had a longer stay in hospital and on oxygen support following discharge is still under question. **OBJECTIVES:** To evaluate the effects after six weeks of pulmonary telerehabilitation on exercise tolerance, fatigue level, perceived exertion, symptoms of depression and quality of life in patients surviving COVID-19. **MATERIALS AND METHODS:** A quasi-experimental study was conducted on 25 post-COVID-19 patients following discharge in a home environment setting. The participants were advised to prepare equipment such as oxygen concentrator, B-type oxygen cylinder (backup), lengthy oxygen tubes, finger pulse oximeter, mini static pedal exerciser, incentive spirometry, weight cuffs or water bottles and sandbags. After six weeks of telerehabilitation, the patients underwent assessments including initial oxygen saturation (SPO<sub>2</sub>), heart rate, peak oxygen demand during exercise to maintain baseline SPO<sub>2</sub>, peak heart rate, maximum drop in SPO<sub>2</sub>, recovery time to baseline SPO<sub>2</sub> measured with a pulse oximeter and stopwatch, peak perceived exertion using the Borg Dyspnea Scale, peak fatigue score using the visual analog scale (VASF), quality of life assessed with the SF-36 questionnaire, and mental health status evaluated with the Hamilton Depression Scale (HAMD). One-way repeated measure ANOVA and paired t-test were used. **RESULTS:** Significant improvements following the intervention on the initial SPO<sub>2</sub> ( $F(2.12, 23.13) = 21.0$ ,  $p < 0.05$ ) and heart rate ( $F(1.839, 20.23) = 43.73$ ,  $p < 0.05$ ), peak maximum oxygen demand during exercise to maintain baseline SPO<sub>2</sub> ( $F(1.487, 16.36) = 8.96$ ,  $p < 0.05$ ), peak maximum perceived exertion ( $F(5, 55) = 112.51$ ,  $p < 0.05$ ), peak maximum fatigue score ( $F(1.755, 19.30) = 67.44$ ,  $p < 0.05$ ), peak heart rate ( $F(1.798, 19.78) = 50.99$ ,  $p < 0.05$ ), peak drop in SPO<sub>2</sub> ( $F(2.467, 27.14) = 41.46$ ,  $p < 0.05$ ) and peak recovery time to achieve baseline SPO<sub>2</sub> ( $F(5, 55) = 78.89$ ,  $p < 0.05$ ). Six-week post-analysis on the depressive symptoms (mean difference = 11.25,  $p < 0.05$ ) and quality of life also showed significant improvement (mean difference = 29.92,  $p < 0.05$ ). **CONCLUSION:** Six weeks of comprehensive pulmonary telerehabilitation with simple equipment improved tolerance to exercise, fatigue, perceived exertion, symptoms of depression and quality of life for post-COVID-19 patients.

**KEYWORDS:** COVID-19. Dyspnea. Pulmonary Rehabilitation. Quality of Life. Telerehabilitation.

**RESUMO | INTRODUÇÃO:** A telereabilitação avançou significativamente com o surgimento da COVID-19 e a recomendação de limitar o tempo de contato entre fisioterapeutas e pacientes sempre que possível. A eficácia da telereabilitação em pacientes que permaneceram mais tempo no hospital e necessitaram de suporte de oxigênio após a alta ainda está em questão. **OBJETIVO:** Para avaliar os efeitos após seis semanas de telereabilitação pulmonar na tolerância ao exercício, nível de fadiga, percepção de esforço, sintomas de depressão e qualidade de vida em pacientes sobreviventes de COVID-19. **MATERIAIS E MÉTODOS:** Foi realizado um estudo quase-experimental com dezesseis pacientes pós-COVID-19 selecionados de um hospital multispecializado. Os participantes foram orientados a preparar equipamentos como concentrador de oxigênio, cilindro de oxigênio tipo B (reserva), tubos de oxigênio longos, oxímetro de pulso, exercitador de pedal estático, espirômetro incentivador, pesos de tornozelo ou garrafas d'água e sacos de areia. Após seis semanas de telereabilitação, os pacientes foram submetidos a avaliações, incluindo saturação inicial de oxigênio (SPO2), frequência cardíaca, demanda máxima de oxigênio durante o exercício para manter a SPO2 basal, frequência cardíaca máxima, queda máxima na SPO2, tempo de recuperação para SPO2 basal medido com um oxímetro de pulso e cronômetro, esforço percebido máximo usando a Escala de Dispneia de Borg, pontuação máxima de fadiga usando a escala analógica visual (VASF), qualidade de vida avaliada com o questionário SF-36 e estado de saúde mental avaliado com a Escala de Depressão de Hamilton (HAMD). **RESULTADOS:** Melhorias significativas após a intervenção foram observadas na SPO2 inicial (F (2,12, 23,13) = 21,0, p <0,05) e na frequência cardíaca (F (1,839, 20,23) = 43,73, p <0,05), demanda máxima de oxigênio durante o exercício para manter a SPO2 basal (F (1,487, 16,36) = 8,96, p <0,05), esforço percebido máximo (F (5, 55) = 112,51, p <0,05), pontuação máxima de fadiga (F (1,755, 19,30) = 67,44, p <0,05), frequência cardíaca máxima (F (1,798, 19,78) = 50,99, p <0,05), queda máxima na SPO2 (F (2,467, 27,14) = 41,46, p <0,05) e tempo máximo de recuperação para alcançar a SPO2 basal (F (5, 55) = 78,89, p <0,05). A análise de seis semanas pós-intervenção nos sintomas depressivos (diferença média = 11,25, p <0,05) e na qualidade de vida também mostrou melhoria significativa (diferença média = 29,92, p <0,05). **CONCLUSÃO:** Seis semanas de telereabilitação pulmonar abrangente com equipamentos simples melhoraram a tolerância ao exercício, a fadiga, a percepção de esforço, os sintomas de depressão e a qualidade de vida em pacientes pós-COVID-19.

**PALAVRAS-CHAVE:** COVID-19. Dispneia. Reabilitação Pulmonar. Qualidade de Vida. Telereabilitação.

## 1. Introduction

The COVID-19 pandemic has had a significant effect on people's lives and healthcare systems around the world.<sup>1</sup> Many nations have reported decreased COVID-19 severity in the last one to two years as a result of immunization and successful recovery.<sup>2</sup> Nevertheless, a high prevalence of long-COVID whereby the patients continued to show new symptoms such as breathlessness, fatigue, neuropsychological symptoms, cough, and musculoskeletal pain three months following the initial COVID-19 infection, was recorded.<sup>3-5</sup>

The American Thoracic Society/European Respiratory Society defines pulmonary rehabilitation as a comprehensive treatment following a detailed patient assessment followed by patient-tailored therapies such as exercise training, education, and behavior change, all aimed at improving the physical condition of people with respiratory disease.<sup>6</sup> Pulmonary rehabilitation (PR) for survivors of severe/critical COVID-19 is crucial to reduce symptoms of dyspnea, improve exercise tolerance, relieve anxiety, minimize fatigue, maintain function and improve quality of life.<sup>7,8</sup> In the case of COVID-19, existing attempts to contain the virus's spread have necessitated a ban on movement in the population. This limitation on movement has the unintended effect of making conventional face-to-face PR intervention and management unavailable. Thus, the need for alternative delivery approaches for PR and physical reconditioning services escalated and in demand.<sup>9</sup>

Telerehabilitation is a way to provide needed treatment while maintaining the need for social isolation, which has been introduced as part of a slew of steps to slow the spread of the SARS-Cov-2 virus in societies.<sup>1,10</sup> A recent research on respiratory rehabilitation following COVID-19 has given several recommendations to maintain patients' physical function while simultaneously promoting psychological reconstruction and capacity for physical remodeling activity.<sup>7</sup> Nevertheless, there are patients unable to gain full benefits from the rehabilitation due to limited resources and access.<sup>9</sup> Thus, the availability of telerehabilitation delivered remotely with the access of experienced therapists providing assessment and therapy can ensure the ongoing rehabilitation and, more importantly, improve the quality of life following the infection. Thus, the current study aimed to evaluate the effects after six weeks of pulmonary telerehabilitation on exercise tolerance, fatigue level, perceived exertion, symptoms of depression and quality of life in patients surviving COVID-19.

## 2. Method

### 2.1. Study settings

The current study adopted a quasi-experimental study of six-week interventions from October 2020 to September 2021 conducted in a post-COVID rehabilitation center of a KMCH multispecialty hospital. The present study obtained approval from the KMCH Ethics Committee (EC/AP/861/11/2021).

### 2.2. Participants

Before the recruitment, the participants in the current study were evaluated by clinicians and investigations including imaging were taken to rule out for any contraindications before being referred to physiotherapy for rehabilitation. The participants were recruited based on the following inclusion criteria.<sup>11</sup>

1. Prolong stay in hospital following COVID-19 (>21 days) or requiring oxygen support after discharge.
2. Persisting symptoms such as tiredness, fatigue and unable to perform daily activities.
3. Patients who had pulmonary involvement alone.

Participants were excluded from the study if present with any of the following criteria:

1. Patients with multiple organ dysfunction syndrome (MODS) following COVID-19, presenting predominantly cardiac, renal, neurological or polytrauma.
2. Coexistence cancer.
3. Severe frailty and end-of-life care.
4. Patients with visual disturbances or hearing problems.
5. Patients without a family member or attender stand by and unable to use telerehabilitation gadgets individually.

The participants will be allowed to stop or take rest at any time during the intervention if they meet any of the following criteria: 1) SPO<sub>2</sub> drops below 88%, 2) HR exceeds 120 bpm or surpasses the target heart rate, or 3) Borg scale score exceeds 3.

### 2.3. Procedure

All the participants were explained on the objectives and procedures as well as obtained written informed consent before the commencement of the current study. The participants were required to attend the first session in person for baseline data measurement such as initial peripheral oxygen saturation (SPO<sub>2</sub>), initial heart rate, peak maximal oxygen requirement for exercise to maintain baseline SPO<sub>2</sub> during exercises (lit/min), peak maximum perceived exertion expressed during exercises, peak maximum fatigue score expressed during exercises, peak heart rate during exercise, peak drop in SPO<sub>2</sub>, peak recovery time taken to reach baseline SPO<sub>2</sub>, quality of life and mental health status. For the exercise prescription at home, 1RM measurement were taken. Participants were required to perform single repetitions with progressively heavier weights until unable to complete a full repetition with proper form. Adequate rest (2-5 minutes) between each 1RM attempt were provided to allow for recovery and prevent fatigue from affecting subsequent lifts. The physiotherapist also advised participants to prepare equipment such as oxygen concentrator, B-type oxygen cylinder (back up), lengthy oxygen tubes, finger pulse oximeter, mini static pedal exerciser, incentive spirometry, weight cuffs or water bottles and sandbags to facilitate the telerehabilitation program at home.

An individualized exercise program was designed based on the target SPO<sub>2</sub>, perceived exertion of Borg's scale and target heart rate using Karvonen's formula<sup>12</sup> as below.

$$\text{Target Heart Rate} = (\text{Maximum Heart Rate} - \text{Resting Heart Rate}) \times (80.0\%) + \text{Resting Heart Rate}$$

The physiotherapist established the tailored individualized exercise programs for the participants based on the guidelines by the British Thoracic Society guideline on pulmonary rehabilitation in adults accredited by NICE.<sup>13,14</sup> Prior to the exercise, the participants were instructed to assess the initial SPO<sub>2</sub> and heart rate using a pulse oximeter. In addition, those with supplemental oxygen supply were requested to increase the flow 1-2 lit/min from the baseline oxygen requirement and maintained until the end of the exercise sessions. The exercises were planned for five days per week, with at least four of the sessions supervised by the physiotherapist. The weight and strength training exercises were given twice out of the five sessions and commenced two weeks after the first telerehabilitation session.

During the sessions, the participants were required to check the SPO<sub>2</sub> and heart rate in frequent intervals as well as the level of fatigue, breathlessness, tiredness, and relevant symptoms. Based on the participants' level of SPO<sub>2</sub> and comfortability, the level of oxygen supplement was tapered accordingly. The exercise programs that were conducted for the participants are as shown in Table 1. As a part of comprehensive rehabilitation, other healthcare team members such as the dietitian, pharmacist, and psychologist work together by closely monitoring, assessing, and prescribing the treatment as per need for the patients. After completing the six-week intervention, participants were expected to attend the final evaluation in person.

**Table 1.** Detailed exercise programs during the six weeks of telerehabilitation intervention

Type of exercises	Duration/ Frequencies (Repetition)
Breathing exercises such as diaphragmatic breathing, incentive spirometry and segmental breathing exercises	
Warm-up:	1- 2 sets of 10 repetitions
Active upper and lower limb exercises	*Frequencies and repetitions were increased based on tolerance on a weekly basis
Endurance walking	10 minutes/session
Static pedal cycling	Upper limbs for (5 minutes/session) and lower limbs (10 minutes/session)
Weight and strength training	(Weekly two sessions with 1- 2 sets of 10 repetitions) – The training was started with 50.0% of 1RM and added accordingly based on the patient's progress weekly
Cool down: stretching to specific major muscle groups	
Breathing exercises: relaxed diaphragmatic breathing	

1RM = one repetition maximum.

Source: British Thoracic Society (2020) and Bolton CE et al. (2013).

## 2.4. Outcome tools

The participants were closely monitored through video conferences (Zoom calls) and WhatsApp communication for all the supervised sessions. All the exercise session details were recorded and participants advised to maintain an exercise diary for daily record purposes. All the data were transferred into Excel and monitored continuously for progress or changes required based on the participant's improvement.

- The level of SPO<sub>2</sub> and heart rate in the current study were measured using a pulse oximeter.<sup>15</sup>
- Perceived exertion of the exercises was assessed using a modified Borg dyspnea scale.<sup>10,16</sup> The scale was administered before and after each exercise session.
- The peak level of fatigue during exercises was measured using the Visual Analog Scale Fatigue (VASF).<sup>10,17</sup> The scale measures from 0 as 'no fatigue' to 10 as 'the worst presumable level of fatigue' recorded during the exercises.
- A stopwatch measured the peak recovery time taken to reach baseline SPO<sub>2</sub>, the resting time between the exercises and total exercise time.
- The improvement of the quality of life of the participants was assessed using the SF-36 questionnaire. The questionnaire consists of two sections: Physical Composite Score (PCS) and a Mental Composite Score (MCS) with the following domains of physical function, role physical, bodily pain, general health, vitality, social function, role emotional, and mental health.<sup>18</sup> The questionnaire was only assessed pre and post-six-week telerehabilitation interventions.

- The psychological functions of the patients post six weeks interventions were administered using the Hamilton Depression Scale (HAMD) pre and post-week interventions. The questionnaire assesses the depressive symptoms among patients post-COVID; comprises 24 items with a scale from 0-2 or 0-4. A higher score indicates a higher level of depression and anxiety.<sup>19,20</sup>

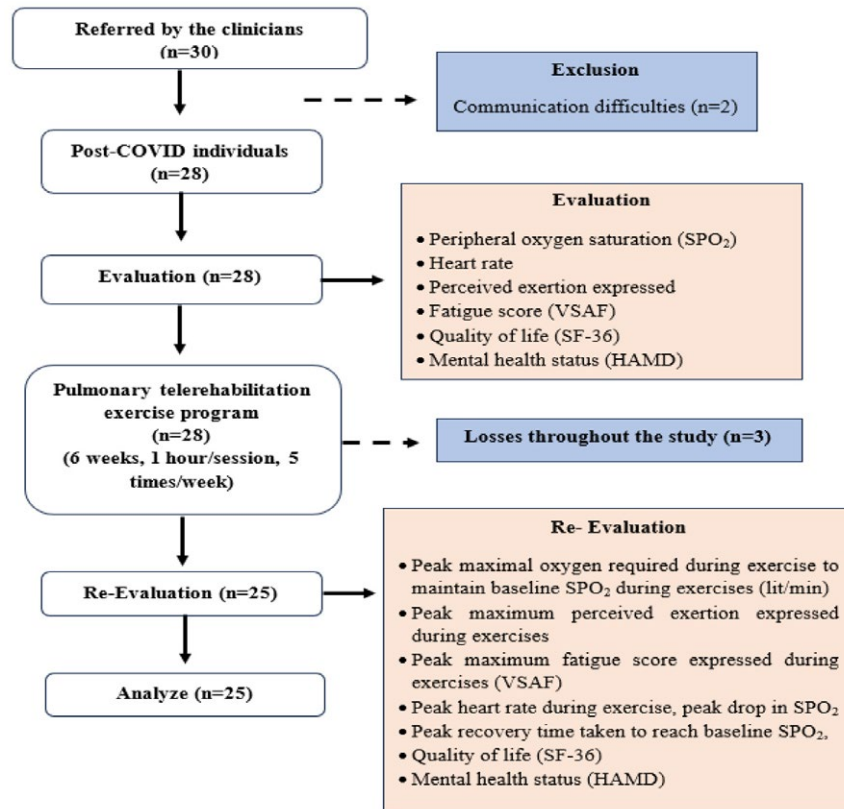
## 2.5. Statistical Analysis

All the data was transferred from Microsoft Excel and analyzed using IBM-SPSS Statistics 24 software. The normality of the data was assessed using a Kolmogorov-Smirnov test and all the data were found to be normally distributed. Mean and standard deviation are employed to present the values of each variable. For statistical analysis, the differences in the peak maximal oxygen requirement for exercise to maintain baseline SPO<sub>2</sub> (lit/min), peak maximum perceived exertion expressed, peak maximum fatigue score expressed, peak heart rate, peak drop in spo<sub>2</sub>, peak recovery time taken to reach baseline SPO<sub>2</sub>, resting time in between the exercises and total exercise time assessed using one-way repeated measure ANOVA. Bonferroni correction were performed for the post-hoc comparisons to account for multiple comparisons testing if ANOVA indicated a significant difference. Whereas the pre and post 6-week intervention on the quality-of-life score and mental health status score were analyzed using the paired test. The significant level was set at 0.05 with a 95.0% confidence level in all the analyses.

### 3. Results

Thirty participants were referred by the clinicians for pulmonary telerehabilitation. However, two participants were excluded due to communication difficulties, and three participants did not complete the proposed six-week intervention. Hence, only 25 (thirteen males and twelve females) post-COVID-19 survivors completed the current six weeks of telerehabilitation intervention. The flowchart of participants is shown in Figure 1.

Figure 1. Flowchart of the study participants



VSAF: visual analog scale fatigue, SF-36: 36-Item Short Form Health Survey, HAMD: Hamilton Depression Scale.  
Source: the authors (2024).

The participants in the current study were recruited following 21 days of post-COVID. The mean  $\pm$  age of the participants was  $57 \pm 7.26$  and BMI of  $25.64 \pm 2.5$ . 36.0% of the participants had previous comorbidities while 32.0% required home oxygen post-discharge. The detailed characteristics of the participants are in Table 2.

**Table 2.** Baseline characteristics of the participants

Variables	Characteristics		
		Frequencies (%)	Mean (S.D.)
<b>Gender</b>	Male	13 (52%)	
	Female	12 (48%)	
<b>Age</b>			57.00 (7.26)
<b>BMI</b>			25.64 (2.5)
<b>Comorbidities</b>	Hypertension	7 (28%)	
	Diabetes	2 (8%)	
<b>Required intubation</b>	Yes	2 (8%)	
<b>Required HFNC or BiPAP</b>	Yes	5 (20%)	
<b>Length of hospital stay</b>			17.25 (12.00)
<b>ICU Admission</b>	Yes	5 (20%)	
<b>Home oxygen requirement after discharge</b>	Yes	8 (32%)	

S.D. = Standard Deviation, BMI = Body Mass Index, HFNC = High Flow Nasal Cannula, BiPAP = Bilevel Positive Airway Pressure, ICU = Intensive Care Unit.  
Source: the authors (2024).

Table 3 represents the detailed six-week intervention comparison on the effectiveness of telerehabilitation among post-COVID-19 survivors. The resting SpO<sub>2</sub> showed a significant improvement (p-value <0.05) from week one (92.17 ± 1.99) to week six (95.08 ± 1.56) with a large effect size. However, the initial heart rate also reported significant improvement (p-value <0.05) from week one (113.75 ± 11.1) to week six (98.42 ± 11.52) with a large effect size.

The peak maximal oxygen requirement (lit/min) to maintain baseline SpO<sub>2</sub> during exercises showed a significant improvement (p-value <0.05) from week one (2.83 ± 1.99) to week six (1.17 ± 0.72) with a large effect size. The perceived exertion during the exercises decreases with the telerehabilitation intervention with significant improvement (p-value <0.05) from week one (4.83 ± 0.58) to week six (1.50 ± 0.52) with a large effect size.

Participants reported reduced levels of fatigue from week one (5.25 ± 1.29) to week six (1.50 ± 0.68) with significant improvement (p-value <0.05) with a large effect size. The peak heart rate per minute during exercise improves significantly over the six weeks of intervention (p-value <0.05) from week one (129.92 ± 9.29) to week six (114.25 ± 10.93) with a large effect size.

The peak drop in SpO<sub>2</sub> among the participants also improved with the mean from week one (86.33 ± 1.67) to week six (90.92 ± 1.73) with a large effect size. In addition, peak recovery time taken to reach baseline SpO<sub>2</sub> (min) also improved from week one (4.42 ± 0.9) to week six (1.33 ± 0.49) with significant improvement (p-value <0.05) and large effect size.

The quality of life among the post-COVID-19 survivors showed significant improvement in SF-36 score from 44.42 ± 13.45 (Week 1) to 74.33 ± 13.02 (Week 6) (p-value <0.05), with mean differences of 29.92. The assessment using the HAMD questionnaire on the depressive symptoms also showed significant improvement with a score of 20.25 ± 6.66 (Week 1) to 9.00 ± 3.10 (Week 6) (p-value <0.05), with mean differences of 11.25.

**Table 3.** Effects of six weeks of pulmonary telerehabilitation on exercise tolerance, level of fatigue and perceived exertion among post-COVID-19 patients

Variables	Mean (S.D.)			One-Way Repeated Measure ANOVA			
	Week 1	Week 3	Week 6	df, error	F value	P-value	$\eta^2p$
<b>Initial SpO<sub>2</sub></b>	92.17 (1.99)	92.92 (1.73)	95.08 (1.56)	2.120, 23.13	21.00	<0.05	0.656
<b>Heart rate per min</b>	113.75 (11.10)	111.67 (11.98)	98.42 (11.52)	1.839, 20.23	43.73	<0.05	0.799
<b>Peak maximal oxygen requirement for exercise to maintain baseline SpO<sub>2</sub> during exercises (Lit/Min)</b>	2.83 (1.99)	2.20 (1.50)	1.17 (0.72)	1.487, 16.36	8.96	<0.05	0.449
<b>Peak maximum Borg's scale expressed during exercises</b>	4.83 (0.58)	3.83 (0.72)	1.50 (0.52)	5, 55	112.51	<0.05	0.911
<b>Peak maximum fatigue score expressed during exercises</b>	5.25 (1.29)	3.75 (0.97)	1.50 (0.68)	1.755, 19.30	67.44	<0.05	0.860
<b>Peak heart rate per min during exercise</b>	129.92 (9.29)	125.5 (11.22)	114.25 (10.93)	1.798, 19.78	50.99	<0.05	0.823
<b>Peak drop in SpO<sub>2</sub></b>	86.33 (1.67)	87.83 (1.40)	90.92 (1.73)	2.467, 27.14	41.46	<0.05	0.790
<b>Peak recovery time taken to reach baseline SpO<sub>2</sub> (min)</b>	4.42 (0.90)	3.42 (0.90)	1.33 (0.49)	5, 55	78.89	<0.05	0.878

S.D. = Standard Deviation, SpO<sub>2</sub> = Peripheral oxygen Saturation, p <0.05 were considered significant.  
Source: the authors (2024).

#### 4. Discussion

Following the treatment regimen and post-discharge protocol, COVID-19 patients are at risk of developing severe symptoms such as deconditioning or hypoxemia or residual fibrotic lesions in the lungs, and this has been a major concern among healthcare professionals because the patients may decompensate at home.<sup>21,22</sup> Nevertheless, post-six-week telerehabilitation, our study reported a significant improvement in exercise tolerance level (initial level of resting SPO<sub>2</sub>, initial heart rate, peak oxygen requirement during exercise, peak drop in SPO<sub>2</sub>, peak heart rate during exercises and peak recovery time to reach baseline SPO<sub>2</sub>). Our findings are consistent with previous research, as the components of pulmonary rehabilitation, which include breathing exercises, respiratory muscle training, aerobic exercise, and resistance training may have improved physiological changes in working respiratory muscles such as the intercostal muscles, parasternal muscles, abdominal muscles, and other related muscles, resulting in improved lung capacity scoring and restoration of lung function.<sup>15,22</sup>

Persistent symptoms such as fatigue and dyspnea were reported in a study of COVID-19 patients six months after hospitalization discharge and showed a significant association with lower physical fitness.<sup>23</sup> Furthermore, in another study of 2113 COVID-19 patients, fatigue (87.0%) and dyspnea (71.0%) were the two most common symptoms reported 79 days after discharge<sup>24</sup> that could be possibly caused by prolonged hospitalization, side



effects of steroid medications, muscle deconditioning and other secondary complications such as atelectasis, alveolitis and pulmonary fibrosis.<sup>23,25</sup> The current study found that after six weeks of pulmonary telerehabilitation, patients' levels of exertion and fatigue improved significantly. Improved aerobic capacity and increased muscle strength as a result of resistance and endurance training, and consistent breathing exercises could all contribute to this.

Similar to previous study results on an integrated three-week supervised pulmonary rehabilitation program in COVID-19 patients<sup>26</sup>, the current study also found a significant improvement in depression and quality of life scores. Improvements in exercise tolerance capacity, progression in breathing pattern and rate, increased muscle strength and endurance level, and participation of multidisciplinary healthcare professionals (physician, physiotherapist, dietitian, pharmacist, and psychologist) during telerehabilitation would further increase patient motivation and indirectly contribute to an improved quality of life.

Telerehabilitation was found to be safe and feasible, with no adverse effects or interurrences observed during home exercises. Similarly, a pilot study of 44 post-COVID-19 survivors following hospitalization also concluded that telerehabilitation was safe, feasible, and had high adherence to recovery.<sup>27</sup>

Many post-COVID-19 patients are still exhibiting chronic, clinically significant sequelae after being discharged due to post-COVID-19 infection especially on the new illness-related fatigue, shortness of breath, neuropsychological impairment, dyspnea, as well as physiological disorders such as sleep deprived, stress, anxiety and depression.<sup>24,28-32</sup> Thus, there is a crucial need for pulmonary rehabilitation following post-COVID-19 to ensure that patients able to improve their exercise tolerance, decrease fatigue, improve quality of life and return to the family and society efficiently especially among those who required hospitalization.<sup>7,9</sup>

However, the proposed rehabilitation was hampered by several barriers, including the rapid spread of nosocomial infection in the community, insufficient supplies of personal protective equipment, the need for a large exercise space (to allow for social distancing), proper use of waiting areas, and equipment preparation and regular cleaning. Thus, hybrid pulmonary telerehabilitation models that include in-person evaluation and exercise testing, as well as a combination of in-person and virtual exercise programs, education, and self-management, can be used to improve exercise capacity, improve quality of life while lowering the spread of infections.<sup>33</sup>

The primary limitations of our study include the six-week intervention's short length, the small sample size, and the lack of COVID-19 severity evaluation. Furthermore, we had no notion if the respondents continued to exercise on their own, despite being told to keep a daily journal of their workout practice. Future studies should include a larger sample size, long-term follow-up, and objective measurement of parameters such as respiratory muscle strength, peripheral muscular strength, and functional ability, as measured by the step test and chair sit-to-stand test.

## 5. Conclusion

Comprehensive pulmonary telerehabilitation with a multi-disciplinary team and with simple home-useable equipment such as a mini peddler, simple weight cuffs, home oxygen concentrator and finger pulse oxy-meter is an efficient, practicable, and feasible intervention that demonstrated a significant improvement in exercise tolerance, fatigue, perceived exertion, depression symptoms, and quality of life. Given the rapid spread of infection in the community and the scarcity of resources, human logistics and financial factors, telepulmonary rehabilitation would be a better option for accelerating the recovery of COVID-19 patients after discharge and which also could be considered for other chronic lung diseases rehabilitation.

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## Authors' contributions

Muthusamy S, Krishnan A, Jagannathan KK and Rajagopal A participated in the data curation and visualization of the manuscript. Subramaniam A and Muthusamy S contributed to the formal analysis and on the review & editing of the manuscript. Ramanathan RP and Muthusamy S worked on the conceptualization and methodology of the study. Ambusam S and Sivaguru M wrote the original draft of the manuscript.

## Conflicts of interest

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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