Original Article

Pulmonary rehabilitation focusing on the regulation of respiratory movement can improve prognosis of severe patients with COVID-19

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Background: Since the coronavirus disease 2019 (COVID-19) emerged in Wuhan, China, it has become a global public health emergency. Besides conventional care, pulmonary rehabilitation (PR) is an equally important treatment for patients with COVID-19 suffering from respiratory, physical and psychological disease. The aim of this study is to investigate the role of PR on the inpatients with severe COVID-19.

Methods: This study was a self-pre- and post-control prospective clinical trial, which totally recruited 31 inpatients confirmed COVID-19 by RT-PCR. They were performed 3-week PR. The demographic data, medical records, symptoms, laboratory findings and chest computed tomographic (CT) scans of patients were collected at baseline. The effect of PR was assessed by questionnaires before PR as well as after 2- and 3-week PR.

Results: After 3-week PR and treatment, neutrophil percentage decreased, while lymphocyte percentage and lymphocyte count increased (before *vs.* 2 weeks after PR respectively: P=0.001; P=0.001; P<0.0001). Besides, CRP and procalcitonin reduced significantly (before *vs.* after respectively: P<0.0001; P=0.023). Patients' oxygen intake decreased and oxygen saturation increased significantly. Meanwhile, PR relieved the patients' symptoms of cough and dyspnea, improved the patients' self-care ability, physical fitness and mental state significantly. Activities of daily living (ADL) score increased and Modified Medical Research Council Dyspnea Scale (mMRC) decreased after PR.

Conclusions: PR can relieve symptoms, enhance health-related quality of life, improve respiratory muscle function and alleviate disease-related anxiety and depression of severe patients with COVID-19. PR should be provided throughout the diseases management process, regardless of whether the patient is hospitalized or at home.

Keywords: Coronavirus disease 2019 (COVID-19); pulmonary rehabilitation; symptoms; activities of daily living (ADL)

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Introduction

Since the coronavirus disease 2019 (COVID-19) emerged in Wuhan, China, in December, 2019 (1), as of 7 July, 2020, a total of 11,653,925 laboratory-confirmed cases has been documented globally (2). It has spread worldwide and has become a global public health emergency. The common initial symptoms of COVID-19 are fever, cough, fatigue, anorexia, myalgia and diarrhea (3). Lung is the most affected organ by COVID-19, with pathologies that contain diffuse alveolar epithelium destruction, capillary damage/bleeding, hyaline membrane formation, alveolar septal fibrous proliferation, and pulmonary consolidation (4). Some severe patients may have long-term impairment and dysfunctions, including pulmonary fibrosis, acute respiratory dyspnea syndrome (ARDS), heart, liver, kidney, nerve and immune system (5). Besides conventional care, such as symptomatic and antiviral therapy, pulmonary rehabilitation (PR) is equally important to the treatment for patients with COVID-19 suffering from respiratory, physical and psychological disease (6).

PR, defined as a comprehensive non-pharmacological intervention, is generally quite effective in patients with chronic obstructive pulmonary disease (COPD) and interstitial lung disease (7,8), and has also been regarded as one of the most important interventions for patients with COPD (9). PR has many benefits including improving respiratory function, exercise endurance, self-care in daily living activities, as well as psychological support, etc. (10). It has been suggested that physical training can improve both the cardiorespiratory and musculoskeletal performances in patients with severe acute respiratory (SARS) (11). Patients with COVID-19 may have some residual fibrotic lesions in the lungs following current treatment and discharge protocols, which can affect the patient's respiratory function (12). Therefore, the evidence of PR for patients with SARS provided strong support and reference for the development of PR for patients with COVID-19.

Rehabilitation specialists in China have developed practical and feasible PR guidelines for patients with COVID-19 (13). With the promulgation of PR guidelines, PR has been used as one of the therapeutic methods for inpatient and discharged patients with COVID-19. Based on the guidelines, we applied "breathing method" as the core of PR for inpatients with COVID-19. Up to now, few studies have been conducted on the improvement of symptoms in inpatients with COVID-19 receiving PR therapy. The purpose of this study is to investigate into the effect of a 3-week PR program on the inpatients with COVID-19 who were severe at the time of admission but had stabilized after standard treatment. We present the following article in accordance with the TREND reporting checklist (available at http://dx.doi.org/10.21037/apm-20-2014).

Methods

Participants

Participants with confirmed COVID-19 by RT-PCR (14) were recruited from Renmin Hospital of Wuhan University from January 30th, 2020 to March 3rd, 2020. Renmin Hospital of Wuhan University, located in Wuhan, Hubei Province, the endemic areas of COVID-19, is one of the major tertiary hospitals assigned by the government for the treatments for severe patients with COVID-19. The definitions of severe patients are: respiratory rate of more than 30/minute or an oxygen saturation (SaO_2) of 93% or less when they were breathing ambient air or a ratio of the partial pressure of oxygen (PaO_2) to the fraction of inspired oxygen (FiO_2) (PaO_2:FiO_2) at or below 300 mmHg (15). We enrolled 31 patients (19 males and 12 females), who accepted standardized treatment according to the Diagnosis and Treatment Guideline for New Coronavirus Pneumonia (6) for 2 weeks and can perform PR after assessment. Exclusion criteria: (I) patients with a high risk of mortality; (II) patients with dementia, tumor or metastatic cancer, and acute myocardial infarction/acute coronary syndrome.

Oral consent was obtained from patients or patients' relatives. Informed consents were obtained for all involved subjects in accordance with the Institutional Review Board (IRB) of the First Affiliated Hospital of Xi'an Jiaotong University (No: XJTU1AF2021LSK-037). The study conformed to the provisions of the Declaration of Helsinki (as revised in 2013).

Study design

This study is a before-after self-control study. The contents of PR included (I) breathing exercise; (II) respiratory muscle training; (III) stretching training; (IV) psychotherapy. Patients can perform PR (2 sessions per day for 3 weeks) in the isolation ward by video teaching (16).

Breathing method exercise (3-5-6 breathing)

It can be performed in a seated, bedside seated or a standing position. Each breathing cycle consists of deep inhalation for 3 seconds—holding breath for 3–5 seconds, and slow exhalation for about 6 seconds; 3–4 respiratory cycles in

Figure 1 The pose in PR. (A) Bridge exercise; (B) air pedal; (C) ankle pump; (D) grasping; (E) tiptoeing.

each set; patients can rest for 30–60 seconds between each set depending on shortness of breath.

Respiratory muscle training (twice a day)

Relax the whole body in the right lateral decubitus position and inhale slowly to let the gas fully into the left lung, then exhale. Inhale and exhale alternately for 15 minutes. Then change to the left lateral decubitus position. Breathe calmly, then bridge exercise (*Figure 1A*), alternating straight leg, air pedal (*Figure 1B*) and ankle pump (*Figure 1C*) in supine position (17).

Stretching training (twice a day)

(I) Upper limbs exercise: upward lift, lateral lift, abduction, chest enlargement and grasping (*Figure 1D*), which were designed to improve the function of muscle groups around the shoulders, upper arms and forearms. (II) Lower limb exercise: lifting, kicking, tiptoeing (*Figure 1E*) and stepping, for building muscle strength in the lower extremities. Each action lasts for 5 seconds, repeat the whole set 2–3 times each time. All exercises can be performed in lying position, sitting position and standing position coordinated with breathing regulation (18).

Psychotherapy

Patients listen to light music for 20 minutes per day, and a professional psychiatrist uses a mobile phone to perform psychological intervention (19).

Safety procedures

In the process of PR, patients should act according to their ability and make gradual progress. Nurses need to closely monitor patients' vital signs, and the patients' oxygen saturation should be greater than 93% and heart rate should be less than 120 beats/minute during PR. If patients feel uncomfortable during PR, such as palpitation, sweating, shortness of breath, they need to stop PR. Additionally, patients who needed oxygen therapy could do it in bed or at bedside.

Data collection and assessment

Baseline

The demographic data, medical records, symptoms, laboratory findings and chest computed tomographic (CT) scans of patients were collected at baseline.

Primary outcome measures

Respiratory symptoms; secondary outcome measures: exercise endurance, activities of daily living (ADL) score, blood oxygen saturation (SaO_2%), and oxygen intake. We prospectively collected patients' outcomes on three different time points: first at admission, second two weeks after they began PR, then three weeks after they began PR.

Assessment of respiratory symptoms

The respiratory symptoms included cough, sputum and dyspnea, which was assessed by questionnaires. Dyspnea was evaluated using the modified Medical Research Council (mMRC) dyspnea scale (20). If mMRC score was equal to or more than 2, exertional dyspnea was identified.

Exercise tolerance, which was an assessment included whether you can elevate leg in bed and stand and sit by yourself.

ADL assessments included whether they can put on their own shoes, wear clothes and go to the toilet. Functional status was subjectively assessed by interviewers using ADL score (the total score ranges from 0 to 100) (21), and high scores indicate strong self-care ability.

Additionally, SaO_2%, oxygen intake, diet and sleep were recorded.

Statistical analysis

The data were analyzed using SPSS version 26 statistical software. Baseline characteristics were presented as count and percentage for categorical data, mean ± standard deviation (SD) for normally distributed continuous data and median (inter quartile range) for continuous data of skewed distribution. As appropriate, before and after PR, comparisons were carried out using paired samples-t test when the data were normally distributed and using the Maan-Whitney test when they were not, while categorical data were tested using the chi-square test. A $P<0.05$ or $P<0.01$ was considered statistically significant.

Results

Demographic and clinical characteristics of patients

We enrolled 31 patients (19 males, 12 females) with COVID-19 from Renmin Hospital of Wuhan University from January 30th, 2020 to March 3rd, 2020. The demographic and clinical characteristics of patients were shown in *Table 1*. Mean age was 60.39±10.20 years and all enrolled patients were never smoked. Among them, 22.58% of patients once accepted PR. In the first 3 days after PR treatment, 21 patients had side effects of muscle soreness and fatigue. However, with regular rehabilitation, side effects disappeared within 1 week.

Laboratory findings of patients before and after PR and treatment

Variations in laboratory findings of patients before and after PR and treatment were listed in *Table 2*. Comparing of inflammatory markers in the blood, we found neutrophil percentage decreased, lymphocyte percentage and lymphocyte count increased after 2-week PR. While, CRP and procalcitonin reduced after 2-week PR. By reflecting the results of nutrient level *in vivo*, we found that RBC and HGB didn't rise until 3 weeks after PR, while ALB and TCHO elevated after 2-week PR.

Assessment of symptoms and results of questionnaires before PR and treatment and after 2- and 3-week PR

Table 3 showed the difference of symptoms and the results of questionnaires before and after PR. We can see that shortness breath, cough and sputum production relieved significantly after PR, while the number of fatigue patients increased ($P<0.0001$). The baseline prevalence for dry cough, productive cough, and dyspnea was 67.74%, 54.84%, and 51.61%, respectively, which all decreased pronouncedly over time. After 2-week PR, the prevalence rate was 6.9% in dry cough, 20.69% in productive cough,

Table 1 Demographic and clinical characteristics of patients

Characteristics	Patients (N=31)
Age (years)	60.39±10.20
Male sex, No. (%)	19 (61.29)
Smoking history, No. (%)	
Never smoked	31 (100.00)
Had a history of PR	7 (22.58)
Symptoms on admission, No. (%)	
Fever	23 (74.19)
Cough	22 (70.97)
Fatigue	1 (3.23)
Shortness breath	12 (38.71)
Diarrhea	2 (6.45)
Sputum production	4 (12.90)
Coexisting disorder, No. (%)	
Diabetes	2 (6.45)
Hypertension	12 (38.71)
Hepatitis B infection	2 (6.45)
Cancer	2 (6.45)
Chronic renal disease	2 (6.45)
Coronary heart disease	2 (6.45)
Tuberculosis	1 (3.23)
Don't have coexisting disorder	9 (29.03)
Abnormalities on chest CT, No. (%)	
Ground-glass opacity	16 (51.61)
Bilateral patchy shadowing	21 (67.74)
Pulmonary bullae	1 (3.23)

and only 31.03% of patients reported dyspnea as a remained symptom. After 3-week PR, none had sputum and fewer felt fatigue or shortness breathe or palpitate and all patients can wear clothes or shoes or go to the toilet by themselves. Those patients only felt fatigue or shortness breathe when walked after 3-week PR. As the progresses of PR, the patients' sleep and diet have improved.

Improvement of hypoxemia and ADL score before and after PR

As shown in *Figure 2*, mMRC both decreased after 2- and 3-week PR. Meanwhile, the patients' oxygen intake decreased. SpO_2 increased after 2- and 3-week PR. The patients' ADL score also improved after PR. There was no significant difference in mMRC, oxygen intake, SpO_2 and ADL between 2 and 3 weeks after PR.

Discussion

COVID-19 is a highly infectious respiratory disease and the initial symptoms of patients with COVID-19 were fever, cough and dyspnea (22). There are currently no effective treatments or vaccines other than meticulous supportive care, so it is necessary to find more measures to deal with this pneumonia. With the accumulation of experience in the treatment, PR is crucial for severe and critically ill patients who have respiratory, physical, and psychological dysfunction.

Veronica illustrated that increased production of inflammatory cytokines occurred in COVID-19 patients, especially in severe patients, whose the inflammatory response is enhanced (23). Through routine treatment and PR, we found that the count and percentage of patients' lymphocytes increased, and inflammatory response was weakened. The results are similar to the findings of Do *et al.* and Davidson. Davidson *et al.* found a reduction in plasma IL-6, IL-8, CRP levels and Davidson indicated that CD8+T lymphocytes increased after PR (24), which proved that the anti-inflammatory response to exercise in patients with COPD. Because the muscle fibers appear to produce anti-inflammatory cytokines, which can inhibit the production of the inflammatory cytokine (25). In healthy individuals, the proinflammatory response is balanced by the anti-inflammatory response after a vigorous aerobic exercise (26). Undoubtedly, with regular treatment and improved symptoms, the patients' inflammatory response will be reduced. So PR can be used as an adjunct therapy to reduce the COVID-19 patients' inflammatory response.

Nanshan Zhong's team revealed that in discharged survivors with COVID-19, impairment of diffusion capacity is the most common abnormality of lung function followed by restrictive ventilatory defect, which were both associated with the severity of the disease (27). Sonnweber's research evaluated data on 145 patients with COVID-19 at 60 and 100 days after confirmed diagnosis, and found that 41% of all subjects exhibited persistent symptoms 100 days after COVID-19 onset, with dyspnea being most frequent (36%). Accordingly, patients still displayed an impaired lung function, with a reduced diffusing capacity in 21% of

Table 2 Laboratory findings of patients before and after PR and treatment

Laboratory findings	Before PR (N=31), n (%)	2 weeks after PR (N=29)*, n (%)	3 weeks after PR (N=31), n (%)	P_1	P_2	P_3
WBC (10^9/L)	5.19 (4.31–6.78)	5.67 (4.59–6.62)	5.50 (4.48–7.10)	0.660	0.179	0.384
RBC (10^{12}/L)	3.75±0.57	3.80±0.37	3.87±0.52	0.556	0.002	0.063
HGB (g/L)	116.48±21.73	117.16±13.80	119.29±18.27	0.779	<0.0001	0.173
NEUT (%)	65.00 (55.00–79.80)	58.30 (47.60–64.80)	58.9 (51.13–63.28)	0.001	0.004	0.616
LYMPH (%)	22.97±11.87	29.90±7.99	29.86±6.93	0.001	0.029	0.939
LYMPH (10^9/L)	1.16±0.67	1.64±0.57	1.66±0.53	<0.0001	<0.0001	0.333
CRP (mg/L)	32.05 (16.35–76.98)	2.93 (2.00–12.80)	2.19 (1.06–9.08)	<0.0001	0.001	0.210
Procalcitonin (ng/mL)	0.050 (0.028–0.10)	0.045 (0.028–0.055)	0.04 (0.03–0.05)	0.023	0.077	0.799
ALB (g/L)	37.00±5.17	38.56±3.85	39.60±4.38	0.033	0.016	0.052
TCHO (mmol/L)	3.98 (3.36–4.58)	4.70 (4.20–5.36)	4.58 (4.18–5.34)	<0.0001	<0.0001	0.453
TG (mmol/L)	1.23 (0.95–1.97)	1.53 (1.10–1.90)	1.33 (0.98–2.16)	0.388	0.716	0.569

P_1, 2 weeks after PR *vs.* before PR; P_2, 3 weeks after PR *vs.* before PR; P_3, 3 weeks after PR *vs.* 2 weeks after PR. *, two patients didn't record data 2 weeks after PR. WBC, white blood cell; RBC, red blood cell; HGB, hemoglobin; PLT, platelet; NEUT, neutrophil; LYMPH, lymphocyte; CRP, C-reactive protein; ALB, albumin; TCHO, total cholesterol; TG, triglycerides.

the cohort being the most prominent finding (28). In our study, after two weeks of PR, the patients' mMRC score and oxygen intake decreased and SpO_2 increased significantly. Meanwhile, PR relieved the patients' symptoms of cough and dyspnea, and improved the patients' self-care ability, physical fitness and mental state. We can conclude that PR does have an impact on the remission of symptoms.

PR has been shown to improve gas change and reverse pathological progression in many respiratory diseases. Because the patients' lung volume and lung compliance were reduced, resulting in shallow and fast breathing and causing restrictive ventilation disorders. Besides, infection led to a reduction in the diffuse area of lung, an increase in shunt and a reduction in arterial oxygen partial pressure, which caused gas exchange dysfunction (29). According to the pathophysiological changes in lung, we applied "breathing method" (3-5-6 breathing), which elevated ventilation and gas exchange function, as the core of PR for inpatients with COVID-19. As a result, tidal volume increased, diaphragmatic muscle capacity enhanced and lung compliance improved by the adjustment of respiratory rhythm. On the one hand, prolonging breathing cycle time such as deep breathing and labial reduction breathing improved the restrictive ventilatory defect. On the other hand, increasing breath retention time in alveoli by breath-holding was to improve gas exchange function and effective alleviate hypoxemia and local atelectasis. Therefore, the patients' maximum oxygen consumption increased dramatically, so that shortness of breath was relieved and mobility and quality of life was improved (30).

Symptoms, especially dyspnea, which caused reductions in ADL, and this situation leads to dependence and disability (31). With the symptoms improved, the patients' ability to take care of themselves can also been restored. Likewise, Zha *et al.* applied Chinese martial art Eight-section Brocade to patients with COVID-19 and found the pronouncedly improved remission rate in respiratory symptoms (32). It can be implied that RP was considered to be capable of inducing positive effects on patients' respiratory muscles through diaphragm breathing exercise and lip puckering breathing exercise. Abdullahi showed the patients with COVID-10 after discharge, chest physiotherapy in the form of respiratory muscle training, cough exercise, diaphragmatic training, stretching exercise have an increase in lung function, diffusing lung capacity for carbon monoxide, endurance, and quality of life, and a reduction in anxiety and depression symptoms (33). López-López discovered the integrated physical therapy focusing on pulmonary function training and active upper limb exercise improved physical and functional performance in elderly patients with pneumonia (34). These results indicated that the upper limb movement enhanced the strength of the upper limb muscles by synchronous lifting, lateral lifting, chest expansion, and grasping movements,

Table 3 Assessment of symptoms and results of questionnaires before and 2 and 3 weeks after PR and treatment

Items	Before PR (N=31), n (%)	2 weeks after PR (N=29)*, n (%)	3 weeks after PR (N=31), n (%)	P_1	P_2	P_3
Current symptoms						
Fatigue	10 (32.26)	18 (62.07)	28 (90.32)	0.013	0.003	0.031
Shortness breath	16 (51.61)	9 (31.03)	1 (3.23)	0.016	<0.0001	0.008
Cough	21 (67.74)	2 (6.90)	3 (9.68)	<0.0001	<0.0001	0.677
Sputum production	17 (54.84)	6 (20.69)	0	0.0007	<0.0001	<0.0001
Effect of cough on life				0.732	0.115	0.018
No effect	15 (48.39)	7 (24.14)	1 (3.23)			
Marginal effect	8 (25.81)	22 (75.86)	30 (96.77)			
Serious effect	8 (25.81)	0	0			
Sputum properties				0.007	<0.0001	0.008
No sputum	14 (45.16)	23 (79.31)	31 (100.00)			
Whitish sputum	17 (54.84)	6 (20.69)	0			
Productive cough						
Easy	6 (19.35)	3 (10.34)	–		–	–
Difficult	3 (9.68)	2 (6.90)	–	0.274	–	–
Can't cough phlegm	8 (25.81)	1 (3.45)	–		–	–
When feel fatigue				0.057	0.301	0.011
Walk	25 (50.65)	28 (96.55)	31 (100.00)			
Go to the toilet	6 (19.35)	1 (3.45)	0			
When feel shortness breathe				0.014	<0.0001	0.068
Prostration	1 (3.23)	0	0			
Stroll	12 (38.71)	3 (10.34)	0			
Scoot	17 (54.84)	26 (89.66)	31 (100.00)			
No shortness breathe	1 (3.23)	0	0			
Whether palpitate				0.001	<0.0001	0.057
Never	10 (32.26)	22 (75.86)	29 (93.55)			
Seldom	20 (64.52)	7 (24.14)	2 (6.45)			
Usually	1 (3.23)	0	0			
Elevate leg in bed				0.189	0.040	0.301
Can	27 (87.10)	28 (96.55)	31 (100.00)			
Can't	4 (12.90)	1 (3.45)	0			
Sand and sit by yourself				0.189	0.040	0.301
Can	27 (87.19)	28 (96.55)	31 (100.00)			
Can't	4 (12.90)	1 (3.45)	0			

Table 3 (*continued*)

Table 3 (*continued*)

Items	Before PR (N=31), n (%)	2 weeks after PR (N=29)*, n (%)	3 weeks after PR (N=31), n (%)	P_1	P_2	P_3
Wear clothes by yourself				0.001	<0.0001	0.301
Can	19 (61.29)	28 (96.55)	31 (100.00)			
Can't (short of breath slightly)	7 (22.58)	0	0			
Can't (short of breath significantly)	5 (16.13)	1 (3.45)	0			
Wear shoes by yourself				<0.0001	0.001	0.301
Can	21 (67.74)	28 (96.55)	31 (100.00)			
Can't	10 (32.36)	1 (3.45)	0			
Go to the toilet by yourself				–	–	–
Can	31 (100.00)	29 (100.00)	31 (100.00)			
Can't	0	0	0			
Oxygen therapy				<0.0001	<0.0001	0.002
Need	29 (93.55)	12 (41.38)	8 (25.81)			
Needn't	2 (6.45)	17 (58.62)	23 (74.19)			
Dietary habit				0.338	0.078	0.301
As usual	28 (90.32)	28 (96.55)	31 (100.00)			
Less than usual	3 (9.68)	1 (3.45)	0			
Sleep quality				0.416	<0.0001	<0.0001
Good	5 (16.13)	6 (20.69)	24 (77.42)			
Wake up 1–2 times a night	23 (74.19)	23 (79.31)	7 (22.58)			
Can't sleep	3 (9.68)	0	0			

P_1, 2 weeks after PR *vs.* before PR; P_2, 3 weeks after PR *vs.* before PR; P_3, 3 weeks after PR *vs.* 2 weeks after PR. *, two patients didn't record data 2 weeks after PR.

and the functions of the muscle groups around the shoulders, upper arms and forearms recovered gradually. Lower limb movement can enhance the strength of lower limb muscles and the stability of the body gradually, promote blood circulation of lower limb, and restore the function of lower limb muscle groups through leg lifting, kicking, bouncing and stepping. Thus, combined with our data, it is suggested that stretching training can increase muscle volume and myoglobin of the patients, resulting in an enhanced ability of the respiratory and circulatory system to coordinate work.

Severe patients with COVID-19 may suffer a higher degree of psychological disorders, such as anxiety, depression, insomnia and anorexic (35). A network platform with doctor-patient participation, psychological assessment, intervention and follow-up were established to adjust patients' psychological state and restore confidence in fighting against COVID-19. Most patients had a good sleep and the diet returned to the normal level so that patients can take in enough nutrition.

To our knowledge, there have been few studies on symptom improvement in hospitalized COVID-19 patients treated with PR. So we performed PR on severe patients with COVID-19 who had received 2 weeks of standardized treatment and were able to undergo PR after assessment. The content of PR we did was not only limited to respiratory exercise, but also included muscle strength training and psychological intervention.

This study has several limitations. In order to prevent infection, we used the improvement of symptom instead of pulmonary function test to evaluate the outcomes of PR. In addition, this is a single center study, which make our

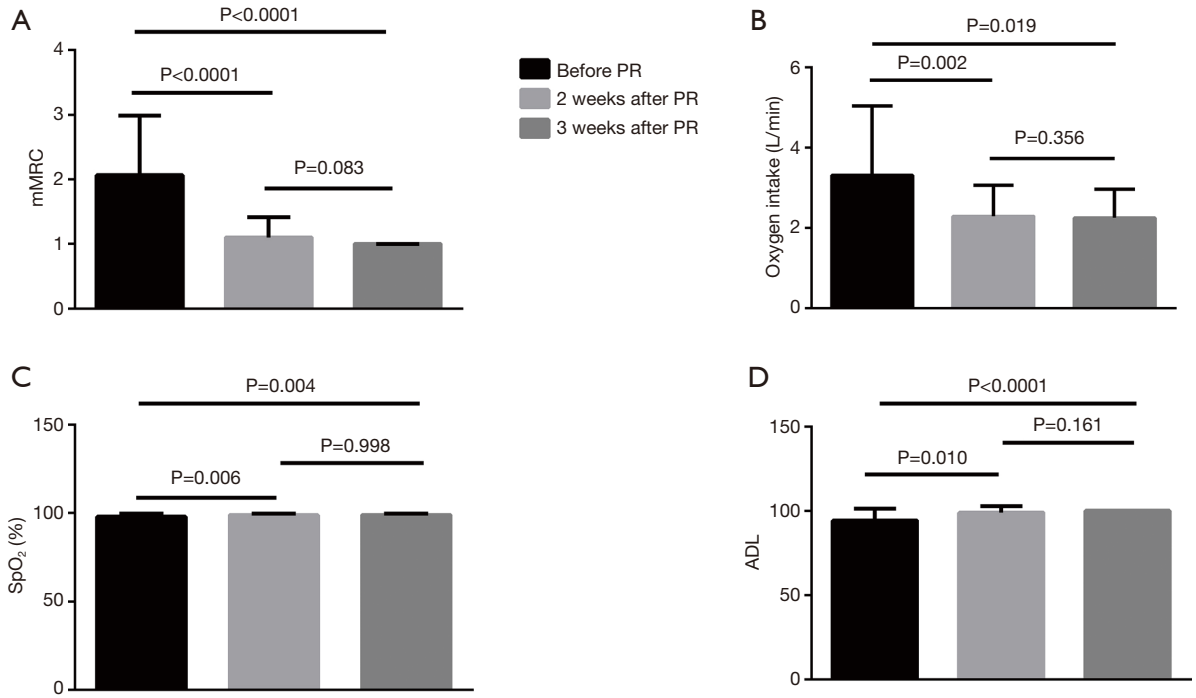

Figure 2 Improvement of hypoxemia and ADL score before and after PR. mMRC both decreased after 2- and 3-week PR (respectively: before *vs.* 2-week PR: 2.07±0.92 *vs.* 1.10±0.31, P<0.0001; before *vs.* 3-week PR: 2.07±0.92 *vs.* 1.00±0.01, P<0.0001). While, the patients' oxygen intake decreased (respectively: before *vs.* 2-week PR: 3.35±1.11 *vs.* 2.29±0.77, P=0.002; before *vs.* 3-week PR: 3.35±1.11 *vs.* 2.25±0.71, P=0.019). SpO_2 both increased after 2- and 3-week PR (respectively: before *vs.* 2-week PR: 97.88±1.99 *vs.* 98.88±0.83, P=0.006; before *vs.* 3-week PR: 97.88±1.99 *vs.* 98.89±0.78, P=0.004). The patients' ADL score also improved after PR (respectively: before *vs.* 2-week PR: 95.00±6.68 *vs.* 98.97±3.87, P=0.010; before *vs.* 3-week PR: 95.00±6.68 *vs.* 100.00±0.00, P<0.0001). ADL, activities of daily living; PR, pulmonary rehabilitation; mMRC, Modified Medical Research Council Dyspnea Scale.

sample size small. To address these limitations, a further double-blind study with a large sample size at multiple centers was required.

Conclusions

In conclusion, PR can ameliorate symptoms, enhance health-related quality of life, improve respiratory muscle function and alleviate disease-related anxiety and depression of severe patients with COVID-19. PR is a process of restoring physical function slowly, promoting respiratory rehabilitation and relieving emotions, which is of great significance to the prognosis of diseases. PR should be provided throughout the diseases management process, regardless of whether the patient is hospitalized or at home.

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Footnote

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org/10.21037/apm-20-2014). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Oral consent was obtained from patients or patients' relatives. Informed consents were obtained for all involved subjects in accordance with the Institutional Review Board (IRB) of the First Affiliated Hospital of Xi'an Jiaotong University (No: XJTU1AF2021LSK-037). The study conformed to the provisions of the Declaration of Helsinki (as revised in 2013).

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