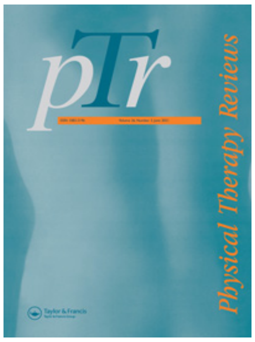


Physical Therapy Reviews

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/yptr20

Rehabilitation strategies and neurological consequences in patients with COVID-19: part II

Nilufer Cetisli-Korkmaz, Furkan Bilek, Tuba Can-Akman, Emre Baskan, Ilke Keser, Esra Dogru-Huzmeli, Mehmet Duray, Bahar Aras & Buse Kilinc

To cite this article: Nilufer Cetisli-Korkmaz, Furkan Bilek, Tuba Can-Akman, Emre Baskan, Ilke Keser, Esra Dogru-Huzmeli, Mehmet Duray, Bahar Aras & Buse Kilinc (2021) Rehabilitation strategies and neurological consequences in patients with COVID-19: part II, Physical Therapy Reviews, 26:3, 222-234, DOI: 10.1080/10833196.2021.1907939

To link to this article: https://doi.org/10.1080/10833196.2021.1907939

Published online: 03 May 2021.

PHYSICAL THERAPY REVIEWS
2021, VOL. 26, NO. 3, 222–234
https://doi.org/10.1080/10833196.2021.1907939

Rehabilitation strategies and neurological consequences in patients with COVID-19: part II

Nilufer Cetisli-Korkmaz[a], Furkan Bilek[b], Tuba Can-Akman[a], Emre Baskan[a], Ilke Keser[c], Esra Dogru-Huzmeli[d], Mehmet Duray[e], Bahar Aras[f] and Buse Kilinc[g]

[a]School of Physiotherapy and Rehabilitation, Pamukkale University, Denizli, Turkey; [b]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Firat University, Elazig, Turkey; [c]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Gazi University, Ankara, Turkey; [d]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Hatay Mustafa Kemal University, Hatay, Turkey; [e]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Suleyman Demirel University, Isparta, Turkey; [f]Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Kutahya Health Sciences University, Kutahya, Turkey; [g]School of Health Sciences, Department of Physiotherapy and Rehabilitation, KTO Karatay University, Konya, Turkey

ABSTRACT

Background: The 2019 novel coronavirus disease (COVID-19) pandemic has triggered a devastating effect worldwide.
Objectives: This review of rehabilitation strategies and neurological consequences in patients with COVID-19 sought to consider potential neurorehabilitation strategies for managing the emerging neurological consequences of COVID-19.
Methods: An exploratory review was conducted that comprised a narrative synthesis in two parts. Part I focused on neurological consequences and physiotherapy and rehabilitation approaches. Part II focused on general principles of rehabilitation interventions and precautions that should be considered. Literature on the use of neurorehabilitation approaches was also included in the review.
Results: Rehabilitation should be initiated as quickly as possible. Neurorehabilitation protocols include public health training valid for the whole community and providing intensive care, pulmonary rehabilitation, mobilization, exercise and strengthening, whole-body vibration, neuromuscular electrical stimulation, telerehabilitation, and other rehabilitation interventions. Interventions should be conducted while correctly implementing personal protective equipment (PPE), hand hygiene, sterilization procedures, and other precautions to avoid the risk of contamination.
Conclusions: Multidimensional assessment should be followed by development of individualized and progressive treatment and neurorehabilitation plans. These plans should focus on existing potential and recovery of mobility and function in particular. It is important for rehabilitation teams to keep gathering and reporting data on patients with COVID-19 and the neurologic complications of COVID-19 during and after the pandemic.

KEYWORDS
COVID-19; neurological consequences; physiotherapy and rehabilitation; neurorehabilitation; exercise; telerehabilitation

1. Background

Coronavirus disease 2019 (COVID-19) is a disease caused by a new coronavirus called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. The World Health Organization (WHO) declared COVID-19 a global pandemic, and the disease triggered devastating effects worldwide such as comorbidities, complications, and consequences associated with severe acute respiratory distress syndrome (ARDS) [1]. With the progress of the COVID-19 pandemic, a growing number of patients with COVID-19 suffer from typical pneumonia with ARDS and a variety of problems with other organ systems, including neurological and cardiovascular problems [2]. The health outcomes of patients with severe COVID-19 and health services could be improved with rehabilitation approaches. This could be achieved by facilitating early discharge, reducing the risk of readmission and optimizing health and functional outcomes [3]. Guidelines for rehabilitation (physiotherapy, occupational therapy, and speech-language pathology) following COVID-19 have been proposed, focusing on the recovery of mobility and function. Details on comorbidities, complications, and the effects of the SARS-CoV-2 on multiple organ systems, including cardiac, neurological, cognitive, and mental health, must be considered. A thorough assessment and the development of individualized and progressive treatment plans should be completed, focusing on the patient's existing function, disabilities (if any), and desire to resume participation in society,

CONTACT Nilufer Cetisli-Korkmaz niluferc75@yahoo.com Fizik Tedavi ve Rehabilitasyon YO, Pamukkale Üniversitesi, A Blok, 3. Kat, Kınıklı Yerleskesi, Kınıklı, 20070, Denizli, Türkiye

to maximize future function and quality of life [4]. An interprofessional team typically consists of a critical care physician, physiotherapist, nurse, psychologist, and other health professionals [5]. Social distancing and infection control measures, such as wearing of masks constitute the current primary arsenal against SARS-CoV-2 infection [6]. As a first step, the rehabilitation team can support public health training valid for the whole community, regarding adherence to effective handwashing, respiratory hygiene techniques, and social distancing to help with stopping the spread of the SARS-CoV-2 [7,8].

Physiotherapists fundamentally have an important public health role in designing and educating personalized recommendations for home-based physical activity. In addition, both physical and biopsychosocial aspects of COVID-19 have been addressed [9]. Physical sequelae of prolonged immobility could also appear as cardiorespiratory deconditioning, venous thromboembolism, postural instability, muscle shortening, contractures, and pressure injuries [4]. It is well known that a healthy lifestyle, balanced nutrition, quality sleep, strong connections with people, and regular exercise are illness-preventive strategies based on psychoneuroimmunity. Therefore, all forms of psychological support should be routinely implemented to enhance the population psychoneuroimmunity against SARS-CoV-2 [9]. This review of rehabilitation strategies and neurological consequences in patients with COVID-19 sought to consider potential neurorehabilitation strategies for managing the emerging neurological consequences of COVID-19, with comprising a narrative synthesis in two parts. Part I focuses on neurological consequences and physiotherapy and rehabilitation approaches. Part II of the review sought to explore general principles of potential rehabilitation strategies for managing the emerging neurological consequences of COVID-19. Part II also focuses on methods to assess their effects, and precautions those should be considered.

2. General principles of physiotherapy and rehabilitation

Many rehabilitation institutions are involved in the acute care of patients with COVID-19. A consensus has emerged, focused on pursuing early rehabilitation in a manner that combines mobilization with physiotherapy practice as a core part and an important strategy to treat critical illness polyneuropathy and myopathy, and to facilitate and improve the long-term recovery and functional independence of patients as well as shorten the duration of ventilation and hospitalization [10]. Suggestions for designing rehabilitation plans for patients with COVID-19 are mostly based on prior experiences on patients with severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), and low quality of evidence from recent literature because there are currently no published randomized controlled trials or quasi-randomized trials [4,6,11,12]. A recent review reported that new studies were conducted in different regions of the world: 10 in Europe (Italy, United Kingdom, Belgium, Germany, Spain), 10 in the Americas (United States of America, Brazil and Canada), one in the Western Pacific (Australia), and one in the Africa (Morocco). The report emphasized that most of these studies ($n = 12$; 55%) described the impact of COVID-19 on the structure and function of the nervous system. There was limited involvement of rehabilitation professionals in the acute phase of COVID-19 care with only seven (32%) studies reporting on the rehabilitation component of acute care [12]. Despite the limited literature, WHO stated that 'COVID-19 actually increases rehabilitation needs – both for patients who are critically unwell with the disease, and for those who continue to experience the long-term consequences of their illness' [3]. Designs and procedures for inpatient rehabilitation of patients with COVID-19 will likely become systematic with the accumulation of experience and research. The guidelines state that it is important for physiotherapists to be well informed and stay up-to-date, and to keep a close eye on developments through WHO updates or local and national public health authorities [13].

Despite the lack of controlled studies examining the efficacy of rehabilitation care and an important information gap in the scientific literature, it is well known that early rehabilitation is the most essential approach for patients with COVID-19, as well as for other patients requiring rehabilitation [12,14,15]. Ideally, rehabilitation should be initiated as soon as possible, while the patient is still in intensive care unit (ICU), and rehabilitation protocols should be included in the acute, postacute, and post-discharge phases [16]. Mechanical ventilation, long-term bed rest, and immobilization cause decreases in physical function and muscle strength leading to impaired respiratory and cognitive functions in individuals with COVID-19 [17]. Given the possibility of symptoms such as decreased physical function and reduced health-related quality of life after discharge from the ICU, physiotherapists can play a role in preparing patients in terms of the physical function required to manage at home with support by designing mobilization, exercise, and rehabilitation interventions [18]. Basic neurorehabilitation should be provided to all affected individuals, especially those with dysphagia, cognitive impairment, paretic extremities, decreased activity, and risk factors for deep vein thrombosis and falls. It should be noted that the delivery of neurorehabilitation should never be delayed for people with disabilities who have chronic progressive diseases and COVID-19 with associated neurologic consequences [16,19,20].

When considering best treatment practices, it is necessary to examine the physiotherapy and rehabilitation management of patients with COVID-19 according to the following three categories:

1. Neurological consequences of viral infection (central nervous system features include headache, dizziness, ataxia, alteration of sensorium, encephalitis, stroke, seizures, neuropathies, and myopathies)
2. Neurological complications in the post-infection process
3. Infection in patients with neurological comorbidity [20]

The most successful physiotherapy and rehabilitation programs are likely to be designed according to the framework of the International Classification of Functioning, Disability, and Health [18]. It is obvious that the capacity to initiate physical activities differs among individuals. It should always be considered that regardless of the level of disability and/or comorbidities, equal access to rehabilitation is required. Special cases and differences to be considered in the rehabilitation of patients with COVID-19 and neurological symptoms are as follows:

- The existence of increased neurorehabilitation needs as a result of health measures adopted during treatment in addition to COVID-19-induced immobilization, bed rest, and acute neurological complications [19]
- Patients with COVID-19 and comorbidities including cerebrovascular diseases and neurologic symptoms related to COVID-19 require more systemic and long-term rehabilitation [4].
- Physiotherapy rehabilitation approaches should be deployed at the home, hospital, nursing home, and ICU in an isolated environment [18,21].
- Home-based rehabilitation may be safer and is a good option with respect to isolation and supports the expansion of rehabilitation services [18].
- Most of the information required for treatment decisions and rehabilitation processes could be provided simultaneously in a virtual environment (i.e., in real time) or asynchronously (e.g., via a prerecorded customized exercise plan), although one or more face-to-face visits might be required [6,22].

2.1. Intensive care

Patients with severe COVID-19 symptoms generally experience pulmonary edema, multiorgan failure, and ARDS. The prevalence of ARDS is reported to be up to 17% among patients with COVID-19 [23]. ARDS develops in 10% of patients in ICU and the mortality rate among these patients is reported to be between 30% and 40% [24]. The pathogenesis of ARDS involves inflammatory injury to the lung endothelium and epithelium, which causes a marked increase in lung vascular and epithelial permeability. The hallmark of ARDS is increased alveolar-capillary permeability to fluid, proteins, neutrophils, and red blood cells [25]. As a result, ARDS is characterized by acute hypoxemia, noncardiac pulmonary edema, decreased pulmonary compliance, and increased respiratory workload. Patients with this condition require positive-pressure ventilation [25]. Endothelial and epithelial injury, and culminating in protein-rich edematous fluid causes many biological changes that contribute to surfactant dysfunction. The risk of biophysical injury can increase, following atelectasis due to surfactant dysfunction. The resulting dyspnea and hypoxemia worsen progressively within hours to days and patients have poor muscle function and functional impairment. Exertional dyspnea and significant decreases in exercise tolerance are generally reported by many patients [25]. Among existing treatment methods, the proning of patients with ARDS can be used as an adjuvant to improve ventilation. The prone position has been co-opted to improve oxygenation in patients with severe hypoxemia and acute respiratory failure since 1974. Long-term prone positioning leads to a decrease in mortality rates [26]. The main mechanisms of the prone position in patients with ARDS include stimulation of the dorsal lung regions, reduction of the alveolar shunt, and increase in end-expiratory lung volume, chest wall elastane, and tidal volume [27]. Prone ventilation could improve lung mechanics and gas exchange, so that both oxygenation and overall results could be improved in patients with COVID-19 [13]. Proning is applied when a low tidal volume is apparent (6 cc/kg body weight) and should continue for at least 12–16 h a day, preferably 72 h after endotracheal intubation [13,27]. At least three to five people are assigned to move intubated patients into the prone position. To solve this problem, a tool called the Vollman Prone Positioner (Hill-Rom, Batesville, IN, USA) could be used. If the prone position proves effective, it should be repeated for at least 4 h after the supine position until the PaO_2/FiO_2 ratio is at least 150 mmHg with a positive end-expiratory pressure of 10 cmH_2O or less and a FiO_2 concentration of 0.60 or less. In the case of deterioration of oxygenation (20% decrease in the PaO_2/FiO_2 ratio relative to the supine position) or serious complications, the pronation procedure should be stopped [25]. Complications such as heterotopic ossification, decubitus ulcers, tinnitus, brachial plexus injuries, and entrapment neuropathies (peroneal and ulnar) have been reported in survivors of ARDS who received mechanical ventilation [28]. In 109 survivors of ARDS, lung volume and spirometry were normal for six months but the carbon monoxide diffusion capacity was decreased [29]. Exercise training interventions (self-delivered, home-based) supported by diaries and regular phone calls, could be recommended to enhance recovery in patients after their discharge from ICU. In particular, post-discharge pulmonary outpatient rehabilitation units must be set up for early and follow-up assessment of symptoms (fatigue, anxiety, depression and dysphagia), pulmonary function and exercise performance in patients who have successfully recovered from the COVID-19 pneumonia [30].

Patients suffering from post-intensive care syndrome (PICS) could also have cognitive and psychosocial impairments in addition to physical impairments. Therefore, special programs/settings of rehabilitation (in-hospital, outpatient, telerehabilitation, tele-coaching, home-rehabilitation, and mixed form) should focus on these situations with an interdisciplinary program mirroring the algorithm of pulmonary rehabilitation [30]. Therefore, this outpatient interdisciplinary rehabilitation follow-up plan should be continued for an extended period [31]. Noninvasive ventilation (NIV) treatments, which include high-flow nasal oxygen (HFNO), continuous positive airway pressure (CPAP), and bilevel positive airway pressure (BiPAP), can fix hypoxemia and respiratory failure and delay or prevent endotracheal intubation in patients with acute hypoxemia. However, physiotherapists should be careful when faced with such treatment modalities as there is evidence, for example, that NIV can increase the risk of SARS-CoV-2 transmission *via* aerosols. Therefore, some COVID-19 guidelines recommend using NIV only as a bridge therapy before transferring the patient to the ICU and starting invasive mechanical ventilation (IMV) Unfortunately, IMV is associated with more adverse outcomes for patients than NIV [32,33].

Homeostatic and neuroinflammatory processes occurring during immobilization and the resulting musculoskeletal consumption are important risks to consider in rehabilitation management, not only after the disease has abated but also during the active disease stage [34]. As such, ICU patients require rehabilitation more often than outpatients. Evidence in the literature suggests the benefits of early rehabilitation in ICU-dependent patients [35]. Rehabilitation in the ICU includes the use of secondary prevention strategies, respiratory rehabilitation, and passive and active mobilization techniques. Critical life support devices such as endotracheal tubes, chest drains, arterial and central venous access lines, and dialysis catheters can prevent active mobilization in the ICU [36]. It is important that the treatment practices used by physiotherapists should not increase the workload on breathing or enhance the risk of respiratory distress. In the presence of acute respiratory failure, decreased lung compliance, increased respiratory workload, and impaired blood oxygenation, there is lead to a fast and shallow breathing pattern followed by decrease in the respiratory muscles [37]. The potential withholding of physiotherapy rehabilitation program are shown in Table 1.

Table 1. The potential with holding of physiotherapy rehabilitation [38].

Parameters	Values
Heart rate	< 40 bpm *or* > 180 bpm
Systolic blood pressure	< 80 mmHg *or* > 200 mmHg
Average arterial blood pressure	< 60 mmHg *or* > 120 mmHg
Increased intracerebral pressure	>20 mmHg
Oxygen saturation	< 88%
Potassium level	< 3.0 mmol/L *or* > 5.5 mmol/L

As part of physical impairments associated with PICS, dyspnea/impaired pulmonary function, pain, sexual dysfunction, impaired exercise tolerance, neuropathies, muscle weakness/paresis, and severe fatigue have been reported [39]. Rehabilitation has had significant consequences on health and quality of life, and functional independence outcomes. The rehabilitation of patients with COVID-19, which starts from the early stages could be correlated with the best clinical and functional recovery, and the reduced duration of NIV, MIV and in ICU. The large number of patients with COVID-19 requiring intensive care means that there is an impending increase in the number of patients requiring rehabilitation and follow-up after discharge [40].

2.2. Pulmonary rehabilitation

Pulmonary rehabilitation can be safely implemented in patients with COVID-19. Early pulmonary rehabilitation and mobilization in the ICU may be approached and graded with safety criteria in mind and cautious consideration. Healthy patients can progress to severe or even critical conditions within 7–14 days of infection. Therefore, early pulmonary rehabilitation and intensive monitoring should be performed by a skilled physiotherapist to avoid exacerbating respiratory distress or unnecessary spread of the virus [4,37,41]. Patients should be monitored closely and the program should be stopped in those with early onset of dyspnea (3 days or less), decreased $SpO2$ ($\leq$ 90%), low or high blood pressure (< 90/60 mmHg or > 140/90 mmHg), high heart rate (<40 or > 100 bpm), high temperature

(>38 °C), new onset of arrhythmia, myocardial ischemia, extreme fatigue, chest pain, severe cough, blurred vision, dizziness, sweating, loss of balance, headache, and altered level of consciousness [4,41].

In the positive phase, if the inspiratory muscles are weak, inspiratory muscle training should be included. Depending on the needs detected, deep and slow breathing, pursed lip breathing, thoracic expansion (with shoulder flexion), diaphragmatic breathing, mobilization of respiratory muscles and the chest cage, bronchial hygiene techniques (when necessary), active cycle of breathing techniques, autogenic drainage, incentive spirometry, strengthening of the inspiratory and expiratory muscles, cough exercises, mobilization, and positive expiratory pressure devices could be added, especially in the subacute phase, and if the patient has no cognitive impairment [4,41]. Although secretions are not a common problem after COVID-19, if the patient has secretions, postural drainage and mobilization (standing for gradually increasing periods) are recommended [4]. The core component of pulmonary rehabilitation is physical exercise, which may start with bed mobility. In the acute phase, mucus clearance techniques should be performed with early mobilization and physical exercise [41].

Respiratory capacity is thought to be affected by the prolonged lockdown during the pandemic [42]. Aerobic exercises could be considered in addition while avoiding overload [4]. Rehabilitation for patients with mild disease or after discharge can be managed in the outpatient setting and with the home exercise program by using telerehabilitation including education, airway clearance techniques, and physical and breathing exercises [41,42]. In a randomized controlled study of COVID-19, a significant improvement was achieved in respiratory function, endurance, quality of life, and depression by performing 10-min pulmonary rehabilitation sessions for six weeks after discharge [43].

2.3. Mobilization

Long-term immobility is a contributing factor to muscle weakness in ICU patients. Therefore, passive and active mobilization could contribute to significant recovery among critical care patients [44]. With mobilization, the risk of airway closure and pulmonary atelectasis, the incidence of respiratory tract infection and pneumonia, the endotracheal intubation time, and the length of hospital stay could be reduced, and pressure areas on the skin could be prevented or their severity mitigated [44]. In addition, together with specific muscle training, this approach could improve the functional status and reduce the risk of venous stasis and deep vein thrombosis [44]. Early mobilization is a feasible and safe intervention after cardiopulmonary and neurological stabilization. Early mobilization should be planned according to the patient's respiratory and hemodynamic conditions [18]. Mobilization can be passive or active in the critical phase, during which it could be done by getting the patient out of bed, frequent posture changes, and continuous rotational therapy in the acute and post-acute phases to prevent disability [16]. In particular, continuous rotation therapy refers to the use of special beds to rotate patients continuously along the longitudinal axis by up to 60° on both sides, relying on preset degrees of rotation and speed. The head of the bed should be positioned at 45°, the position should be changed regularly at standard intervals of 2 h, daily passive movement of all joints, sit-up exercises, simple bed exercises, and passive cycling in the bed should be performed. Rehabilitation is usually performed by increasing these exercises gradually, both in terms of intensity and duration [44,45].

Early mobilization should be started as soon as possible. The mobilization steps include the following:

- Phase 1 mobilization (if the patient has a supported sitting balance and lower limb muscle strength is below three points): sitting balance practice, using the tilt table
- Phase 2 mobilization (if the patient has an unsupported sitting balance and lower limb muscle strength is above three points): supported/active weight-bearing exercises such as sit-to-stand, standing on the foot with walking aid, and walking with walking aid [4,46].

Mobility and functional assessments should include range of motion, strength, balance, exercise capacity, and cardiopulmonary exercise testing [47]. Mobilization and rehabilitation include simple bed exercises, bed mobility, tilt table, sitting out of bed, sitting balance, sit-to-stand, walking, standing hoists, activities of daily living, upper-/lower-limb ergometry, and tailored exercise programs [18]. Maintaining an upright posture is largely dependent on gaining feedback from the somatosensory system; therefore, sensory losses with motor neuropathy greatly disrupt the balance, gait, and general function [48]. Balance training includes the manipulation of certain variables such as the support base, posture configuration, and walking surface. Later stage balance rehabilitation programs could progress from stable to unstable surfaces and include perturbation training or multisensory difficulties (eyes open or eyes closed) or narrowing of the base of support according to the patient's capacity [49]. During rehabilitation and early mobilization, protection of health care staff who were on the frontline should be considered as a major point (e.g. wearing appropriate PPE, strict infection control measures and precautions) (see section 3). Meanwhile, if physiotherapists have to use tilt-table and auxiliary devices for mobility, they should also pay attention to infection control measures regarding these surfaces, by consulting with local infection control experts and by considering the usage of available disinfectants [6].

2.4. Strengthening based exercises

Prolonged immobility is more likely to cause dysfunction and atrophy in the antigravity muscles and reduction of aerobic capacity [44]. As such, physiotherapists are responsible for assigning musculoskeletal, neurological, and cardiopulmonary rehabilitation tasks to affected individuals. Function, disability, and activities of daily living can be measured using a number of validated scales [18]. The effect of viral infections on muscle activity is not known, so to maintain a normal function, exercises programs with a gradual load increase based on subjective symptoms are recommended [16]. Therefore, physiotherapists should develop a patient-specific rehabilitation program based on clinical reasoning and the frequency, intensity, time, and type (FITT) principle, which is one of the foundations of exercise. The objectives of passive, active-supported, or active-resistant range of motion exercises are to maintain or improve joint integrity, range of motion, soft tissue length, and muscle strength and to reduce the risk of thromboembolism [16,50]. A growing body of evidence indicates that early and progressive exercise programs have significant benefits (e.g. fewer ICU days, respiratory status, muscle strength and overall function) in intubated adults [51]. In the acute disease phase, only passive exercises might be provided; however, in the subacute phase, more active limb exercises could be performed, followed by progressive muscle strengthening efforts in the chronic phase [4]. On the first day of eligibility, the patient should be evaluated in terms of physiological stability.

During all exercise sessions vital signs should be monitored continuously. A 20-min exercise program for once a day can be started with in-bed exercises and can be progressed towards to the either assisted or active out-of-bed exercises [51]. Peripheral muscle training (e.g. lifting weights or pushing against something with one's extremities) can trigger certain gains in strength and recovery in the activities of daily life in patients with severe disabilities [44]. In addition, active limb exercises should be accompanied by progressive muscle strength training (e.g. repetition-maximum loading for eight to 12 repetitions, one to three sets with two minutes of rest between sets, three sessions a week for six weeks) [47]. Qigong was reported to have a potential role in the prevention, treatment, and rehabilitation of respiratory infections; therefore, it was considered for application in patients with COVID-19. The movements that make up qigong are mind-body exercises, and the regimen involve the regulation of breath rhythm and pattern, body movement and posture, and meditation. Stress reduction, emotion regulation, strengthening of the respiratory muscles, reduction of inflammation, and enhancement of immune function are potential results [52].

Resistive exercise training programs could be prescribed for decreased muscle strength that may occur secondary to immobility in quarantine and the social isolation period, especially after discharge from the hospital. Specific resistance exercises could be prescribed to address weaknesses in antigravity muscles that can cause gait dysfunction [49]. Balance, coordination, muscle strength, and endurance training affect the physical functioning of patients. Interventions include therapeutic exercises, balance training, neuromuscular electrical stimulation, and aerobic reconditioning according to the patient's needs [49]. While aerobic activity might start at less than three metabolic equivalents of the task, aerobic exercise should be increased to 20–30 min, three to five times a week. Exercise interventions can assist in gaining endurance, increasing the maximum oxygen consumption, and enhancing the strength of patients with SARS [53]. Post-acute rehabilitation in survivors of COVID-19 using an individualized and progressive treatment plan that focuses on improving function, reducing disability, and preparing for the return to participation in society, will help patients to maximize their future function and quality of life [4]. It was stated that adults should aim to do physical activity of any intensity (including light, but preferably moderate-to vigorous) to reduce the detrimental effects of high levels of sedentary behavior on health in the 'WHO guidelines on physical activity and sedentary behavior' [54].

2.5. Whole body vibration

Whole body vibration (WBV), is a passive exercise approach that does not trigger dyspnea, and may be tolerated by patients with COVID-19. WBV exercise increases the production of anti-inflammatory cytokines (e.g. interleukin-10), myokines, and lymphocytes and reduces inflammation and proinflammatory cytokine production [55,56]. Research suggests that WBV can also stimulate T-cell–mediated immunity [56]. In severely ill patients with COVID-19, WBV devices can be used with inclination angles of the intensive care bed up to 30°; here, the WBV platform should be fixed to the bed and the patient's knees should be slightly flexed (approximately 10°). It has also been shown that WBV therapy can be applied using a tilt-table in those patients who cannot stand alone [57]. WBV application begins with the patient in a supine position with a very small slope, and then the slope is repeatedly increased vertically during several rehabilitation sessions until patients can stand freely. With this approach, all musculoskeletal functions necessary for posture, movement standing, and walking are stimulated, which also reduces the need for close contact with the patient, who may still be infectious [57]. To apply pressure to the platform in the case of sedated patients, the patient's legs can be fixed with a strap during therapy with the knee and hip flexed at approximately 20° (24 Hz over one minute for three repetitions) [38]. The World Association of Vibration Exercise Experts suggested that WBV exercise is a useful and safe means to attenuate the decline in physical function and improve post–COVID-19 recovery in affected patients, as well as reduce the total time spent in ICU. Notably, these considerations could stimulate future research on the use of WBV exercise in patients with COVID-19 [58].

2.6. Neuromuscular electrical stimulation

Neuromuscular electrical stimulation (NMES) can induce changes in muscle function without any ventilation stress. NMES was offered to the patients with COVID-19 in the critical, acute, and post-acute phases [16]. NMES could be easily performed in the ICU and could be applied to the muscles of the lower limbs in hospitalized patients and at any stage of the disease course. However, during the rehabilitation program, physiotherapists should be careful regarding the potential for contamination and should try to use disposable single-use electrodes. Importantly, to date, no clinical trial has fully demonstrated the additional effect of NMES on exercise tolerance relative to traditional training, so further research in this regard is warranted [18].

2.7. Telerehabilitation

Additional strategies that might help to improve disability outcomes among survivors from COVID-19 exist, one of which is increasing the use of telerehabilitation during hospital stay. Another is the use of home-based rehabilitation provided over the internet and telephone as telerehabilitation after discharge [16,59,60]. Telerehabilitation is an effective method to provide social rehabilitation services to patients outside the hospital, especially during the COVID-19 pandemic, and aids health care professionals in teaching accurate and effective breathing techniques and other types of exercises to patients [61]. Along these lines, telerehabilitation also allows health care professionals to observe existing and persistent functional deficiencies directly and visually [62]. In poststroke telerehabilitation studies, telerehabilitation interventions were found to be equally or more efficient than conventional face-to-face treatment with respect to addressing mood, high cortical, and motor impairments [63]. Therefore, telerehabilitation can be a good choice to enforce recovery in patients with COVID-19 after discharge from inpatient rehabilitation [4]. In some countries, rehabilitation staff members are encouraged to use webcams for telehealth programs and tele-consultation, and telerehabilitation can be performed *via* WhatsApp, phone, e-mail, and Zoom etc. [16,64]. An exercise booklet or disc (educational audio and video) could also be provided to patients, and exercises could be performed using a small exercise apparatus (e.g. TheraBand's, ergometer, or pedometer). Patients' progression in their treatment plan could be followed daily by using a spirometer, blood pressure, and pulse oximeter measurement devices. However, the precautions that should be considered and evaluated during video-connected rehabilitation are balance disorders, fall risk, limited range of motion, and pain [65]. In addition, some basic steps should be taken to control the spread, such as proper handling, cleaning and disinfection of patient care equipments and medical instruments [13].

There are also some limitations inherent to telerehabilitation services; for example, physical tests such as manual muscle test, grip strength, and gait assessments cannot be performed [62]. However, exercises and functional evaluations specific to a patient (e.g. lifting arms upside down or placing them on the back of the neck, tandem walking, walking short distances, and finger-to-nose movements) might be provided by synchronous videoconferencing over the internet or *via* telephone [18]. Meanwhile, the present status of patients can be evaluated using paper or web-based platforms wherein the patients can report results by themselves with assessments such as the 6 min Walking Test, Functional Independence Measurement, Short Form–36 (SF-36), Borg Scale of Perceived Exertion, 1 min Sit to Stand Test (1STS) (to evaluate cardiovascular responses) and 5 times STS (for muscle strength) [66]. Correct use of an inhaler, breathing patterns, and cough can be easily evaluated by virtual connection. The Dyspnea Modified Medical Research Council Scale, St. George Respiratory

Questionnaire (SGRQ), the Chronic Obstructive Pulmonary Disease Evaluation Test, Cardiac Self-efficacy Scale (CSES), and Duke Activity Status Index (DASI) can also be used [62]. The limited scope for physical examination, reduced availability of equipment, limited technical opportunities, potential for inadvertent personal data disclosure, and inability to attend to sessions, communicate, and interact at the same time are some of the limitations of virtual care [67]. In addition, telerehabilitation requires technology literacy or the ability of both the rehabilitation staff and the patient to use a device, the infrastructure of the region to be suitable, and the availability of the internet. Patients would need to be trained in the measurement of blood pressure, oxygen saturation, and other such assessments [68,69].

In addition to following the patient's rehabilitation process, family conferences for the training of caregivers are recommended for the evaluation of the home environment and periodic follow-up of the patients. In telerehabilitation programs for outpatient treatment, a telerehabilitation platform should be established before discharge and patients and their relatives should be trained to use this platform. Patients' hesitation to seek medical consultation resulted in interruption of continuity of care and face-to-face consultations were greatly reduced in number and canceled during the ongoing pandemic [15]. Patients' routine telerehabilitation follow-up should be shortened to identify potential complications or functional decline earlier. Thus, changes in health status could be noticed earlier without going to the hospital and with the advantage of preventing contamination during the pandemic [61]. With telerehabilitation, face-to-face contact can be avoided, enabling medical follow-up during lockdown, and limiting spread of SARS-CoV-2 and exposure to health-care professionals [15].

3. Taking precautions during physiotherapy and rehabilitation

Symptoms that are often associated with conditions such as ischemic stroke, including hyperventilation, vomiting, and cough, can increase the spread of viral-laden droplets [61]. Although it is accepted that the disease often dissipates and the patient is not contagious after two consecutive negative results, there remains a risk inherent to patients who are eligible for discharge to rehabilitation centers or long-term care since there have been reports of cases where their tests were positive after five to 13 days when using another test kit [4]. Therefore, it should not be forgotten that the risk of transmitting SARS-CoV-2 to others will remain even when some patients who have had COVID-19 some time ago attend rehabilitation [16]. However, the possibility of reinfection with SARS-CoV-2 is not well known and understood. Total immunity might not be guaranteed by previous exposure to SARS-CoV-2. To avoid infection or re-infection with SARS-CoV-2, identical precautions should be taken by all individuals, irrespective of a previous COVID-19 diagnosis [70]. As the WHO stated, 'rehabilitation professionals are frontline health workers who should be engaged in the care of patients who experience severe cases of COVID-19.' In addition, it is well known that during the ongoing pandemic, essential care was provided for some patients who were free of COVID-19. Therefore, COVID-19 emergency health planning and medical teams should include rehabilitation professionals [3]. It must be recognized that, although rehabilitation is important, physiotherapists must adhere to their own government/state/territory policy regarding whether they can be classified as essential health care workers and are able to have person-to-person contact with patients/rest-home residents, and others. Coordinated rehabilitation teams are part of the treatment programs for patients with COVID-19 [16]. As physiotherapists providing rehabilitation are frontline health care professionals in this context, they must take the necessary precautions to reduce the risk of contamination [69,71]. Protecting ourselves should be a priority for healthcare providers so that we can continue to help others [13]. Physiotherapy and rehabilitation interventions should only be performed when there are clinical signs to prevent unneeded personnel from lingering in the patient room. A subjective evaluation should be performed in the isolation room, obtaining information about the mobility status without face-to-face contact with the patient [72]. In association with these evaluations, the most appropriate targets should be determined within a short time, feasible rehabilitation programs should be created, and the number of staff members involved should be kept to a minimum [24,72]. In addition, it is strongly suggested that gloves, medical/surgical face masks, goggles, face shield, and gowns, as well as items for specific procedures such as filtering face piece respirators (i.e. N95 or FFP2 or FFP3 standard or equivalent) be used [8,13,73].

Physiotherapists play a prominent role in providing mobilization, exercise, and rehabilitation interventions, so precautions should be taken while delivering physiotherapy and rehabilitation directions to patients. If close contact with the patient is required, airborne precautions should be taken [18]. In particular, hand hygiene efforts should be adopted according to the WHO's instructions before and after seeing every patient, and when the hands

Table 2. Recommendations concerning the use of PPE by physiotherapists treating patients with COVID-19 [8,13,18,73,74].

A. For all confirmed or suspected cases, droplet precautions should be implemented, at a minimum 1. Staff must wear the following items: • Medical/surgical face masks • Fluid-resistant, long-sleeved gown • Goggles • Face shields • Gloves • Gowns • Items for specific procedures-filtering face piece respirators (i.e. N95 or FFP2 or FFP3 standard or equivalent) 2. Staff with beards should be encouraged to remove facial hair to ensure good mask fit 3. Hair should be tied back out of the face and eyes 4. PPE should be worn correctly and in accordance with the rules (gowns, masks, goggles, face protection, gloves) before and during the treatment 5. Doffing should also be done in accordance with the rules 6. PPE (especially masks) should not be adjusted during treatment 7. The mask should be removed after leaving the patient's room and then the appropriate hand hygiene protocol should be applied 8. If reusable PPE items are used (e.g. goggles), these must be cleaned and disinfected prior to re-use 9. All personal items should be removed before entering clinical areas and donning PPE, including earrings, watches, lanyards, mobile phones, pagers, and pens
B. In cases of prolonged or very close contact patients with COVID-19, airway isolation should be performed 1. Staff should wear the following items: • Respirator N95 or FFP2 or FFP3 standard, or equivalent • Fluid-resistant, long-sleeved gown • Goggles or face shield • Gown • Gloves In addition, the following can be considered: 1. Hair cover for aerosol-generating procedures 2. Shoes that are impermeable to liquids and can be wiped down; recurrent use of shoe covers are not recommended, as repeated removal is likely to increase the risk of staff contamination

touch other surfaces. If the hands are visibly soiled, good hand hygiene should be ensured using water and soap, while if the hands are not visibly soiled, alcohol-containing antiseptics may be used. It should be remembered that the use of gloves does not substitute for or preclude the need for proper hand hygiene [8].

As participants in the COVID-19 recovery process, physiotherapists must be trained to use the correct PPE and should provide rehabilitation while using PPE as it may be difficult to maintain a distance of 1.5 m at all times during sessions (Table 2) [8,13,18,73,74]. Physiotherapists should use a surgical mask, a liquid-resistant and long-sleeved surgical gown, goggles or a face shield and gloves that ensure droplet prevention when seeing any patient who is a suspected or confirmed case of COVID-19 [18]. Although the protection offered by masks persists for a long time, they are recommended to be used only for up to four hours due to the risk of developing skin lesions with long-term use [75]. PPE should be used to provide airway isolation, as the procedures used to treat patients with COVID-19 in the ICU cause aerosol generation. The diameter of the SARS-CoV-2 virus has been shown to be 70–90 nm by electron microscopy [76]. Surgical masks have been found to provide little protection for particles of 10–80 nm in size. Meanwhile, N95/FFP2 masks are 95% effective for particles measuring 0.1–0.3 µm and 99.5% effective for those measuring over 0.75 µm [64]. Thus, N95/FFP2 or equivalent masks are required in addition to the surgical mask, especially in procedures with a high risk of contamination such as tracheal intubation, bronchoscopy, or NIV [8]. In addition, the general guidelines of PPE, its selection, the sequence for donning on and doffing PPE are also important [13].

There are guidelines and several suggestions that have been made available for allied health care professionals who are working in the rehabilitation process of patients with COVID-19. Primarily, a separate area or unit is recommended to separate the rehabilitation of other patients coming to the unit and those being rehabilitated post-COVID-19. Rehabilitation should be done on a one-to-one basis and in patients' rooms rather than *via* group training after acute care [4]. Group therapy should never be performed [18]. When gait training is required, it is recommended in empty or not widely used areas of the hospital [4,18]. To minimize the number of staff members required during gait training, gait training can be provided by a single physiotherapist using a gait aid instead of another physiotherapist or assistant staff [4]. Unless necessary for primary functions, equipment should not be used; however, if equipment is used, large and single pieces of equipment should be prioritized as much as possible. Physiotherapists should be sure that all equipment is working and properly cleaned before entering the room [18]. If equipment needs to be shared between patients, it must be disinfected in the isolation chamber after each patient's use, since SARS-CoV-2 is ineffective within 1 min when disinfected with certain proportions of ethanol, hydrogen peroxide, and sodium hypochlorite [6,18]. The persistence of SARS-CoV-2 has been demonstrated on rehabilitation equipment such as electrode sponges, water in hot-pack tubs, gels, topical lotions, dexterity training items, and therapy ball pools; therefore, particular attention should be paid to infection control for such surfaces [4,6]. Whenever possible, transferring equipment between infected and non-infected areas should be avoided [18].

There is an urgent need for early intervention and ongoing rehabilitation in order to optimize the potential for long-term functional outcomes. However, this can be costly. [28]. Furthermore, the lack of beds and the occupation of rehabilitation facilities by other patients cause difficulties in hospitalized patients. People with severe COVID-19 need rehabilitation during the acute, sub-acute, and long-term phases of care. Therefore, physiotherapists should be positioned in ICUs, hospital wards, step-down facilities, and in the community [3]. Furthermore, there is a need to reorganize hospital and outpatient rehabilitation activities [11]. Another important issue is supporting health care provider wellness in the face of an extraordinarily stressful social and work environment to prevent/overcome 'burn-out' and 'traumatic stress' [78].

4. Conclusions

Evidence from the literature suggests that patients experiencing disability, even if infected or not, are suffering from the pandemic worldwide, because of restrictions imposed on rehabilitation service delivery. In addition, it is currently clear that all patients, all health professionals, and society globally are impacted by the pandemic. This review focused on possible rehabilitation strategies for the neurological consequences of COVID-19, which could help the rehabilitation team in their clinical decision-making and close the gap in the available scientific literature. A variety of rehabilitation modalities, ranging from face-to-face to telerehabilitation can be chosen according to careful monitoring of conditions, signs, and symptoms, with the patients' needs and the bounds of possibility considered and any precautions taken to control or prevent infection. Interdisciplinary rehabilitation is an essential part of COVID-19 recovery. Therefore, an individualized and progressive treatment and rehabilitation plan should be established by focusing on current function, presence of disabilities, the desire to resume participation in society, and maximization of function and quality of life. While the COVID-19 pandemic currently limits access to rehabilitation services, it is also important for rehabilitation teams to continue providing rehabilitation services to gather and report data on patients with COVID-19 and neurologic consequences secondary to COVID-19 during and after the pandemic.

Acknowledgements

We would like to thank for *EDITINGSERVICES Supporting Taylor & Francis authors* English language and academic editing.

Disclosure statement

The authors declare that they have no conflict of interest.

Funding

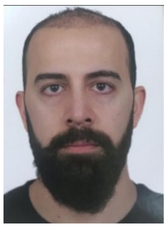
None.

Associated grant projects

There is no associated grant project.

Notes on contributors

Nilufer Cetisli-Korkmaz, PT. PhD. Prof. She is experienced in neurological rehabilitation, geriatric rehabilitation, community-based rehabilitation, technology and electrophysical agents in physiotherapy and rehabilitation, and has publications in prestigious journals. E-mail: nkorkmaz@pau.edu.tr



Furkan Bilek, PT. MSc. Lecturer. He continues his studies in the fields of neurological rehabilitation, geriatric rehabilitation and cardiopulmonary. His area of interest is physiotherapy and rehabilitation in multiple sclerosis. E-mail: fbilek@firat.edu.tr

Tuba Can-Akman, PT. PhD. Lecturer. She is interested in adult neurological rehabilitation such as multiple sclerosis, polyneuropathy and burden of care. E-mail: tubacan@pau.edu.tr

Emre Baskan, PT. PhD. Lecturer. He is interested in neurological rehabilitation, geriatric rehabilitation and sports in individuals with disabilities. E-mail: ebaskan@pau.edu.tr

Ilke Keser, PT. PhD. Prof. Special interest areas are neurological rehabilitation, oncological rehabilitation, lymphedema rehabilitation and geriatric rehabilitation. E-mail: ilkekeser@gazi.edu.tr

Esra Dogru-Huzmeli, PT. PhD. Assoc. Prof. She is working in patients with Parkinson's Disease, stroke and multiple sclerosis. Her last publications about effect of deep brain stimulation in Parkinson's Disease Patients. She has many publications in prestigious journals. E-mail: esradogru001@hotmail.com

Mehmet Duray, PT. PhD. Lecturer. His special interests were neurological rehabilitation, geriatric rehabilitation, pain management, and pediatric rehabilitation. E-mail: mehmetduray@sdu.edu.tr

Bahar Aras, PT. PhD. Lecturer. She continues her studies as a teaching fellow in the fields of neurological rehabilitation and pediatric rehabilitation. E-mail: bahar.aras@ksbu.edu.tr

Buse Kilinc, PT. Her research interests were physiotherapy and rehabilitation, neurological rehabilitation and diabetes mellitus. E-mail: buse.kilinc@karatay.edu.tr

ORCID

Nilufer Cetisli-Korkmaz http://orcid.org/0000-0003-3471-8240
Furkan Bilek http://orcid.org/0000-0003-1567-7201
Tuba Can-Akman http://orcid.org/0000-0001-5230-2009
Emre Baskan http://orcid.org/0000-0001-7069-0658
Ilke Keser http://orcid.org/0000-0001-6999-4056
Esra Dogru-Huzmeli http://orcid.org/0000-0002-7025-8192
Mehmet Duray http://orcid.org/0000-0002-3764-215X
Bahar Aras http://orcid.org/0000-0002-3669-9461
Buse Kilinc http://orcid.org/0000-0001-9822-0965

References

1. World Health Organization. Coronavirus disease (COVID-19); 2020. [updated 2020 Oct 12; cited 2020 Dec 27]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19.
2. Good D, Hoemberg V, Pistarini C, et al. Rehabilitation of COVID and post-covid patients Chapter 1; 2020 [updated 2020 May 26; cited 2020 Dec 27]. Available from: http://wfnr.co.uk/.
3. World Health Organization. Support for rehabilitation self-management after COVID-19-related illness (No. WHO/EURO: 2020-855-40590-54571) Regional Office for Europe; 2020. [updated 2020 June 25; cited 2020 Dec 27]. Available from: https://www.who.int/publications/m/item/support-for-rehabilitation-self-management-after-covid-19-related-illness.
4. Sheehy LM. Considerations for postacute rehabilitation for survivors of COVID-19. JMIR Public Health Surveill. 2020;6(2):e19462.
5. Van Der Schaaf M, Bakhshi-Raiez F, Van Der Steen M, et al. Recommendations for intensive care follow-up clinics; report from a survey and conference of Dutch intensive cares. Minerva Anestesiol. 2015;81(2):135–144. PMID: 24824957
6. Koh GC-H, Hoenig H. How should the rehabilitation community prepare for 2019-nCoV? Arch Phys Med Rehabil. 2020;101(6):1068–1071.
7. Alinia-Ahandani E, Sheydaei M. Overview of the introduction to the new coronavirus (COVID-19): A review. JMBSR. 2020;6(2):14–20.
8. World Health Organization. Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance; 2020. [updated 2020 April 6; cited 2020 Dec 27]. Available from: https://apps.who.int/iris/handle/10665/331695.
9. Kim SW, Su KP. Using psychoneuroimmunity against COVID-19. Brain Behav Immun. 2020;87:4–5.
10. Rawal G, Yadav S, Kumar R. Post-intensive care syndrome: an overview. J Transl Int Med. 2017;5(2):90–92.
11. McNeary L, Maltser S, Verduzco-Gutierrez M. Navigating Coronavirus Disease 2019 (COVID-19) in physiatry: A CAN report for inpatient rehabilitation facilities. PM R. 2020;12(5):512–515.
12. Negrini F, De Sire A, Andrenelli E, et al. International Multiprofessional Steering Committee of Cochrane Rehabilitation REH-COVER action. Rehabilitation and COVID-19: a rapid living systematic review 2020 by Cochrane Rehabilitation Field. Update as of October 31st, 2020. Eur J Phys Rehabil Med. 2021;57(1):166–170.
13. Physiopedia. Introduction to COVID; 2020. December [cited 2020 Feb 15]. Available from: https://www.physio-pedia.com/Coronavirus_Disease_(COVID-19).
14. Curci C, Pisano F, Bonacci E, et al. Early rehabilitation in post-acute COVID-19 patients: data from an Italian COVID-19 Rehabilitation Unit and proposal of a treatment protocol. Eur J Phys Rehabil Med. 2020;56(5):633–641.
15. Fieux M, Duret S, Bawazeer N, et al. Telemedicine for ENT: effect on quality of care during COVID-19 pandemic. Eur Ann Otorhinolaryngol Head Neck Dis. 2020;137(4):257–261.
16. Vitacca M, Carone M, Clini EM, et al. Joint statement on the role of respiratory rehabilitation in the COVID-19 crisis: The Italian Position Paper. Respiration. 2020;99(6):493–499.

17. Brugliera L, Spina A, Castellazzi P, et al. Rehabilitation of COVID-19 patients. J Rehabil Med. 2020;52(4):46–53.
18. Thomas P, Baldwin C, Bissett B, et al. Physiotherapy management for COVID-19 in the acute hospital setting: clinical practice recommendations. J Physiother. 2020;66(2):73–82.
19. Leocani L, Diserens K, Moccia M, et al. Disability through COVID-19 pandemic: neurorehabilitation cannot wait. Eur J Neurol. 2020;27(9):e50–e51.
20. Lahiri D, Ardila A. COVID-19 pandemic: A neurological perspective. Cureus. 2020;12(4):e7889.
21. Visser LH. Critical illness polyneuropathy and myopathy: clinical features, risk factors and prognosis. Eur J Neurol. 2006;13(11):1203–1212.
22. Shepherd S, Batra A, Lerner DP. Review of critical illness myopathy and neuropathy. Neurohospitalist. 2017;7(1):41–48.
23. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. The Lancet. 2020;395(10223):507–513.
24. Feng Y, Ling Y, Bai T, et al. COVID-19 with different severities: a multicenter study of clinical features. Am J Respir Crit Care Med. 2020;201(11):1380–1388.
25. Matthay MA, Zemans RL, Zimmerman GA, et al. Acute respiratory distress syndrome. Nat Rev Dis Primers. 2019;5(1):18
26. Guérin C, Reignier J, Richard J-C, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med. 2013;368(23):2159–2168.
27. Kallet RH. A comprehensive review of prone position in ARDS. Respir Care. 2015;60(11):1660–1687.
28. Herridge MS, Moss M, Hough CL, et al. Recovery and outcomes after the acute respiratory distress syndrome (ARDS) in patients and their family caregivers. Intens Care Med. 2016;42(5):725–738.
29. Herridge MS, Cheung AM, Tansey CM, Canadian Critical Care Trials Group, et al. One-year outcomes in survivors of the acute respiratory distress syndrome. N Engl J Med. 2003;348(8):683–693.
30. Polastri M, Nava S, Clini E, et al. COVID-19 and pulmonary rehabilitation: preparing for phase three. Eur Respir J. 2020;55(6):2001822.
31. Sevin CM, Jackson JC. Post-ICU clinics should be staffed by ICU clinicians. Crit Care Med. 2019;47(2):268–272.
32. Seto W, Tsang D, Yung R, et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). The Lancet. 2003;361(9368):1519–1520.
33. Schünemann HJ, Khabsa J, Solo K, et al. Ventilation techniques and risk for transmission of Coronavirus Disease, including COVID-19: A living systematic review of multiple streams of evidence. Ann Intern Med. 2020;173(3):204–216.
34. Capri M, Morsiani C, Santoro A, et al. Recovery from 6-month spaceflight at the International Space Station: muscle-related stress into a proinflammatory setting . FASEB J. 2019;33(4):5168–5180.
35. Thomas S, Mehrholz J, Bodechtel U, et al. Effect of physiotherapy on regaining independent walking in patients with intensive-care-unit-acquired muscle weakness: A cohort study. J Rehabil Med. 2019;51(10):797–804.
36. Hodgson CL, Capell E, Tipping CJ. Early mobilization of patients in intensive care: organization, communication and safety factors that influence translation into clinical practice. Crit Care. 2018;22(1):1–7.
37. Lazzeri M, Lanza A, Bellini R, et al. Respiratory physiotherapy in patients with COVID-19 infection in acute setting: A Position Paper of the Italian Association of Respiratory Physiotherapists (ARIR). Monaldi Arch Chest Dis. 2020;90(1):1285.
38. Wollersheim T, Haas K, Wolf S, et al. Whole-body vibration to prevent intensive care unit-acquired weakness: safety, feasibility, and metabolic response. Crit Care. 2017;21(1):9.
39. Flaatten H, Waldmann C. The post-ICU syndrome, history and definition. In: Preiser JC, Herridge M, Azoulay E, editors. Post-intensive care syndrome. Lessons from the ICU (Under the Auspices of the European Society of Intensive Care Medicine). Cham: Springer; 2020. p. 3–12.
40. Kalirathinam D, Guruchandran R, Subramani P. Comprehensive physiotherapy management in COVID-19–a narrative review. Sci Med. 2020;30(1):e38030.
41. Wang TJ, Chau B, Lui M, et al. Physical medicine and rehabilitation and pulmonary rehabilitation for COVID-19. Am J Phys Med Rehabil. 2020;99(9):769–774.
42. Nici L, Donner C, Wouters E, ATS/ERS Pulmonary Rehabilitation Writing Committee, et al. American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. Am J Respir Crit Care Med. 2006;173(12):1390–1413.
43. Liu K, Zhang W, Yang Y, et al. Respiratory rehabilitation in elderly patients with COVID-19: A randomized controlled study. Complem Ther Clin Pract. 2020;39:101166.
44. Ambrosino N, Venturelli E, Vagheggini G, et al. Rehabilitation, weaning and physical therapy strategies in chronic critically ill patients. Eur Respir J. 2012;39(2):487–492.
45. Gosselink R, Bott J, Johnson M, et al. Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. Intens Care Med. 2008;34(7):1188–1199.
46. Simpson R, Robinson L. Rehabilitation after critical illness in people with COVID-19 Infection. Am J Phys Med Rehabil. 2020;99(6):470–474.
47. Zhao HM, Xie YX, Wang C, Chinese Association of Rehabilitation Medicine; Respiratory Rehabilitation Committee of Chinese Association of Rehabilitation Medicine; Cardiopulmonary Rehabilitation Group of Chinese Society of Physical Medicine and Rehabilitation. Recommendations Recommendations for respiratory rehabilitation in adults with coronavirus disease 2019. Chin Med J (Engl)). 2020;133(13):1595–1602.
48. Aung NL, Meardon SA, Lin C-C, et al. Sensory cut-off value for predicting postural instability in people with peripheral neuropathy secondary to diabetes. Am Diab Assoc. 2018;67(Supplement 1):561-P.
49. Stubblefield MD, McNeely ML, Alfano CM, et al. A prospective surveillance model for physical

rehabilitation of women with breast cancer: chemotherapy-induced peripheral neuropathy. Cancer. 2012;118(8 Suppl):2250–2260.
50. Scala R, Ciarleglio G, Maccari U, et al. Ventilator support and oxygen therapy in palliative and end-of-life care in the elderly. Turk Thorac J. 2020; 21(1):54–60.
51. Winkelman C, Johnson KD, Hejal R, et al. Examining the positive effects of exercise in intubated adults in ICU: a prospective repeated measures clinical study. Intens Crit Care Nurs. 2012; 28(6):307–318.
52. Feng F, Tuchman S, Denninger JW, et al. Qigong for the prevention, treatment, and rehabilitation of COVID-19 infection in older adults. Am J Geriatr Psychiatry. 2020;28(8):812–819.
53. Lau HM-C, Ng GY-F, Jones AY-M, et al. A randomized controlled trial of the effectiveness of an exercise training program in patients recovering from severe acute respiratory syndrome. Aust J Physiother. 2005;51(4):213–219.
54. World Health Organization. WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization; 2020 [updated 2020 Nov 25; cited 2020 Dec 27]. Available from: https://www.who.int/publications/i/item/9789240015128.
55. Leal LG, Lopes MA, Batista ML. Physical exercise-induced myokines and muscle-adipose tissue crosstalk: a review of current knowledge and the implications for health and metabolic diseases. Front Physiol. 2018;9:1307
56. Tossige-Gomes R, Avelar NCP, Simão AP, et al. Whole-body vibration decreases the proliferativeb response of TCD4(+) cells in elderly individuals with knee osteoarthritis. Braz J Med Biol Res. 2012; 45(12):1262–1268.
57. Stark C, Herkenrath P, Hollmann H, et al. Early vibration assisted physiotherapy in toddlers with cerebral palsy–a randomized controlled pilot trial. J Musculoskelet Neuronal Interact. 2016;16(3): 183–192. PMID: 27609033
58. Sañudo B, Seixas A, Gloeckl R, et al. Potential application of whole-body vibration exercise for improving the clinical conditions of COVID-19 infected individuals: a narrative review from the World Association of Vibration Exercise Experts (WAVex) Panel. IJERPH. 2020;17(10):3650.
59. O'Brien KK, Tynan A-M, Nixon SA, et al. Effectiveness of aerobic exercise for adults living with HIV: systematic review and meta-analysis using the Cochrane Collaboration protocol. BMC Infect Dis. 2016;16(1):182.
60. Grabowski DC, Joynt Maddox KE. Postacute care preparedness for COVID-19: thinking ahead. JAMA. 2020;323(20):2007–2008.
61. Smith EE, Mountain A, Hill MD, et al. Canadian stroke best practice guidance during the COVID-19 pandemic. Can J Neurol Sci. 2020;47(4):474–478.
62. Bryant MS, Bandi VD, Nguyen CK, et al. Telehealth pulmonary rehabilitation for patients with severe chronic obstructive pulmonary disease. Fed Pract. 2019;36(9):430–435. PMID: 31571812.
63. Sarfo FS, Ulasavets U, Opare-Sem OK, et al. Telerehabilitation after stroke: an updated systematic review of the literature. J Stroke Cerebrovasc Dis. 2018;27(9):2306–2318.
64. Bettger JP, Thoumi A, Marquevich V, et al. COVID-19: maintaining essential rehabilitation services across the care continuum. BMJ Glob Health. 2020;5(5):e002670.
65. Bryant M, Fedson S, Sharafkhaneh A. Using telehealth cardiopulmonary rehabilitation during the COVID-19 Pandemic. J Med Syst. 2020;44(7):125
66. Gephine S, Bergeron S, Tremblay-Labrecque P-F, et al. Cardiorespiratory response during the 1-min Sit-to-Stand Test in chronic obstructive pulmonary disease. Med Sci Sports Exerc. 2020;52(7): 1441–1448.
67. Jansen-Kosterink S, Dekker-van Weering M, van Velsen L. Patient acceptance of a telemedicine service for rehabilitation care: A focus group study. Int J Med Inform. 2019;125:22–29.
68. Asadi-Pooya AA, Simani L. Central nervous system manifestations of COVID-19: a systematic review. J Neurol Sci. 2020;413:116832
69. Wu Y, Xu X, Chen Z, et al. Nervous system involvement after infection with COVID-19 and other coronaviruses. Brain Behav Immun. 2020;87:18–22.
70. Tillett RL, Sevinsky JR, Hartley PD, et al. Genomic evidence for reinfection with SARS-CoV-2: a case study. Lancet Infect Dis. 2021;21(1):52–58.
71. Mao L, Jin H, Wang M, et al. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. JAMA Neurol. 2020; 77(6):683–690.
72. Filatov A, Sharma P, Hindi F, et al. Neurological complications of coronavirus disease (COVID-19): encephalopathy. Cureus. 2020;12(3):e7352
73. World Health Organization. COVID-19 technical specifications for personal protective equipment and related IPC supplies; 2020 [updated 2020 Aug 7; cited 2020 Dec 27]. Available from: WHO/2020-nCoV/MedDev/TS/InfDev
74. Bartolo M, Intiso D, Lentino C, et al. Urgent measures for the containment of the Coronavirus (COVID-19) epidemic in the Neurorehabilitation/Rehabilitation Departments in the phase of maximum expansion of the epidemic. Front Neurol. 2020;11:423.
75. Beckman S, Materna B, Goldmacher S, et al. Evaluation of respiratory protection programs and practices in California hospitals during the 2009-2010 H1N1 influenza pandemic. Am J Infect Control. 2013;41(11):1024–1231.
76. Kim J-M, Chung Y-S, Jo HJ, et al. Identification of coronavirus isolated from a patient in Korea with COVID-19. Osong Public Health Res Perspect. 2020;11(1):3–7.
77. Bałazy A, Toivola M, Adhikari A, et al. Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? Am J Infect Control. 2006;34(2):51–57.
78. Sliwa JA, Clark GS, Chiodo A, et al. Burnout in Diplomates of the American Board of Physical Medicine and Rehabilitation-Prevalence and Potential Drivers: A prospective cross-sectional survey. PM R. 2019;11(1):83–89.