Current Physical Medicine and Rehabilitation Reports (2022) 10:182–187
https://doi.org/10.1007/s40141-022-00352-9

BRAIN INJURY MEDICINE AND REHABILITATION (M SEGAL, SECTION EDITOR)

Rehabilitation Strategies for Cognitive and Neuropsychiatric Manifestations of COVID-19

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Accepted: 24 April 2022 / Published online: 14 May 2022

Abstract

Purpose of Review Extrapulmonary manifestations of COVID-19 are abundant, including after recovery of acute SARS-CoV-2 infection. This review seeks to explore the cognitive and neuropsychiatric manifestations of COVID-19 and post-acute sequelae of SARS-CoV-2 (PASC), including Long COVID syndromes. Furthermore, the review will discuss rehabilitation strategies for the emerging neurological consequences of COVID-19 to help those experiencing long-term effects of COVID-19.

Recent Findings There is emerging evidence depicting the neural involvement of COVID-19. Health priorities have shifted from understanding pathogenesis and treatment of pulmonary symptoms to targeting the acute and chronic sequelae of COVID-19, including cognitive and neuropsychiatric symptoms. The sequelae of COVID-19 often co-occur with other medical problems and is best managed by assessment and care across multiple disciplines. Symptoms following infection are similar to those found by other syndromes and disorders that disrupt the central nervous system.

Summary The acute and chronic sequelae of COVID-19 have become major targets of current health care providers given its significant public health impact, inclusive of cognitive and neuropsychiatric sequelae. Assessment and referral to rehabilitation based on each individual's needs and symptoms can decrease morbidity and improve quality of life.

Keywords Cognitive · Neuropsychiatric · Long COVID · Rehabilitation

Introduction

Coronavirus disease 2019 (COVID-19) is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. COVID-19 has profoundly affected life around the world from isolation and economic shutdown to illness, multiorgan failure, and death. In the beginning of the pandemic, the health care community was focused on the pathogenesis and acute treatment of COVID-19. As the pandemic evolved, the focus has shifted to address the sequelae of COVID-19, as extrapulmonary manifestations of COVID-19 are increasingly more abundant. Although neurotropic viruses and their central nervous system (CNS) effects have been reported since the 1918 influenza epidemic, the cognitive consequences have not piqued the interest of many until COVID-19 [2].

As of December 2021, there have been over 200 million confirmed cases of COVID-19, including approximately 5 million deaths and approximately 195 million people "recovered" [3]. Recovery from COVID-19 takes approximately 2 to 4 weeks and is dependent on age and comorbidities [4], as well as severity of symptoms [5]. However, the number of those who have "recovered" remains unclear, as even mild cases of COVID-19 can have enduring or emergent symptoms [5]. These post COVID-19 symptoms and conditions are referred to as the post-acute sequelae of SARS-CoV-2 infection (PASC) [6, 7].

Cognitive and neuropsychiatric manifestations are seen both in the acute and chronic phases of SARS-CoV-2

This article is part of the Topical Collection on *Brain Injury Medicine and Rehabilitation*

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infection. Notable neurological and psychiatric residual effects of SARS-CoV-2 include but are not limited to acute cerebrovascular disease, altered mental status, Guillain–Barre syndrome, headache, fatigue, dizziness, dysphagia, encephalitis, myelitis, myopathies, neuralgia/polyneuropathy, seizures, sensory disturbances, anosmia, ageusia, cognitive changes, and mood or psychotic disorders [8]. In addition, COVID-19 pandemic has upended normal life around the world from economic disturbance to social isolation. These indirect factors may contribute to mental health implications seen in COVID-19 patients, such as depression, anxiety, and posttraumatic stress disorder [8].

The exact pathophysiology of SARS-CoV-2 on the nervous system is not completely understood but several mechanisms have been proposed. ACE-2 receptors are the functional receptors on cell surfaces through which SARS-CoV-2 enters host cells. These receptors expressed by neurons, although in less density compared to respiratory and gastrointestinal epithelium [9]. In addition, endothelial cell damage and thromboinflammation, hypoxia secondary to vasculopathy, dysregulation of immune response and autoimmunity, systemic inflammatory processes, cellular bioenergetics, and dysregulation of the renin–angiotensin–aldosterone system are thought to contribute to SARS-CoV-2 pathogenicity [10•].

A multidisciplinary approach in assessment and treatment plan is recommended to address the sequelae of COVID-19. This review will focus on cognitive and neuropsychiatric manifestations of COVID-19 and their rehabilitation strategies.

Cognitive and Neuropsychiatric Manifestations in Acute COVID

Acute COVID-19 is defined as up to 4 weeks from onset of symptoms [10•]. More than 80% of hospitalized patients during the acute phase of COVID-19 infection experience neurological symptoms. In about one-third of the cases drawn from a meta-analysis of approximately 4,000 adult cases of severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), and COVID-19 epidemics, cognitive impairment was reported at the time of hospital admission [2]. More than 80% of the sample also endorsed neurological symptoms during the acute phase of COVID-19 infection [11].

Cognitive and neuropsychiatric manifestations of acute COVID-19 have been divided by initial studies into central, peripheral, and psychological [12]. Central symptoms included dizziness and headache as the most prevalent. Peripheral symptoms include dysgeusia, anosmia, and muscle pain. Anxiety, depression, delirium, and psychosis are common psychological manifestations [12]. Given the preliminary nature of current research on SARS-CoV-2 manifestations, research examining the neuropsychiatric effects of earlier coronavirus outbreaks predicts possible long-term neuropsychiatric sequelae and likely mechanisms [11]. These include encephalopathy, delirium/confusion, psychiatric disorders, acute psychosis, and other acute and chronic neuropsychiatric effects [11]. Cognitive and neuropsychiatric manifestations, as well as other common symptoms of COVID-19, are depicted in Table 1.

Toxic metabolic encephalopathy (TME) is the most common neurological complication in patients with COVID-19, occurring in 12% of hospitalized patients [13]. Older age, male sex, history of previous neurologic or psychiatric disease, chronic kidney or liver disease, hypertension, diabetes, and coronary artery disease are the top reported risk factors for TME [13]. TME etiology seems to be multifactorial in patients with COVID-19 and has been found to be associated with hypoxia, sepsis, and uremia and is associated with a 24% increase in hospital mortality [13].

Cognitive and Neuropsychiatric Manifestations in PASC

PASC symptoms are defined as persistent symptoms and/or delayed long-term complications beyond 4 weeks from initial onset of illness [10•]. Approximately 80% of COVID-19 cases are asymptomatic and mild [14]. Many patients typically recover within 2 to 6 weeks of onset of illness [15]. Approximately 30% and 80% of patients affected by COVID-19 and hospitalized for COVID-19, respectively; however, even those not hospitalized experience post-acute COVID-19 sequelae [15]. PASC does not discriminate and has been reported to affect children, adults, and those with mild and severe COVID-19 infections [16]. PASC symptoms

Table 1 Cognitive and neuropsychiatric manifestations, as well as other common symptoms of COVID-19

Cognitive and neuropsychiatric manifestations of acute COVID-19
Headache
Dizziness
Myalgia
Fatigue
Anosmia
Dysgeusia
Cognitive impairment
Stroke
Encephalopathy
Encephalitis
Guillain–Barre syndrome
Acute hemorrhagic necrotizing encephalopathy

range from mild to severe and can persist for months affecting one's day to day life [17].

It is estimated that anywhere from around 30 to 80% of patients affected by COVID-19 will experience one or more long-term symptoms [10•]. In a meta-analysis, 55 long-term effects associated with COVID-19 were identified, the most common depicted in Table 2 [18]. Prominent post-acute infection neurologic and psychiatric symptoms among COVID-19 patients include fatigue, headaches, myalgia, sleep disturbance, numbness/tingling, dysgeusia, anosmia, anxiety, depression, dizziness, and cognitive impairment [19•]. In addition, COVID-19 can affect the autonomic system, as several case reports have described the development of postural orthostatic tachycardia syndrome (POTS) [11]. The most debilitating features of PASC include fatigue and cognitive impairment. In a literature review, it was identified that one-third of individuals experienced fatigue and one-fifth of individuals experienced cognitive impairment 12 weeks following COVID-19 diagnosis [20].

The cognitive and neuropsychiatric manifestations of COVID-19 are an emergent concern as more patients will be seen for these persisting symptoms in the foreseeable future [21]. The effects of these symptoms on patient's functional outcome, quality of life, and the economic burden of PASC indicate a need for rehabilitation intervention to improve patient outcome and reduce the impact of PASC [22–24].

Rehabilitation Assessment, Referrals, and Treatment for Recovery

In acute patients, multidisciplinary approaches to rehabilitation in an in-patient setting have been shown to be effective in improving clinical outcomes. An approach combining general medical, pulmonary, cardiovascular, neurological, and neuropsychological intervention is recommended.

Treatment for post-acute patients should be considered in light of the availability of access to rehabilitation units in the unique environment created by the pandemic. Traditional rehabilitation protocols may not be accessible due to the limitations on health care systems and need for hospital beds for patients suffering from more acute illness. Therefore, treatments should be considered as a formulated program with greater attention to patients with comorbid conditions, patients living alone, and those from rural settings [17]. Rehabilitation programs should also focus on developing an outpatient multidisciplinary programmatic team approach to improve functional outcome and facilitate recovery.

Table 2 The most common long-term effects associated with COVID-19

Cognitive and neuropsychiatric manifestations of PASC
Fatigue
Headache
Attention disorder
Dyspnea
Ageusia
Anosmia
Post-activity polypnea
Joint pain
Sweat
Memory loss
Hearing loss
Anxiety
Depression

Neurocognitive and Functional Outcome

Cognitive deficits reported include problems with immediate memory, attention, processing speed, and executive functioning difficulties [25]. Over 75% of 18 patients in a study with mild to moderate disease were found to have the cognitive deficits listed above, indicating that cognitive impairment can even effect those with mild disease [26]. Cognitive impairments in areas of working memory, executive functioning, memory, visuospatial ability, abstraction, and orientation have also been found [17, 27]. Recovery in some or most of these areas in the post-acute phase of the illness has been demonstrated [28]; however, there are persisting deficits seen in this phase, including patients who were not hospitalized [29].

ICU stay has not been associated with having a greater risk of a specific cognitive domain deficit as a result of infection, but has been associated specifically with a risk of poorer overall global cognitive ability and impairment in executive functioning and working memory, particularly in patients requiring at least 48 h of ICU care [30]. Cognitive deficits were widespread in those with and without ICU stays and occurred most commonly on measures of oral processing speed and verbal fluency as well as learning and memory [30, 31]. Those who required hospitalization were also more likely to have objective cognitive deficits persisting after the acute phase [29]. However, there have also been conflicting findings suggested that cognitive deficits are not greater in those requiring higher levels of acute care [35, 36].

Psychiatric distress and functional decline are also common, with 35% of COVID-19 survivors producing at least one moderately elevated score across measures of anxiety, depression, trauma, and functional decline [30]. One in four patients requiring treatment in the ICU reported trauma-related distress [30]. The prevalence of symptoms of PTSD, anxiety, and depression 3 to 6 months post COVID-19 infection has not been found to differ between those who were

hospitalized and those who were not, and has been found to be unrelated to cognitive functioning [32]. A neuropsychological evaluation can be useful in determining areas of decrement in order to direct treatments, including recommendations for psychotherapy, medication management, and physical, speech, and occupational therapies [33]. Objective cognitive assessments have been found as a more reliable means to detect the presence of cognitive PASC versus subjective assessment or self-report [27].

Intervention

Cognitive remediation and rehabilitation has been established as an effective treatment for ongoing sequelae of brain injury [34]. Common interventions that can be applied to PASC patients include compensatory strategies based on areas of deficit and training in metacognitive strategies and are outlined in recently published consensus guidance statements, which can be referenced [33].

Tele-rehabilitation, including home-based exercises tailored to the patients' needs, can be implemented based on demonstrated areas of cognitive deficit [35]. Telemedicine services may not be available based on factors such as access to reliable internet connections, technology, and availability of providers. Thus, in-person therapies may be warranted, and these limitations should be particularly considered when treating patients from disparate health populations.

Exercise programs have been applied as a means to improve cognition, and cardiovascular exercise has been found to improve attention, processing speed, executive functioning, and memory [36]. Application-based exercise programs in other rehabilitation populations have been found to improve exercise engagement, but not functional outcomes such as motor ability and cognition [37]. In PASC patients, rehabilitation exercise programs focusing on resistance, endurance, and balance training, which include an education and pacing element, have yielded gains in cognition [38]. Improvements in symptoms of fatigue and breathlessness [38] have also been found, as well as an improvement in overall functional status [39]. Thus, it is recommended that exercise programs be applied that are in-person or virtual, and include education on pacing and psychoeducation of symptoms, as well as physical exertion.

Psychiatric

It is common for psychiatric symptoms to develop after infection from COVID-19; primarily depression, anxiety, and symptoms of PTSD present in both the acute and post-acute course of the illness [27, 40–42]. Data demonstrates an increased risk, when compared to other medical illnesses, of a psychiatric diagnosis within 90 days of a patient receiving a positive test result [43••]. Research supports the need for treatment of both psychological support and neurocognitive deficits after infection in the post-acute phase [28].

PTSD symptoms often include frequent rumination of the illness, insomnia, and emotional lability, which most often are likely to be seen in the post-illness stage [44]. Many self-reported persisting symptoms have been found to be more related to mood/anxiety rather than objective neuropsychological cognitive test findings [45]. Treatment of these symptoms will likely be necessary to yield functional gains. Treatment modalities include psychoeducation, psychotherapy, psychopharmacology, and peer support.

On an in-patient basis, it has been recommended that occupational therapists, social workers, and psychologists should provide psychological support and intervention [46]. A plan for discharge should also include follow up with psychological services. Patients can benefit from tele-therapy or tele-counseling to address emotional and mood disturbances [47], and initial studies have demonstrated improvement with this intervention [48]. Moreover, some patients may have reservations about in-person visits, particularly those with symptoms of PTSD, and may be more likely to engage in treatment if remote treatment is made available.

Conclusion

The SARS-CoV-2 virus causing COVID-19 infection has uprooted life around the world. Many patients infected with COVID-19 will recover within a few weeks; however, some may experience new, reoccurring, or persisting symptoms after the acute infection. Clinical presentations are often multifactorial in nature, and include both psychiatric and neurocognitive symptoms. These life-changing symptoms can be experienced by all age groups and even those with mild disease and impact functional ability. The mechanisms of neurologic and psychiatric complications related to COVID-19 are not completely understood but is thought to be due to pulmonary dysfunction and secondary to prolonged inflammatory response, with vascular and perfusion abnormalities [11]. The expected neurocognitive and psychiatric outcomes post COVID-19 infection may be similar to effects from prior pandemics, and other medical conditions that impact the central nervous systems, including respiratory illness, metabolic disorders, and critical illness [49].

Multidisciplinary rehabilitation of the cognitive and neuropsychiatric manifestations of COVID-19 during all levels of care is essential. It is predicted that the delayed and chronic effects of PASC will become known in the years to come, and the medical community will need to respond with a perspective considering this a public health crisis, given the extensive reach of the virus and infection rates [50]. New strategies for clinical care, research, and advocacy need to

be addressed in PASC going forward to ensure recovery and improve functional outcomes for our patients.

Declarations

Conflict of Interest Dr. Rolin is a panelist and has received honorarium as an expert panelist for the Project ECHO Family Health Centers of San Diego (FHCSD) Long COVID and Fatiguing Illness Recovery Program (LC&FIRP). Dr. Verduzco-Gutierrez has received speaking honorarium for speaking on Long COVID. Ms. Chakales has no conflicts to disclose.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. Higgins V, Sohaei D, Diamandis EP, Prassas I. COVID-19: from an acute to chronic disease? Potential long-term health consequences. Crit Rev Clin Lab Sci. 2020;58(5):297–310. https://doi.org/10.1080/10408363.2020.1860895.
2. Ritchie K, Chan D. The emergence of cognitive COVID. World Psychiatry. 2021;20(1):52–3. https://doi.org/10.1002/wps.20837.
3. WHO coronavirus (COVID-19) dashboard. Covid19.who.int. https://covid19.who.int/. Published 2022. Accessed January 4, 2022.
4. CDC COVID-19 Response Team. Severe outcomes among patients with coronavirus disease 2019 (COVID-19) — United States, February 12–March 16, 2020. MMWR Morb Mortal Wkly Rep. 2020;69(12):343–6. https://doi.org/10.15585/mmwr.mm6912e2.
5. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. JAMA. 2020;323(11):1061. https://doi.org/10.1001/jama.2020.1585.
6. Mandal S, Barnett J, Brill SE, et al. 'Long-COVID': a cross-sectional study of persisting symptoms, biomarker and imaging abnormalities following hospitalisation for COVID-19. Thorax. 2020;76(4):396–8. https://doi.org/10.1136/thoraxjnl-2020-215818.
7. NIH launches new initiative to study "long COVID". National Institutes of Health. https://www.nih.gov/about-nih/who-we-are/nih-director/statements/nih-launches-new-initiative-study-long-covid. Published February 23, 2021. Accessed April 21, 2021.
8. Groff D, Sun A, Ssentongo AE, et al. Short-term and long-term rates of postacute sequelae of SARS-COV-2 infection. JAMA Netw Open. 2021;4(10):e2128568. https://doi.org/10.1001/jamanetworkopen.2021.28568.
9. Gupta A, Madhavan MV, Sehgal K, et al. Extrapulmonary manifestations of COVID-19. Nat Med. 2020;26(7):1017–32. https://doi.org/10.1038/s41591-020-0968-3.
10.• Nalbandian A, Sehgal K, Gupta A, et al. 2021 Post-acute COVID-19 syndrome. Nat Med 27(4):601–615. https://doi.org/10.1038/s41591-021-01283-z. **This comprehensive review of literature discusses pathophysiology, organ specific sequelae, and framework for identifying PASC and providing multidisciplinary care.**
11. Banerjee D, Viswanath B. Neuropsychiatric manifestations of COVID-19 and possible pathogenic mechanisms: insights from other coronaviruses. Asian J Psychiatr. 2020;54: 102350. https://doi.org/10.1016/j.ajp.2020.102350.
12. 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. https://doi.org/10.1001/jamaneurol.2020.1127.
13. Frontera JA, Melmed K, Fang T, et al. Toxic metabolic encephalopathy in hospitalized patients with COVID-19. Neurocrit Care. 2021;35(3):693–706. https://doi.org/10.1007/s12028-021-01220-5.
14. W-jie Guan, Ni Z-yi HuY, et al. Clinical characteristics of coronavirus disease 2019 in China. New England J Med. 2020;382(18):1708–20. https://doi.org/10.1056/nejmoa2002032.
15. Post COVID-19 condition (long COVID). World Health Organization. https://www.who.int/srilanka/news/detail/16-10-2021-post-covid-19-condition. Accessed February 28, 2022.
16. Younger DS. Post-acute sequelae of SARS-COV-2 infection (PASC): peripheral, autonomic, and central nervous system features in a child. Neurol Sci. 2021;42(10):3959–63. https://doi.org/10.1007/s10072-021-05345-5.
17. Demeco A, Marotta N, Barletta M, et al. Rehabilitation of patients post-COVID-19 infection: a literature review.
18. Lopez-Leon S, Wegman-Ostrosky T, Perelman C, et al. More than 50 long-term effects of COVID-19: a systematic review and meta-analysis. Sci Rep .2021;11:16144. https://doi.org/10.1038/s41598-021-95565-8.
19.• Graham EL, Clark JR, Orban ZS, et al. 2021 Persistent neurologic symptoms and cognitive dysfunction in non-hospitalized COVID-19 "long haulers." Ann Clin Transl Neurol 8(5):1073–1085. https://doi.org/10.1002/acn3.51350. **Findings from this prospective study establish symptoms of fatigue and persisting cognitive difficulties in non-hospitalized PASC patients.**
20. Ceban F, Ling S, Lui LMW, et al. Fatigue and cognitive impairment in POST-COVID-19 syndrome: a systematic review and meta-analysis. Brain Behav Immun. 2022;101:93–135. https://doi.org/10.1016/j.bbi.2021.12.020.
21. Mendelson M, Nel J, Blumberg L, et al. Long-COVID: an evolving problem with an extensive impact. S Afr Med J. 2020;111(1):10. https://doi.org/10.7196/samj.2020.v111i11.15433.
22. Jacobs LG, Gourna Paleoudis E, Lesky-Di Bari D, et al. Persistence of symptoms and quality of life at 35 days after hospitalization for COVID-19 infection. PLOS ONE. 2020;15(12):e0243882. https://doi.org/10.1371/journal.pone.0243882
23. O'Keefe JB, Minton HC, Morrow M, et al. Postacute sequelae of SARS-COV-2 infection and impact on quality of life 1–6 months after illness and association with initial symptom severity. Open Forum Infect Dis. 2021;(8):ofab352.
24. Lambert N, Corps S, El-Azab SA, et al. COVID-19 survivors'reports of the timing, duration, and health impacts of post-acute sequelae of SARS-COV-2 (PASC) infection. [Internet]. medRxiv [Preprint]; 2021. https://doi.org/10.1101/2021.03.22.21254026.
25. Jaywant A, Vanderlind WM, Alexopoulos GS, Fridman CB, Perlis RH, Gunning FM. Frequency and profile of objective cognitive deficits in hospitalized patients recovering from COVID-19. Neuropsychopharmacology. 2021;46(13):2235–40. https://doi.org/10.1038/s41386-021-00978-8.

26. Woo MS, Malsy J, Pöttgen J, et al. Frequent neurocognitive deficits after recovery from mild COVID-19. Brain Commun. 2020;2(2). https://doi.org/10.1093/braincomms/fcaa205
27. Apple AC, Oddi A, Peluso MJ, et al. Risk factors and abnormal cerebrospinal fluid associate with cognitive symptoms after mild COVID-19. Ann Clin Transl Neurol. 2022;9(2):221–6. https://doi.org/10.1002/acn3.51498.
28. Alemanno F, Houdayer E, Parma A, et al. COVID-19 cognitive deficits after respiratory assistance in the subacute phase: a COVID-rehabilitation unit experience. PLOS ONE. 2021;16(2):e0246590. https://doi.org/10.1371/journal.pone.0246590.
29. Krishnan K, Miller AK, Reiter K, Bonner-Jackson A. Neurocognitive profiles in patients with persisting cognitive symptoms associated with COVID-19. Arch Clin Neuropsychol. 2022. https://doi.org/10.1093/arclin/acac004.
30. Vannorsdall TD, Brigham E, Fawzy A, et al. Cognitive dysfunction, psychiatric distress, and functional decline after COVID-19. J Acad Consultat Liaison Psychiatry. 2022;63(2):133–43. https://doi.org/10.1016/j.jaclp.2021.10.006.
31. Wild C, Norton L, Menon D, Ripsman D, Swartz R, Owen A. Seeing through brain fog: disentangling the cognitive, physical, and mental health sequalae of COVID-19. [Internet]. Research Square [Preprint]; 2021. https://doi.org/10.21203/rs.3.rs-373663/v1.
32. Houben-Wilke S, Goërtz YMJ, Delbressine JM, et al. The impact of long COVID-19 on mental health: observational 6-month follow-up study. JMIR Mental Health. 2022;9(2). https://doi.org/10.2196/33704.
33. Herrera JE, Niehaus WN, Whiteson J, et al. Multidisciplinary collaborative consensus guidance statement on the assessment and treatment of fatigue in postacute sequelae of SARS-COV-2 infection (PASC) patients. PM&R. 2021;13(9):1027–43. https://doi.org/10.1002/pmrj.12684.
34. Cicerone KD, Goldin Y, Ganci K, et al. Evidence-based cognitive rehabilitation: systematic review of the literature from 2009 through 2014. Arch Phys Med Rehabil. 2019;100(8):1515–33. https://doi.org/10.1016/j.apmr.2019.02.011.
35. Maggio MG, De Luca R, Manuli A, Calabrò RS. The five 'W' of cognitive telerehabilitation in the COVID-19 ERA. Expert Rev Med Devices. 2020;17(6):473–5. https://doi.org/10.1080/17434440.2020.1776607.
36. Smith PJ, Blumenthal JA, Hoffman BM, et al. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosom Med. 2010;72(3):239–52. https://doi.org/10.1097/psy.0b013e3181d14633.
37. Li I, Bui T, Phan HT, Llado A, King C, Scrivener K. App-based supplemental exercise in rehabilitation, adherence, and effect on outcomes: a randomized controlled trial. Clin Rehabil. 2020;34(8):1083–93. https://doi.org/10.1177/0269215520928119.
38. Daynes E, Gerlis C, Chaplin E, Gardiner N, Singh SJ. Early experiences of rehabilitation for individuals post-COVID to improve fatigue, breathlessness exercise capacity and cognition—a cohort study. Chron Respir Dis. 2021;18:147997312110156. https://doi.org/10.1177/14799731211015691.
39. Udina C, Ars J, Morandi A, Vilaró J, Cáceres C, Inzitari M. Rehabilitation in adult post-COVID-19 patients in post-acute care with therapeutic exercise. The J Frailty Aging. 2021;10(3):297–300. https://doi.org/10.14283/jfa.2021.1.
40. Holmes EA, O'Connor RC, Perry VH, et al. Multidisciplinary research priorities for the COVID-19 pandemic: a call for action for mental health science. Lancet Psychiatry. 2020;7(6):547–60. https://doi.org/10.1016/s2215-0366(20)30168-1.
41. Rogers JP, Chesney E, Oliver D, et al. Psychiatric and neuropsychiatric presentations associated with severe coronavirus infections: a systematic review and meta-analysis with comparison to the COVID-19 pandemic. Lancet Psychiatry. 2020;7(7):611–27. https://doi.org/10.1016/s2215-0366(20)30203-0.
42. Wang C, Pan R, Wan X, et al. Immediate psychological responses and associated factors during the initial stage of the 2019 coronavirus disease (COVID-19) epidemic among the general population in China. Int J Environ Res Public Health. 2020;17(5):1729. https://doi.org/10.3390/ijerph17051729.
43.●● Taquet M, Luciano S, Geddes JR, Harrison PJ. 2021 Bidirectional associations between COVID-19 and psychiatric disorder: retrospective cohort studies of 62 354 COVID-19 cases in the USA. Lancet Psychiatry. 8(2):130–140. https://doi.org/10.1016/s2215-0366(20)30462-4. **This large review of electronic health records in the USA found that survivors of COVID-19 are at an increased risk for psychiatric sequelae and a psychiatric diagnosis is an independent risk factor for COVID-19 infection.**
44. Pistarini C, Fiabane E, Houdayer E, Vassallo C, Manera MR, Alemanno F. Cognitive and emotional disturbances due to COVID-19: an exploratory study in the rehabilitation setting. Front Neurol. 2021;17. https://doi.org/10.3389/fneur.2021.643646.
45. Whiteside DM, Basso MR, Naini SM, et al. Outcomes in post-acute sequelae of COVID-19 (PASC) at 6 months post-infection part 1: cognitive functioning. Clin Neuropsychol. 2022;1–23. https://doi.org/10.1080/13854046.2022.2030412.
46. Sun T, Guo L, Tian F, et al. Rehabilitation of patients with COVID-19. Expert Rev Respir Med. 2020;14(12):1249–56. https://doi.org/10.1080/17476348.2020.1811687.
47. De Luca R, Calabrò RS. How the COVID-19 pandemic is changing mental health disease management: the growing need of telecounseling in Italy. Innov Clin Neurosci. 2020;17(4–6):16–7.
48. Liu S, Yang L, Zhang C, et al. Online mental health services in China during the COVID-19 outbreak. Lancet Psychiatry. 2020;7(4). https://doi.org/10.1016/s2215-0366(20)30077-8.
49. Bailey EK, Steward KA, VandenBussche Jantz AB, Kamper JE, Mahoney EJ, Duchnick JJ. Neuropsychology of COVID-19: anticipated cognitive and mental health outcomes. Neuropsychology. 2021;35(4):335–51. https://doi.org/10.1037/neu0000731.
50. Troyer EA, Kohn JN, Hong S. Are we facing a crashing wave of neuropsychiatric sequelae of COVID-19? Neuropsychiatric symptoms and potential immunologic mechanisms. Brain Behav Immun. 2020;87:34–9. https://doi.org/10.1016/j.bbi.2020.04.027.