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Review Article

A Multicenter Data Comprehensive Analysis of Rehabilitation Strategies for COVID-19 Sequelae: Current Status, Challenges, and Future Perspectives

Tian Ruan[1, †], Tao Yu[2, †], Fang Zhao[3], Yaohua Tang[4, *]

[1]Basic and Pharmacy Department, Yunnan Medical Health College, Kunming, China
[2]Department of Neurology and Geriatrics, Hekou County People's Hospital, Honghe, China
[3]Geriatric Department, Mengzi Hospital of Traditional Chinese Medicine, Mengzi, China
[4]Clinical Medical College, Yunnan Medical Health College, Kunming, China

Abstract

The COVID-19 pandemic has led to a substantial proportion of survivors experiencing persistent, multisystem sequelae, encompassing respiratory dysfunction, neuromuscular impairments, cardiovascular complications, and psychological disorders. These heterogeneous and complex late effects pose significant challenges for rehabilitation professionals in conducting comprehensive assessments and designing tailored interventions. This review integrates data from multicenter studies to elucidate the clinical manifestations of COVID-19 sequelae, evaluate the validity and reliability of existing assessment instruments, and examine the efficacy of diverse rehabilitation modalities. Emphasis is placed on the pivotal role of multidisciplinary teams, the feasibility of tele-rehabilitation platforms, and the incorporation of innovative technologies—such as virtual reality, wearable sensors, and artificial intelligence—in optimizing rehabilitation outcomes. By systematically analyzing rehabilitation pathways across different sequelae, this paper aims to furnish evidence-based recommendations to refine clinical protocols, enhance the efficiency of rehabilitation services, and ultimately facilitate functional recovery and quality-of-life improvements for individuals affected by long COVID.

Keywords

COVID-19 Sequelae, Rehabilitation Strategies, Multicenter Studies, Remote Rehabilitation, Neurocognitive Disorders, Pulmonary Function Recovery, Cardiovascular Rehabilitation, Mental Health

1. Methods

This review was conducted by performing a systematic search of literature across multiple electronic databases, including PubMed, Embase, and Web of Science. The search strategy utilized a combination of keywords such as "COVID-19," "Long COVID," "Post-Acute COVID-19 Syndrome," and "rehabilitation." The selection process involved

*Corresponding author: 15288238661@163.com (Yaohua Tang)

† Tian Ruan and Tao Yu are co-first authors.

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screening titles and abstracts, followed by a full-text review based on predefined inclusion and exclusion criteria. We included multicenter studies, cohort studies, and clinical trials that focused on rehabilitation strategies for post-COVID-19 sequelae. Non-English articles, case reports, and editorials were excluded. The final synthesis of the selected literature was performed narratively to summarize the current evidence.

2. Introduction

The COVID-19 pandemic has emerged as a global health crisis, revealing a multifaceted disease that extends beyond its acute phase. While the immediate respiratory and systemic impacts of SARS-CoV-2 infection have been extensively documented, the long-term sequelae, often referred to as post-acute sequelae of SARS-CoV-2 infection (PASC) or Long COVID, are increasingly recognized as a significant public health concern. These sequelae encompass a broad spectrum of symptoms affecting multiple organ systems, including the respiratory, cardiovascular, and neurological systems, as well as mental health outcomes such as anxiety and depression. The complexity and heterogeneity of these manifestations pose substantial challenges for healthcare providers, emphasizing the need for comprehensive rehabilitation strategies tailored to individual patient needs [1, 2].

The diversity of post-COVID symptoms can severely disrupt patients' quality of life and functional capacity, necessitating systematic and evidence-based rehabilitation interventions. Patients often report a range of debilitating symptoms, including fatigue, dyspnea, cognitive impairment, and psychological distress, which can persist for months following the initial infection. This prolonged symptomatology not only affects the physical health of survivors but also their social functioning and overall well-being. As such, there is an urgent need for structured rehabilitation programs that can effectively address these multifaceted challenges and support patients in their recovery journey [3, 4].

Multicenter studies have provided valuable insights into the rehabilitation needs of diverse patient populations affected by COVID-19. These studies have highlighted significant disparities in recovery outcomes based on demographic factors, pre-existing health conditions, and the severity of the acute illness. For instance, individuals from socio-economically disadvantaged backgrounds may experience greater barriers to accessing rehabilitation services, resulting in poorer health outcomes compared to their more affluent counterparts. This underscores the importance of tailoring rehabilitation approaches to not only the clinical needs of patients but also their socio-economic contexts [5, 6].

Current rehabilitation models for post-COVID patients encompass both in-person and remote modalities, integrating multidisciplinary team approaches to optimize care delivery. The integration of telehealth services has proven beneficial in overcoming geographical and logistical barriers, allowing for continuous monitoring and support of patients in their recovery process. Furthermore, the collaboration among healthcare professionals across various disciplines is essential in developing comprehensive rehabilitation pathways that address the diverse and evolving needs of individuals recovering from COVID-19 [7, 8].

This review aims to synthesize recent multicenter data on rehabilitation strategies for COVID-19 sequelae, examining the current landscape of challenges and opportunities in this area. By analyzing existing literature and clinical findings, we seek to elucidate effective rehabilitation practices, identify gaps in care, and propose future directions for research and practice. Understanding the complexities of post-COVID recovery will be crucial in shaping evidence-based interventions that enhance the quality of life for affected individuals and inform public health policies moving forward [8, 9]. To provide a holistic view of the rehabilitation process, Figure 1 presents a schematic overview of post-acute sequelae of SARS-CoV-2 infection (PASC) and their corresponding multidisciplinary rehabilitation pathways.

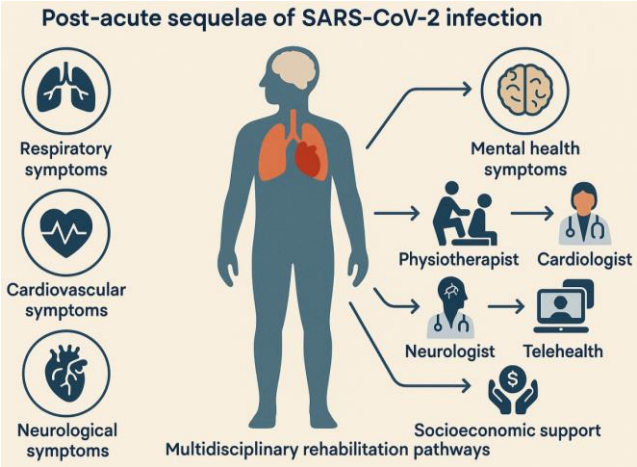

Figure 1. *Schematic overview of post-acute sequelae of SARS-CoV-2 infection (PASC) and corresponding multidisciplinary rehabilitation pathways. Major long-term symptoms—fatigue, dyspnea, cognitive impairment, anxiety/depression—are shown alongside target organs. Arrows illustrate assessment and personalized rehabilitation steps, incorporating telehealth and socioeconomic support. Created with BioRender.com.*

3. Main Body

3.1. Clinical Manifestations and Multisystem Effects of Post-COVID-19 Sequelae

3.1.1. Respiratory Sequelae

The respiratory sequelae following COVID-19 infection have emerged as significant clinical concerns, particularly in patients who experienced severe manifestations of the disease. One of the most prevalent symptoms is dyspnea, which can persist long after the acute phase of the illness has resolved.

Studies indicate that approximately 19% of COVID-19 survivors report ongoing respiratory symptoms, which may include not only dyspnea but also chronic cough and reduced exercise tolerance [10]. The development of pulmonary fibrosis is another critical aspect of post-COVID-19 respiratory sequelae, particularly in patients who suffered from acute respiratory distress syndrome (ARDS). Research has shown that ARDS-related lung fibrosis can lead to long-term pulmonary impairment, with some patients exhibiting significant declines in lung function as measured by forced vital capacity (FVC) and diffusion capacity for carbon monoxide (DLCO) [11]. The clinical implications of these findings are profound, as they suggest that a substantial number of patients may require ongoing pulmonary rehabilitation and monitoring to manage these chronic conditions effectively.

Pulmonary function tests (PFTs) are essential tools for assessing the extent of lung impairment in COVID-19 survivors. Studies have demonstrated that many patients exhibit obstructive or restrictive patterns on spirometry, indicating significant alterations in lung mechanics and gas exchange capabilities [12]. Specifically, post-COVID-19 patients often show reduced FEV1/FVC ratios, which can signify obstructive lung disease, while others may present with restrictive patterns characterized by decreased lung volumes [13]. These changes in pulmonary function are not merely academic; they have direct implications for rehabilitation strategies. Effective rehabilitation programs can help improve lung function, enhance exercise capacity, and reduce symptoms of dyspnea. For instance, structured pulmonary rehabilitation has been shown to yield significant improvements in both subjective measures of breathlessness and objective measures of lung function, reinforcing the importance of early and ongoing rehabilitative care in this population [14]. Focusing on the respiratory system, Figure 2 illustrates the key manifestations of post-COVID sequelae and the targeted rehabilitation interventions.

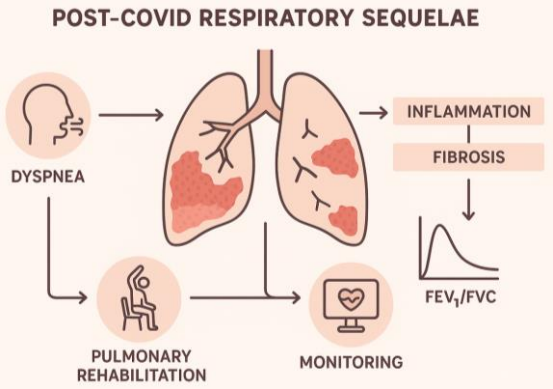

Figure 2. *Post-COVID-19 respiratory sequelae and rehabilitation schematic. Key manifestations—dyspnea, chronic cough, reduced exercise tolerance, pulmonary fibrosis—are depicted in lung anatomy and PFT graphs (FEV_1/FVC, DLCO). Arrows indicate pathological pathways (inflammation → fibrosis) and rehabilitation interventions (pulmonary exercises, monitoring). Created with BioRender.com.*

The underlying pathological mechanisms contributing to respiratory sequelae in COVID-19 patients are complex and multifactorial. The acute inflammatory response triggered by SARS-CoV-2 infection can lead to alveolar damage, interstitial inflammation, and subsequent fibrosis, which are critical components of the post-viral lung pathology observed in many survivors [15]. Additionally, the dysregulation of the immune response, characterized by a hyper-inflammatory state and cytokine storm, may exacerbate lung injury and promote fibrotic changes [16]. Long-term impacts of these respiratory sequelae extend beyond the lungs, influencing overall health outcomes and quality of life. Patients with persistent pulmonary dysfunction may experience limitations in physical activity, increased healthcare utilization, and a heightened risk of comorbid conditions, including cardiovascular disease and mental health disorders [8]. Therefore, understanding the pathophysiological mechanisms at play is crucial for developing targeted interventions aimed at mitigating the long-term consequences of COVID-19 on respiratory health.

3.1.2. Neuromuscular and Cognitive Dysfunction

The neurological manifestations of COVID-19 have emerged as a significant concern, with various pathological presentations including polyneuropathy, myopathy, and cognitive impairment. Neuromuscular complications are not uncommon during the acute phase of the infection, and they can lead to severe outcomes, including high mortality rates. Research indicates that both direct viral effects and indirect mechanisms such as hypercytokinemia contribute to these complications [17]. The spectrum of neurological symptoms observed in post-COVID-19 patients includes not only classic neuromuscular manifestations like muscle weakness and myopathy but also cognitive disturbances commonly referred to as “brain fog.” These cognitive impairments manifest as difficulties in attention, memory, and executive function, significantly impacting patients’ quality of life [18]. The underlying mechanisms of these neurological sequelae are complex and multifactorial, involving direct neuronal injury from the virus, inflammatory responses, and potential autoimmune processes triggered by the infection [19].

Cognitive dysfunction and neuropsychiatric symptoms have been identified as critical components of post-acute COVID-19 syndrome, with clinical features that require careful assessment and management. Patients often present with a range of cognitive deficits, including impaired concentration, memory loss, and mood disturbances such as anxiety and depression. These symptoms can be assessed using various standardized neuropsychological tests and scales, which help to quantify the extent of cognitive impairment and its impact on daily functioning [20]. The prevalence of these cognitive issues underscores the necessity for comprehensive evaluation protocols in post-COVID-19 care settings, as early identification can facilitate timely interventions that may mitigate long-term consequences. Further-

more, the psychological burden associated with these cognitive impairments can exacerbate the overall morbidity experienced by patients, making it essential to adopt a holistic approach to rehabilitation that addresses both neurological and psychological needs [21].

The mechanisms underlying neurological damage in COVID-19 patients remain an area of active investigation, and several hypotheses have been proposed to explain the observed neurological sequelae. One prominent theory suggests that the virus may directly invade the central nervous system (CNS) or induce a hyper-inflammatory response, leading to neuronal injury and dysfunction. This cytokine storm, characterized by an overproduction of pro-inflammatory cytokines, has been implicated in causing encephalopathy and other central nervous system disorders [18]. Additionally, the potential for autoimmune-mediated neurological conditions following COVID-19 infection cannot be overlooked, as post-infection autoantibodies may target neuronal tissues, further complicating the clinical picture [17]. Rehabilitation strategies for these patients face significant challenges, as the heterogeneity of neurological symptoms necessitates personalized treatment plans that can adapt to the evolving nature of the patient's condition. Multidisciplinary approaches involving neurologists, rehabilitation specialists, and psychologists are crucial for addressing the complex needs of individuals suffering from post-COVID neurological sequelae, ensuring that both physical and cognitive rehabilitation are prioritized [20, 21]. Figure 3 details the neuromuscular and cognitive sequelae, such as polyneuropathy and "brain fog," alongside the necessary multidisciplinary rehabilitation pathways.

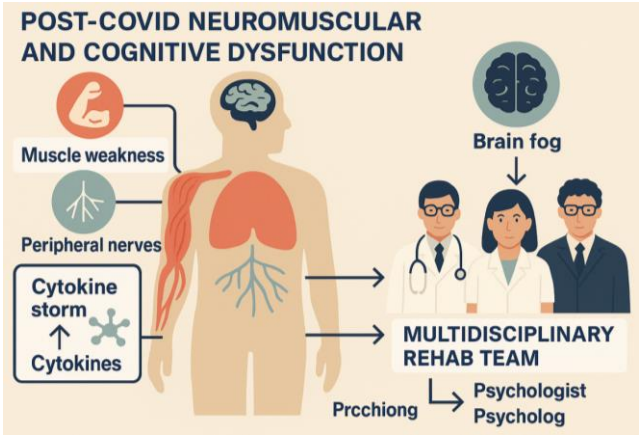

Figure 3. *Neuromuscular and cognitive sequelae of COVID-19 and corresponding multidisciplinary rehabilitation pathways. Key features—polyneuropathy, myopathy, brain fog, cytokine storm—are depicted with arrows indicating assessment and tailored interventions by neurologists, physiotherapists, and psychologists. Created with BioRender.com.*

In conclusion, the implications of neuromuscular and cognitive dysfunction in post-COVID-19 patients are profound, affecting not only individual health outcomes but also broader public health considerations. As the pandemic continues to evolve, ongoing research into the pathophysiology of these neurological complications and the development of effective rehabilitation strategies will be essential in managing the long-term sequelae of COVID-19. The integration of comprehensive rehabilitation programs that address both physical and cognitive impairments will be critical in improving the quality of life for survivors of this debilitating disease.

3.1.3. Cardiovascular System Sequelae

The cardiovascular sequelae following COVID-19 infection have emerged as a significant concern, particularly regarding autonomic nervous system dysfunction and arrhythmias. Studies indicate that a notable percentage of COVID-19 survivors experience long-lasting cardiovascular issues, including dysautonomia characterized by symptoms such as fatigue, palpitations, and orthostatic intolerance. The autonomic nervous system, which regulates involuntary bodily functions, can be disrupted by the inflammatory response triggered by the SARS-CoV-2 virus. This disruption may lead to an imbalance between sympathetic and parasympathetic activity, resulting in conditions like postural orthostatic tachycardia syndrome (POTS) and other forms of dysautonomia. Moreover, arrhythmias, including atrial fibrillation and ventricular tachycardia, have been documented in patients recovering from COVID-19, particularly those with a history of cardiovascular disease or myocardial injury during the acute phase of the infection. The underlying mechanisms are thought to involve direct viral invasion of cardiac tissues, inflammatory cytokine release, and subsequent myocardial inflammation, which can lead to electrical conduction abnormalities. As such, it is crucial for healthcare providers to monitor and manage these sequelae in patients recovering from COVID-19 to improve their quality of life and reduce the risk of further cardiovascular complications [22-24].

Fatigue and reduced exercise tolerance are prevalent among COVID-19 survivors, with significant implications for cardiovascular function. Research has shown that many individuals experience a decline in cardiorespiratory fitness, which can be attributed to a combination of factors including deconditioning, persistent inflammation, and autonomic dysfunction following infection. The relationship between fatigue and cardiovascular health is particularly concerning as it may lead to a vicious cycle where reduced physical activity exacerbates cardiovascular deconditioning, further impairing exercise tolerance. This phenomenon is particularly pronounced in patients who experienced severe COVID-19, where prolonged hospitalization and reduced physical activity during recovery can lead to significant declines in functional capacity. Furthermore, studies have suggested that the severity of initial COVID-19 symptoms correlates with the degree of post-infection fatigue and exercise intolerance. Consequently, targeted rehabilitation strategies

focusing on gradually increasing physical activity levels are essential to restore cardiovascular function and improve overall health outcomes for these patients [13, 10, 25].

The potential mechanisms underlying cardiovascular sequelae in COVID-19 patients are multifaceted and include direct myocardial injury, endothelial dysfunction, and systemic inflammation. Cardiovascular rehabilitation (CR) has emerged as a promising intervention to address these sequelae, with evidence suggesting that structured CR programs can significantly enhance recovery outcomes. These programs typically involve supervised exercise training, education on lifestyle modifications, and psychosocial support, all aimed at improving cardiovascular health and physical capacity. Mechanistically, CR is thought to stimulate the parasympathetic nervous system, enhance endothelial function, and reduce systemic inflammation, which collectively contribute to improved cardiovascular outcomes. Furthermore, emerging data indicates that CR can alleviate symptoms of fatigue and dysautonomia in post-COVID patients, thereby enhancing their quality of life. The integration of CR into the post-COVID care pathway is vital, as it not only addresses the immediate cardiovascular concerns but also empowers patients to engage in their recovery actively. As the understanding of COVID-19 sequelae evolves, ongoing research into the efficacy and optimization of CR protocols. will be essential for improving long-term health outcomes in this patient population [22, 25, 24] The cardiovascular system's long-term effects are summarized in Figure 4, which outlines sequelae like dysautonomia and the corresponding rehabilitation pathways.

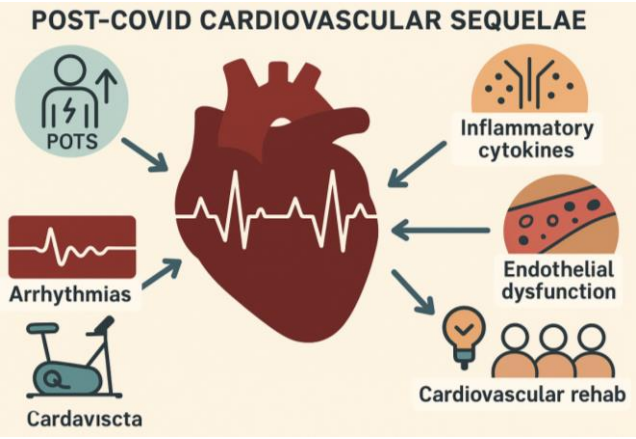

Figure 4. *Post-COVID cardiovascular sequelae including dysautonomia (POTS), arrhythmias, and endothelial dysfunction, and corresponding cardiovascular rehabilitation pathways encompassing supervised exercise, lifestyle education, and psychosocial support. Created with BioRender.com.*

3.1.4. Mental Health and Psychological Disorders

The COVID-19 pandemic has significantly impacted mental health globally, with increasing reports of depression, anxiety, and post-traumatic stress disorder (PTSD) among various populations. Studies indicate that up to 71.8% of individuals recovering from COVID-19 experience poor mental health, with specific rates of anxiety and depression reported at 22% and 21%, respectively, among survivors [26, 27]. The prevalence of PTSD among COVID-19 survivors has also been highlighted, with rates reaching approximately 20% [27]. Factors contributing to these mental health challenges include the direct effects of the virus on the central nervous system, the psychological impact of social isolation, and the stress associated with the pandemic's uncertainties and health risks [28, 29]. Vulnerable populations, such as healthcare workers and individuals with pre-existing mental health conditions, have been particularly affected, exhibiting higher rates of mental health disorders following COVID-19 infection [30, 31]. The epidemiological data underscores the urgent need for targeted mental health interventions and support systems for those affected by COVID-19, as the long-term implications of these mental health disorders may persist long after the acute phase of the illness has resolved.

Mental health issues significantly influence rehabilitation outcomes for COVID-19 survivors, impacting their recovery trajectories and overall quality of life. Studies have shown that individuals experiencing symptoms of depression and anxiety exhibit poorer rehabilitation outcomes, including reduced physical function and increased fatigue [26, 32]. The presence of mental health disorders can exacerbate physical symptoms, leading to a cycle of worsening health and rehabilitation challenges [28]. For instance, a meta-analysis indicated that COVID-19 survivors with mental health disorders faced a higher risk of developing long-term sequelae, including fatigue and cognitive impairments, which can hinder participation in rehabilitation programs [27, 33]. Furthermore, psychological distress can also lead to lower adherence to rehabilitation protocols, as individuals may struggle with motivation and engagement in physical activities [26]. Addressing mental health issues through integrated care models that encompass psychological support alongside physical rehabilitation is essential for improving recovery outcomes and enhancing the overall well-being of COVID-19 survivors. Addressing the psychological impact, Figure 5 provides a schematic for integrated mental health rehabilitation, covering conditions such as depression, anxiety, and PTSD.

Psychological interventions play a crucial role in the comprehensive rehabilitation of COVID-19 survivors, addressing the mental health challenges that often accompany physical recovery. Evidence suggests that integrating psychological support, such as cognitive-behavioral therapy (CBT) and mindfulness-based interventions, can significantly improve mental health outcomes for individuals suffering from anxiety, depression, and PTSD following COVID-19 [28, 26]. These interventions not only help mitigate the psychological distress associated with the pandemic but also enhance the effectiveness of physical rehabilitation efforts by fostering resilience and coping strategies [33]. For example, studies

have demonstrated that patients who engage in psychological therapies alongside physical rehabilitation report improved adherence to exercise regimens and better overall recovery outcomes [26, 32]. Additionally, the incorporation of telehealth services has expanded access to mental health support, allowing for timely interventions that can address mental health needs in real-time, thus facilitating a more holistic approach to rehabilitation [33]. The integration of psychological interventions into rehabilitation programs is vital for addressing the multifaceted impacts of COVID-19 on survivors, ultimately leading to improved health outcomes and quality of life.

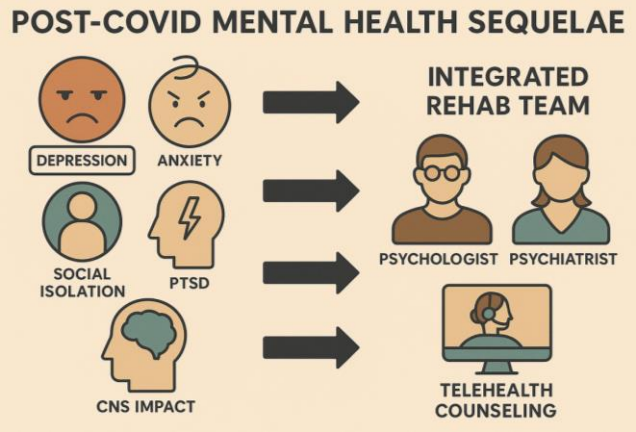

Figure 5. *Post-COVID mental health sequelae—including depression, anxiety, PTSD, social isolation, and CNS effects—and corresponding integrated rehabilitation pathways involving psychologists, psychiatrists, and telehealth counseling. Created with BioRender.com.*

3.2. Systematic Assessment and Monitoring Tools for Post-COVID-19 Sequelae

3.2.1. Multidisciplinary Assessment Model Construction

The integration of respiratory, neurological, cardiovascular, and psychological evaluations is critical in addressing the multifaceted nature of post-COVID-19 conditions. COVID-19 survivors frequently experience a range of long-term sequelae that affect multiple organ systems, necessitating a comprehensive and multidisciplinary approach to rehabilitation. This approach is supported by evidence indicating that patients enrolled in multidisciplinary programs demonstrate significant improvements in health-related quality of life (HRQoL) and symptom resolution compared to those receiving standard care [34]. The assessment model should encompass specialists from various fields, including pulmonologists, neurologists, cardiologists, and mental health professionals, to provide a holistic evaluation of the patient's condition. For instance, respiratory assessments can identify lingering pulmonary issues, while neurological evaluations can address cognitive impairments and mood disorders that often accompany long COVID. This comprehensive assessment ensures that all aspects of a patient's health are considered, leading to more tailored and effective rehabilitation strategies.

Standardization of the assessment process is essential to ensure that all patients receive a consistent evaluation, which can be adjusted based on individual needs. The development of standardized assessment protocols, such as the COVID-19 Yorkshire Rehabilitation Scale, allows for systematic data collection and comparison across different patient populations [35]. These protocols can guide clinicians in identifying specific deficits and tracking progress over time. Furthermore, individualized adjustments to the assessment process can be made based on the patient's unique clinical presentation and history. For example, patients with pre-existing conditions may require additional cardiovascular assessments, while those with significant psychological distress may need more extensive mental health evaluations. This individualized approach not only enhances the accuracy of the assessments but also fosters patient engagement and adherence to rehabilitation programs, as patients feel their specific needs are being addressed.

The integration of telehealth and remote monitoring technologies can further enhance the assessment model, allowing for continuous evaluation of patients' progress and symptoms. This is particularly relevant in the context of COVID-19, where many patients may be hesitant to attend in-person appointments due to ongoing concerns about infection risk. Utilizing telehealth platforms can facilitate regular check-ins and assessments, ensuring that patients remain connected to their care team and receive timely interventions as needed. Additionally, remote monitoring tools can provide valuable data on patients' daily activities and symptom fluctuations, enabling healthcare providers to make informed decisions about rehabilitation strategies and adjustments to treatment plans. Overall, the construction of a multidisciplinary assessment model that incorporates standardized protocols, individualized adjustments, and telehealth capabilities is essential for effectively addressing the complex needs of post-COVID-19 patients and optimizing their recovery outcomes.

3.2.2. Remote Monitoring and Digital Tools

The COVID-19 pandemic has significantly accelerated the adoption of remote monitoring and digital tools in healthcare, particularly in the management of patients recovering from COVID-19 and those experiencing long-term sequelae, commonly referred to as Long COVID. Among the innovative solutions developed during this period is the COVID-19 Yorkshire Rehabilitation Screen (C19-YRS), which serves as a remote assessment tool designed to evaluate the rehabilitation needs of patients post-COVID-19. This tool exemplifies how digital health technologies can facilitate timely assessments and personalized care plans without requiring

in-person visits, thereby minimizing the risk of virus transmission [36]. The C19-YRS, alongside other digital health applications, enables healthcare providers to monitor patient progress remotely, ensuring that individuals receive appropriate interventions based on real-time data. Furthermore, the integration of wearable devices has revolutionized personal healthcare by continuously tracking physiological parameters such as heart rate, respiratory rate, and oxygen saturation [37]. These devices not only support early detection of complications but also empower patients to engage actively in their recovery process, fostering a sense of autonomy and responsibility for their health.

The advantages of remote monitoring and digital tools during the pandemic are manifold. Firstly, they provide a practical solution to the challenges posed by social distancing measures and reduced in-person healthcare services. For instance, a study demonstrated that remote monitoring systems could effectively identify cardiac arrhythmias in COVID-19 survivors, significantly improving early detection rates compared to traditional care models [38]. This proactive approach to monitoring patients has proven essential in managing the ongoing health challenges associated with COVID-19, including cardiovascular complications that may arise post-infection. Additionally, remote monitoring technologies facilitate data collection and integration, allowing for dynamic tracking of patient health over time. This capability is crucial for understanding the long-term effects of COVID-19 and tailoring rehabilitation strategies accordingly [39].

However, the rapid implementation of these digital solutions has not been without challenges. Issues such as technological literacy, access to devices, and concerns about data privacy have emerged as significant barriers to the widespread adoption of remote monitoring tools [40]. Furthermore, the reliance on digital platforms may inadvertently exacerbate health disparities among populations with limited access to technology or the internet. It is imperative that healthcare systems address these inequities to ensure that all patients can benefit from the advancements in digital health. Strategies such as providing training for patients and caregivers, as well as ensuring equitable access to technology, are essential for maximizing the effectiveness of remote monitoring initiatives [41].

In conclusion, the integration of remote monitoring and digital tools into the rehabilitation strategies for COVID-19 survivors represents a significant advancement in healthcare delivery. While these technologies offer numerous benefits, including enhanced patient engagement and improved health outcomes, it is crucial to address the associated challenges to ensure equitable access and effectiveness. As we move forward, the lessons learned from the pandemic will undoubtedly shape the future of healthcare, emphasizing the need for innovative solutions that prioritize patient-centered care and accessibility.

3.2.3. Physiological Function and Imaging Examinations

The aftermath of COVID-19 has revealed significant physiological impairments, particularly in lung and cardiac function, as well as potential neurological sequelae. Lung function tests, including spirometry and diffusing capacity for carbon monoxide (DLCO), have become essential in evaluating the respiratory health of COVID-19 survivors. Studies indicate that a substantial proportion of patients exhibit persistent pulmonary dysfunction, with one study reporting that 61% of patients had at least one pulmonary function abnormality shortly after recovery, which decreased to 22% by one year post-infection [42]. Cardiac involvement is also prevalent among COVID-19 survivors, with echocardiographic assessments revealing subclinical left and right ventricular dysfunction in a significant number of patients [43]. Moreover, neurophysiological evaluations, including electromyography and nerve conduction studies, are increasingly being utilized to assess potential neurological impairments, which may manifest as cognitive dysfunction or peripheral neuropathy in the post-acute sequelae of COVID-19 (PASC) population. The integration of these assessments is crucial for a comprehensive understanding of the long-term sequelae of COVID-19 and for guiding rehabilitation strategies.

Imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) play a pivotal role in the assessment of post-COVID-19 sequelae. CT imaging has been instrumental in identifying lung abnormalities, including ground-glass opacities and fibrotic changes, in a significant proportion of patients recovering from COVID-19 pneumonia [44]. These imaging findings have been correlated with functional impairments, as patients exhibiting persistent CT abnormalities often demonstrate reduced exercise capacity and impaired lung function [45]. Furthermore, MRI is increasingly utilized to evaluate cardiac involvement, where findings such as myocardial inflammation and fibrosis have been documented in a substantial number of recovered patients [46]. The ability of these imaging techniques to provide insights into the structural and functional changes in various organ systems underscores their importance in the ongoing management and rehabilitation of COVID-19 survivors.

Biomarkers and laboratory tests offer additional insights into the physiological status of COVID-19 survivors and can aid in the assessment of long-term sequelae. Elevated levels of inflammatory markers, such as high-sensitivity troponin T, have been associated with cardiac involvement in recovered COVID-19 patients, indicating ongoing myocardial inflammation despite the resolution of acute symptoms [46]. Additionally, laboratory tests assessing markers of lung injury and inflammation, such as C-reactive protein and D-dimer, can provide valuable information regarding the risk of pulmonary complications and guide therapeutic interventions. The integration of biomarker analysis with imaging and function-

al assessments could enhance the understanding of the pathophysiological mechanisms underlying PASC and facilitate the development of targeted rehabilitation strategies. Furthermore, ongoing research into novel biomarkers may uncover new avenues for predicting and managing the long-term effects of COVID-19, ultimately improving patient outcomes in this population.

3.3. Rehabilitation Intervention Strategies and Multidisciplinary Collaboration Models

3.3.1. Respiratory Rehabilitation Programs

Respiratory rehabilitation is a crucial component in the recovery of patients post-COVID-19, particularly those suffering from persistent respiratory symptoms. Exercise training, respiratory muscle training, and oxygen therapy management are integral to these rehabilitation efforts. Exercise training focuses on improving physical endurance and strength, which can be significantly impaired following COVID-19 infection. Studies have shown that structured exercise programs can enhance lung function and overall physical capacity, leading to improved quality of life for patients [47, 20]. Respiratory muscle training specifically targets the diaphragm and intercostal muscles, which are often weakened in patients who have experienced severe respiratory distress during their illness. This training not only aids in improving respiratory mechanics but also enhances the effectiveness of cough and secretion clearance, which is vital for preventing further pulmonary complications [48, 49]. Additionally, oxygen therapy management is essential for patients experiencing hypoxemia or exertional dyspnea. The personalized application of supplemental oxygen during rehabilitation can help optimize exercise performance and safety, allowing patients to engage more fully in their rehabilitation programs [50, 51]. Collectively, these elements of respiratory rehabilitation work synergistically to restore functional independence and improve the overall health outcomes of COVID-19 survivors.

The recovery of exercise endurance and lung function in post-COVID-19 patients can be effectively guided by evidence-based methods. Recent systematic reviews and clinical trials have highlighted the significance of tailored rehabilitation programs that incorporate both aerobic and resistance training to enhance functional capacity [52, 53]. Aerobic exercises, such as walking or cycling, are particularly beneficial in improving cardiovascular fitness and endurance, which are often compromised in patients recovering from COVID-19. The incorporation of resistance training further supports muscle strength, which is critical for daily activities and overall mobility [54, 20]. Moreover, pulmonary rehabilitation programs that utilize a combination of these exercise modalities have been shown to result in significant improvements in lung function, as measured by forced vital capacity (FVC) and forced expiratory volume (FEV1) [52, 50]. Additionally, the implementation of individualized exercise regimens that account for the patient's baseline fitness level, comorbidities, and specific respiratory limitations can lead to more effective outcomes. Such personalized approaches not only optimize recovery but also enhance patient adherence to rehabilitation protocols, thereby fostering a more sustainable recovery trajectory [48, 20].

The design of personalized pulmonary rehabilitation plans is essential for addressing the unique needs of each post-COVID-19 patient. Given the heterogeneity of symptoms and functional impairments associated with long COVID, rehabilitation strategies must be tailored to individual patient profiles, including their medical history, severity of symptoms, and personal recovery goals [49, 48]. A comprehensive assessment should be conducted at the outset, evaluating respiratory function, exercise capacity, and psychological well-being. This assessment informs the development of a customized rehabilitation plan that incorporates specific exercises, frequency, and intensity levels appropriate for the patient's condition [20, 48]. Furthermore, ongoing monitoring and adjustment of the rehabilitation program are vital to ensure that it remains effective and responsive to the patient's evolving needs. Incorporating multidisciplinary teams, including physiotherapists, respiratory therapists, and psychologists, can enhance the rehabilitation experience by providing holistic care that addresses both physical and mental health challenges [50, 47]. Ultimately, personalized rehabilitation plans not only facilitate better recovery outcomes but also empower patients to take an active role in their rehabilitation journey, fostering greater engagement and motivation throughout the recovery process.

3.3.2. Neurocognitive Rehabilitation

Cognitive training has emerged as a pivotal component in the neurocognitive rehabilitation of patients recovering from COVID-19, particularly those experiencing post-acute sequelae. Cognitive deficits, commonly referred to as "brain fog," have been reported in a significant proportion of COVID-19 survivors, manifesting as impairments in attention, memory, and executive function [55, 56]. The implementation of structured cognitive training programs can enhance neuroplasticity and facilitate recovery of cognitive functions. Techniques such as memory exercises, attention tasks, and executive function challenges are designed to stimulate neural pathways and promote cognitive resilience. For instance, a study highlighted the effectiveness of a multidisciplinary rehabilitation program that included cognitive training, which resulted in substantial improvements in memory recall and verbal fluency among participants [56]. Moreover, the integration of technology, such as computer-based cognitive training platforms, has shown promise in engaging patients and providing personalized rehabilitation experiences. These interventions not only target cognitive deficits but also aim to improve overall quality of life by enabling patients to regain independence in daily activities

and social interactions.

Psychological support and behavioral interventions are essential in addressing the mental health challenges faced by individuals recovering from COVID-19. Many survivors report heightened levels of anxiety, depression, and emotional distress, which can exacerbate cognitive impairments and hinder rehabilitation efforts [57, 58]. A comprehensive approach that includes psychological counseling, group therapy, and behavioral modification strategies has been shown to alleviate these symptoms and enhance coping mechanisms. For example, cognitive-behavioral therapy (CBT) has been effectively utilized to help patients reframe negative thought patterns and develop adaptive coping strategies, thereby improving their psychological well-being [57]. Additionally, the incorporation of mindfulness and stress-reduction techniques can further support mental health recovery. These interventions not only provide emotional support but also foster a sense of community and belonging among patients, which is crucial for their overall rehabilitation journey. By addressing both cognitive and emotional dimensions, psychological support and behavioral interventions play a vital role in facilitating a holistic recovery process for COVID-19 survivors.

The COVID-19 pandemic has accelerated the adoption of remote cognitive rehabilitation and virtual reality (VR)-assisted therapy as innovative approaches to neurocognitive rehabilitation. With the restrictions imposed by the pandemic, many rehabilitation services transitioned to online platforms, allowing patients to engage in cognitive training from the safety of their homes [59, 60]. Remote cognitive rehabilitation programs have demonstrated efficacy in improving cognitive functions such as attention, memory, and executive skills, while also providing flexibility and accessibility for patients [60]. Furthermore, VR-assisted therapy offers immersive experiences that can enhance engagement and motivation during rehabilitation sessions. By simulating real-world scenarios, VR can help patients practice cognitive skills in a controlled environment, facilitating the transfer of learned skills to daily activities. Studies have shown that VR interventions can lead to significant improvements in cognitive performance and quality of life for individuals with post-COVID cognitive impairments [60]. As these technologies continue to evolve, they hold the potential to revolutionize neurocognitive rehabilitation, making it more accessible and effective for a broader range of patients.

3.3.3. Cardiovascular Rehabilitation Programs

The management of cardiovascular risks in patients recovering from COVID-19 is critical, given the observed increase in cardiovascular complications associated with the virus. Studies have established that individuals who have survived COVID-19 are at a heightened risk for various cardiovascular events, including myocardial infarction, heart failure, and arrhythmias, which necessitates the implementation of structured cardiovascular rehabilitation programs. These programs typically encompass a combination of risk factor modification, functional training, and lifestyle interventions aimed at improving overall cardiovascular health. For instance, a nationwide cohort study demonstrated that survivors of COVID-19 who engaged in exercise-based cardiac rehabilitation experienced significantly lower risks of adverse cardiovascular outcomes compared to those who did not participate in such programs [61]. Functional training, including aerobic and resistance exercises, has been shown to enhance exercise capacity and quality of life in this population, thereby addressing both physical deconditioning and psychological distress often seen post-infection [53]. Furthermore, the integration of risk management strategies, such as monitoring blood pressure, cholesterol levels, and promoting smoking cessation, is vital to mitigate the long-term cardiovascular sequelae associated with COVID-19 [62].

The autonomic nervous system (ANS) plays a pivotal role in cardiovascular health, particularly in the context of post-COVID-19 syndrome, where dysregulation of the ANS is frequently observed. Many COVID-19 survivors report symptoms such as fatigue, palpitations, and orthostatic intolerance, which are indicative of autonomic dysfunction [22]. Rehabilitation strategies aimed at autonomic regulation can significantly improve patient outcomes. Techniques such as controlled breathing exercises, biofeedback, and gradual reconditioning through physical activity can help restore autonomic balance and enhance cardiovascular responses during exertion. Moreover, fatigue management is essential in this population, as persistent fatigue can severely impair functional capacity and quality of life. A comprehensive rehabilitation program that includes cognitive behavioral therapy, education on energy conservation techniques, and tailored exercise regimens has been shown to alleviate fatigue and improve overall well-being in patients recovering from COVID-19 [63]. By addressing both the physical and psychological aspects of fatigue, these interventions can enhance the recovery trajectory for individuals suffering from long COVID.

The integration of traditional and innovative cardiovascular rehabilitation techniques is essential to optimize recovery outcomes for COVID-19 survivors. Traditional rehabilitation methods, such as supervised exercise training and education on lifestyle modifications, have long been established as effective in improving cardiovascular health. However, the COVID-19 pandemic has accelerated the adoption of innovative approaches, such as tele-rehabilitation and digital health interventions, which have proven to be effective in reaching patients who may have barriers to in-person rehabilitation [64]. For example, cardiac telerehabilitation has been shown to maintain the core components of rehabilitation, including exercise training and patient education, while ensuring safety during the pandemic [65]. Additionally, novel strategies, such as the use of wearable technology to monitor heart rate variability and physical activity levels, can provide real-time feedback to patients and healthcare providers, enhancing adherence to rehabilitation protocols [66].

By combining these traditional and innovative techniques, rehabilitation programs can be tailored to meet the unique needs of each patient, ultimately improving cardiovascular outcomes and quality of life for those recovering from COVID-19.

3.3.4. Psychological Health Interventions

The COVID-19 pandemic has had profound effects on mental health, particularly among individuals who have recovered from the virus. Psychological interventions targeting conditions such as depression, anxiety, and post-traumatic stress disorder (PTSD) are crucial in addressing the mental health sequelae of COVID-19. Studies have shown that a significant proportion of COVID-19 survivors experience mental health issues, with one study indicating that 71.8% of respondents reported poor mental health after recovery [26]. Effective psychological treatment strategies include cognitive-behavioral therapy (CBT), mindfulness-based interventions, and telehealth services, which have gained prominence during the pandemic. These approaches not only help mitigate symptoms but also foster resilience among patients, enabling them to cope better with the psychological aftermath of the pandemic. Furthermore, addressing mental health issues through targeted interventions is essential in preventing the long-term effects of COVID-19 on mental health, as untreated psychological distress can lead to chronic conditions and diminished quality of life [67].

The establishment of multidisciplinary psychological support teams is vital in providing comprehensive care for COVID-19 survivors. These teams typically consist of psychologists, psychiatrists, social workers, and other mental health professionals who collaborate to address the diverse needs of individuals recovering from COVID-19. The integration of various specialties allows for a holistic approach to treatment, ensuring that both physical and psychological health are prioritized. Evidence suggests that such collaborative models can enhance the effectiveness of mental health interventions, leading to improved outcomes for patients [68]. Additionally, these teams can facilitate the identification of at-risk individuals, particularly those with pre-existing mental health conditions or those who experienced severe illness during COVID-19, thus enabling timely interventions that can significantly alter the trajectory of recovery [30].

Psychological interventions not only address mental health issues but also promote physical recovery among COVID-19 survivors. Research indicates that individuals who receive psychological support during their recovery process experience better physical health outcomes, including improved functional capacity and lower rates of fatigue [69]. This connection between mental and physical health underscores the importance of integrated care models that address both aspects simultaneously. For instance, programs that combine physical rehabilitation with psychological support have shown promising results in enhancing overall recovery and quality of life for COVID-19 survivors [70]. As the long-term effects of COVID-19 continue to emerge, it is imperative that healthcare systems prioritize the development and implementation of comprehensive psychological health interventions that not only address immediate mental health needs but also contribute to the overall rehabilitation of individuals affected by the virus.

3.3.5. Multidisciplinary Team Collaboration and Rehabilitation Pathways

The integration of healthcare, rehabilitation, psychological, and social support into a cohesive multidisciplinary team approach is vital for addressing the complex needs of COVID-19 survivors experiencing long-term sequelae. Evidence indicates that the sequelae of COVID-19 are multifaceted, affecting various systems such as respiratory, cardiovascular, neurological, and psychological health [34, 39]. A comprehensive rehabilitation strategy should therefore encompass not only physical rehabilitation but also psychological support and social reintegration. For instance, a study highlighted that patients engaged in multidisciplinary rehabilitation programs exhibited significant improvements in both physical and mental health outcomes, demonstrating the effectiveness of such an integrated approach [34]. This underscores the necessity for healthcare systems to adopt a holistic view of recovery, ensuring that all aspects of a patient's health and well-being are addressed.

The case management model, which emphasizes cross-departmental collaboration, is essential in the rehabilitation of COVID-19 patients. This model facilitates the coordination of care among various specialists, including physiotherapists, psychologists, nutritionists, and occupational therapists, to create a personalized rehabilitation plan tailored to each patient's unique needs [71, 72]. Effective communication and collaboration within the multidisciplinary team are crucial for ensuring continuity of care, particularly in managing the diverse and evolving symptoms associated with long COVID. For example, a structured follow-up program that incorporates regular assessments and adjustments to the rehabilitation plan can significantly enhance patient outcomes and quality of life [73, 74]. The integration of telemedicine and digital health technologies can further support this model by facilitating remote consultations and ongoing monitoring, thereby improving accessibility and adherence to rehabilitation protocols [39]. Figure 6 Multidisciplinary team collaboration and tiered rehabilitation pathways for addressing respiratory, cardiovascular, neurological, and psychological sequelae of COVID-19, integrating case management and digital health support.

Optimizing rehabilitation pathways and resource allocation is a critical component of managing the long-term effects of COVID-19. Rehabilitation programs must be designed to be flexible and responsive to the changing needs of patients as they progress through their recovery journey [75, 72]. This may involve the development of tiered rehabilitation pathways that cater to different levels of severity and

types of sequelae, ensuring that patients receive the appropriate level of care at each stage of their recovery. Additionally, resource allocation must consider the potential for increased demand on healthcare services due to the long-term impact of COVID-19, necessitating strategic planning and investment in rehabilitation services [73, 74]. By prioritizing multidisciplinary collaboration and optimizing rehabilitation pathways, healthcare systems can effectively address the complex challenges posed by post-COVID-19 sequelae and improve the overall recovery experience for patients.

Figure 6. *Multidisciplinary team collaboration and tiered rehabilitation pathways for post-COVID-19 sequelae. Created with BioRender.com.*

3.3.6. Innovative Technologies and Future Directions

The application of innovative technologies in rehabilitation strategies for COVID-19 survivors is rapidly evolving, particularly with the integration of robotic-assisted rehabilitation and virtual reality (VR) technologies. Robotic-assisted rehabilitation has shown promise in enhancing motor recovery and functional independence in patients suffering from long COVID symptoms, such as fatigue and mobility impairments. These robotic systems provide tailored exercises that adapt to the patient's progress, ensuring a personalized rehabilitation experience. Studies have indicated that robotic devices can facilitate repetitive task training, which is crucial for neuroplasticity and recovery of motor functions post-COVID-19 [76]. Concurrently, virtual reality technologies are being explored as effective tools for cognitive rehabilitation and psychological support. VR can simulate real-world environments, allowing patients to engage in therapeutic exercises that improve cognitive function, reduce anxiety, and enhance overall quality of life. A case study demonstrated that VR interventions significantly reduced symptoms of post-traumatic stress disorder (PTSD) and anxiety in a patient recovering from COVID-19-related intensive care treatment [76]. As these technologies continue to develop, they present a unique opportunity to address the multifaceted challenges posed by long COVID, thereby improving patient outcomes and enhancing the rehabilitation process.

The development of remote rehabilitation platforms and digital health tools is another significant trend in the management of long COVID. Telehealth services have gained traction during the pandemic, allowing for continuous monitoring and support of patients from the comfort of their homes. This is particularly beneficial for individuals who may have difficulty accessing traditional rehabilitation services due to mobility issues or geographical barriers. Remote rehabilitation platforms facilitate virtual consultations, enabling healthcare providers to assess patients' progress and adjust treatment plans accordingly. Moreover, the integration of wearable devices for real-time health monitoring has transformed patient engagement in their recovery journey. These devices can track vital signs, physical activity levels, and even mental health metrics, providing valuable data that can inform clinical decisions and enhance personalized care [77]. The trend towards digital health solutions is expected to continue, with ongoing research focusing on optimizing these technologies to improve adherence to rehabilitation protocols and overall patient satisfaction.

Looking ahead, future research priorities must focus on addressing the challenges associated with the widespread adoption of innovative rehabilitation technologies. Key areas of investigation include the efficacy and safety of robotic and VR interventions in diverse patient populations, particularly among those with varying degrees of severity in long COVID symptoms. Additionally, understanding the long-term impacts of remote rehabilitation on functional recovery and quality of life will be crucial. There is also a pressing need to explore the integration of these technologies within existing healthcare frameworks, ensuring that they are accessible and equitable for all patients. Furthermore, addressing the barriers to technology adoption, such as digital literacy and access to devices, will be essential in maximizing the benefits of these innovations [78]. As we move forward, a collaborative approach involving healthcare professionals, technology developers, and patients will be vital in shaping effective rehabilitation strategies that meet the needs of COVID-19 survivors.

3.4. Rehabilitation Effects and Differences Revealed by Multicenter Study Data

3.4.1. Differences in Rehabilitation Between Severe and Non-Severe Patients

The rehabilitation journey for COVID-19 patients varies significantly based on the severity of their illness, particularly distinguishing between those who required intensive care unit (ICU) treatment and those who did not. ICU patients often experience more profound functional impairments due

to prolonged mechanical ventilation and critical illness myopathy, which can lead to a range of complications including muscle weakness and cognitive dysfunction [79]. Studies indicate that ICU survivors frequently exhibit a slower recovery trajectory, characterized by persistent fatigue, dyspnea, and reduced exercise capacity. For instance, a study revealed that ICU patients had significantly lower scores in functional assessments compared to non-ICU patients, highlighting the impact of critical illness on physical capabilities [80]. Conversely, non-ICU patients may experience a less severe decline in functional status, allowing for a more rapid rehabilitation process. However, it is essential to note that even non-ICU patients can exhibit lingering symptoms such as fatigue and cognitive impairments, suggesting that rehabilitation strategies must be tailored to address the specific needs of both groups [81]. Furthermore, the psychological impact of severe illness, including anxiety and depression, is prevalent among ICU patients, necessitating a comprehensive approach to rehabilitation that encompasses both physical and mental health support [82]. The integration of multidisciplinary rehabilitation programs is crucial to optimize recovery outcomes for both ICU and non-ICU patients, emphasizing the importance of individualized care plans that consider the unique challenges faced by each patient cohort. The rehabilitation journey for COVID-19 patients varies significantly based on disease severity, necessitating tailored approaches for ICU and non-ICU survivors. Figure 7.

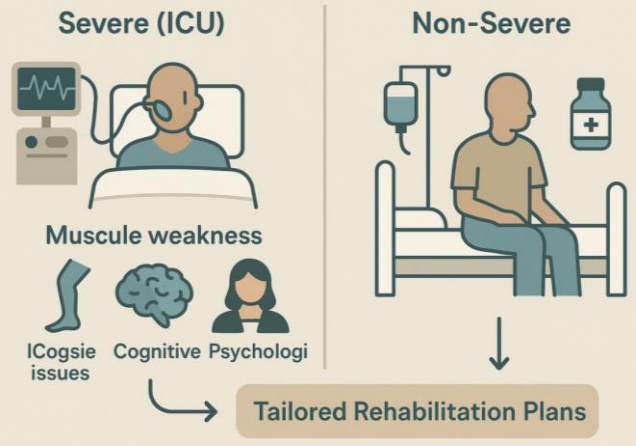

Figure 7. *Rehabilitation pathways tailored for severe (ICU) versus non-severe COVID-19 patients. Created with BioRender.com.*

The severity of COVID-19 not only influences the immediate clinical outcomes but also significantly affects the long-term rehabilitation needs of patients. Patients who experienced severe disease often require more intensive rehabilitation services due to the extensive physical and psychological sequelae associated with their illness [80]. For instance, individuals recovering from severe COVID-19 frequently report persistent respiratory issues, decreased exercise tolerance, and cognitive deficits, which can complicate their rehabilitation process [80, 81]. In contrast, patients with mild to moderate COVID-19 may experience fewer complications and, thus, have different rehabilitation requirements that can often be addressed through less intensive interventions [79]. A systematic review highlighted that severe COVID-19 patients are at a heightened risk for long-term complications, including chronic respiratory impairment and cardiovascular issues, which necessitates a more structured and prolonged rehabilitation approach [79]. Furthermore, the psychological burden, including increased rates of anxiety and depression among severe cases, underscores the necessity for integrated mental health support within rehabilitation programs [82]. Therefore, understanding the impact of disease severity on rehabilitation needs is vital for developing effective recovery strategies, ensuring that both physical and mental health aspects are adequately addressed to facilitate optimal recovery outcomes for all COVID-19 survivors.

3.4.2. Utilization Rates and Outcomes of Rehabilitation Across Different Populations

The utilization of rehabilitation services among individuals recovering from COVID-19 is influenced by a complex interplay of demographic factors such as race, age, gender, and the presence of comorbidities. Figure 2. Demographic factors influencing COVID-19 rehabilitation service utilization rates.

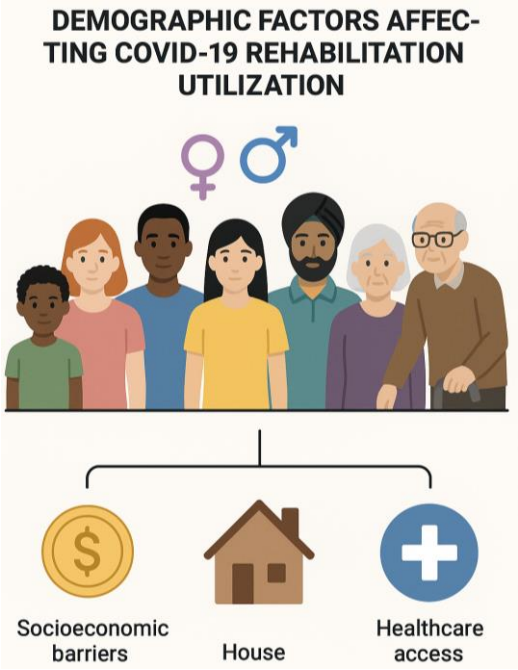

Figure 8. *Depicting demographic disparities in COVID-19 rehabilitation service utilization across different populations. Created with BioRender.com.*

This illustration demonstrates the impact of multiple factors including age, gender, race, comorbidities, and socioec-

onomic status on access to COVID-19 rehabilitation services. The figure 8 shows higher utilization rates among older adults and female patients, while minority populations and low-income groups face significant access barriers.

Research indicates that certain groups, particularly older adults and those with pre-existing health conditions, are more likely to require and utilize rehabilitation services following COVID-19 infection. For instance, a study in Quebec found that older individuals, particularly those aged 55 and above, demonstrated a higher likelihood of accessing rehabilitation services, with factors such as hospitalization and the presence of comorbidities significantly influencing this trend [83]. Additionally, gender disparities have been observed, with females more likely to seek rehabilitation services compared to their male counterparts, potentially due to differences in health-seeking behavior and the prevalence of specific symptoms associated with long COVID [84]. Racial and ethnic disparities also play a critical role, as marginalized communities often face barriers to accessing healthcare, including rehabilitation services, which can exacerbate health inequalities. For example, Black and Hispanic populations have reported higher rates of severe COVID-19 outcomes and may experience additional challenges in accessing necessary rehabilitation due to socioeconomic factors [85]. Overall, these demographic factors significantly impact the rates of rehabilitation service utilization and highlight the need for targeted interventions to ensure equitable access to care for all individuals recovering from COVID-19.

Socioeconomic status (SES) is a critical determinant of health outcomes and significantly influences the accessibility and utilization of rehabilitation services for individuals recovering from COVID-19. Lower SES is often associated with barriers such as limited access to healthcare facilities, financial constraints, and inadequate health insurance coverage, which can hinder individuals from seeking necessary rehabilitation services [86]. For example, individuals from lower-income backgrounds may lack the resources to afford transportation to rehabilitation centers or may be unable to take time off work to attend therapy sessions, resulting in decreased utilization of available services [83]. Furthermore, the COVID-19 pandemic has exacerbated existing disparities, with many low-income individuals experiencing heightened vulnerability to both the virus and its long-term effects, leading to increased demand for rehabilitation services that they may be unable to access [87]. Studies have shown that individuals with lower SES report higher levels of long COVID symptoms and functional impairments, which further underscores the importance of addressing these socioeconomic barriers in rehabilitation planning [84]. To improve accessibility, healthcare systems must implement strategies that consider the unique challenges faced by low-income populations, such as offering telehealth options, providing transportation assistance, and ensuring that rehabilitation services are culturally and linguistically appropriate. By addressing these socioeconomic factors, healthcare providers can enhance the accessibility of rehabilitation services and improve outcomes for individuals recovering from COVID-19.

3.4.3. Efficacy Assessment of Multidisciplinary Rehabilitation Interventions

As illustrated in Figure 9, multidisciplinary rehabilitation interventions demonstrate efficacy across multiple domains...

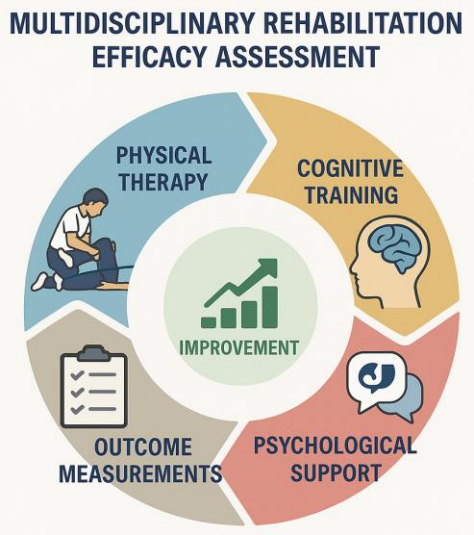

Figure 9. *Depicting the efficacy assessment framework of multidisciplinary rehabilitation interventions for COVID-19 patients. Created with BioRender.com.*

The assessment of the efficacy of multidisciplinary rehabilitation interventions for patients suffering from long COVID has become increasingly important as the pandemic continues to impact global health. A significant body of evidence suggests that these interventions can lead to improvements in various functional domains, including exercise capacity, pulmonary function, and cognitive abilities. For instance, a systematic review indicated that pulmonary rehabilitation programs significantly improve dyspnea, exercise tolerance, and overall quality of life among individuals with post-COVID-19 symptoms, particularly those who were hospitalized during their acute illness [88]. Furthermore, a randomized clinical trial demonstrated that an eight-week cardiopulmonary rehabilitation program notably enhanced cardiorespiratory fitness ($V\dot{O}2max$) in long COVID patients, alongside improvements in functional capacity and perceived stress levels [50]. These findings underscore the potential of structured rehabilitation programs to facilitate recovery in patients experiencing persistent symptoms after COVID-19.

In addition to physical rehabilitation, cognitive rehabilitation has emerged as a critical component of comprehensive care for long COVID patients. Studies have reported that neuropsychological interventions, when integrated into rehabilitation programs, can lead to significant improvements in

cognitive function, particularly in areas such as attention, memory, and executive function [56]. For example, a cohort study revealed that patients who received tailored neuropsychological treatment alongside standard rehabilitation exhibited marked improvements in cognitive assessments, with a substantial proportion achieving normalized cognitive function by discharge [56]. This highlights the necessity of addressing cognitive impairments in the context of long COVID, as these issues can severely impact daily functioning and quality of life.

The psychological health of long COVID patients is another critical aspect that multidisciplinary rehabilitation aims to address. Evidence suggests that individuals recovering from COVID-19 frequently experience anxiety, depression, and fatigue, which can hinder their rehabilitation progress [89]. A study focusing on outpatient rehabilitation for post-COVID sequelae found that a significant percentage of patients reported severe anxiety and depression, which correlated with lower health-related quality of life scores [90]. Multidisciplinary teams, including mental health professionals, can provide essential support to help patients cope with these psychological challenges, thereby enhancing their overall recovery process.

Long-term follow-up studies have also demonstrated that patients who engage in multidisciplinary rehabilitation experience sustained improvements in functional independence and quality of life. For instance, a systematic review of older adults undergoing rehabilitation after COVID-19 showed significant enhancements in functional ability and a high rate of discharge to home settings following multidisciplinary interventions [91]. These findings underscore the importance of ongoing assessment and tailored rehabilitation strategies to ensure that patients continue to make progress in their recovery journey.

In conclusion, the efficacy assessment of multidisciplinary rehabilitation interventions for long COVID patients reveals promising outcomes across multiple domains, including physical, cognitive, and psychological health. The integration of diverse therapeutic approaches within a cohesive rehabilitation framework is essential for addressing the complex and multifaceted challenges posed by long COVID. As the understanding of long COVID evolves, continued research and adaptation of rehabilitation strategies will be crucial in optimizing recovery and enhancing the quality of life for affected individuals.

3.5. Challenges in Continuous Symptom Management and Rehabilitation

3.5.1. Symptom Heterogeneity and Individualized Needs

The phenomenon of long COVID presents a complex tapestry of symptoms that vary widely among individuals, necessitating a nuanced approach to rehabilitation strategies. The heterogeneity of symptoms associated with long COVID—ranging from chronic fatigue and respiratory issues to cognitive impairments—demands that rehabilitation programs be tailored to meet the unique needs of each patient. Studies have highlighted that the prevalence of long COVID symptoms can reach as high as 38%, with common manifestations including dyspnoea, mental health challenges, fatigue, and effort intolerance [92]. This diversity in symptomatology underscores the importance of personalized rehabilitation plans that account for the specific clinical profiles of patients. For instance, individuals experiencing chronic fatigue syndrome may require different therapeutic interventions compared to those with cognitive dysfunction or respiratory difficulties. Furthermore, the identification of symptom clusters—such as neurocognitive, psychosocial, and inflammatory symptoms—can guide healthcare providers in developing targeted rehabilitation strategies that address the multifaceted nature of long COVID [93]. The complexity of managing these symptoms is compounded by the fluctuating nature of long COVID, where patients may experience periods of exacerbation and remission, making it critical for rehabilitation plans to remain flexible and responsive to the evolving health status of the patient.

Additionally, the management of complex symptoms like chronic fatigue syndrome poses significant challenges. Chronic fatigue is not merely a symptom but a debilitating condition that can severely impact quality of life and functional capacity. The interplay of physical, psychological, and social factors in chronic fatigue necessitates a multidisciplinary approach to rehabilitation that includes physical therapy, psychological support, and lifestyle modifications [94]. Effective management strategies may involve cognitive-behavioral therapy to address the psychological aspects of fatigue and tailored exercise programs to enhance physical endurance without exacerbating symptoms. The individualization of rehabilitation protocols is further supported by findings that highlight the role of pre-existing health conditions, such as obesity and chronic diseases, in predicting long COVID outcomes and symptom severity [95]. Thus, a comprehensive assessment of each patient's medical history, current health status, and personal goals is essential for creating effective rehabilitation strategies that not only alleviate symptoms but also empower patients to reclaim their lives post-COVID-19.

In conclusion, the heterogeneity of long COVID symptoms necessitates a shift towards individualized rehabilitation strategies that are adaptable to the unique experiences of each patient. By recognizing the complexity of symptoms and the need for personalized interventions, healthcare providers can better support patients in their recovery journey, ultimately improving their quality of life and functional outcomes. Future research should continue to explore the diverse manifestations of long COVID and the most effective rehabilitation approaches to address these challenges, ensuring that all patients receive the tailored care they need to

recover fully.

3.5.2. Resource Limitations and Inequities in Rehabilitation Services

The accessibility of rehabilitation services for individuals suffering from post-acute sequelae of COVID-19 (PASC) varies significantly across different regions and populations, highlighting a critical issue of healthcare inequity. In many areas, particularly rural and underserved urban settings, access to specialized rehabilitation services is limited due to a lack of resources, including trained personnel and facilities equipped to handle the complex needs of post-COVID patients. For instance, studies have shown that patients from lower socioeconomic backgrounds or those living in remote areas are less likely to receive timely and adequate rehabilitation care, exacerbating existing health disparities [96]. Furthermore, the COVID-19 pandemic has intensified these inequities, as healthcare systems have been overwhelmed, leading to a diversion of resources away from rehabilitation services that are essential for recovery from long-term COVID symptoms. This situation is compounded by the fact that many individuals with PASC experience a range of debilitating symptoms, including fatigue, cognitive impairment, and respiratory issues, which require multidisciplinary rehabilitation approaches that are often unavailable in resource-limited settings [97]. As a result, there is an urgent need for policy interventions that prioritize equitable access to rehabilitation services, ensuring that all patients, regardless of their geographic or socioeconomic status, can receive the care they need to recover from the long-term effects of COVID-19.

In addition to geographic disparities, the promotion of remote rehabilitation technologies has encountered various technical and policy-related barriers that hinder their widespread adoption. Telehealth and digital rehabilitation solutions have emerged as promising alternatives to traditional in-person rehabilitation, especially during the COVID-19 pandemic when physical distancing measures were necessary [98]. However, the effectiveness of these technologies is often limited by several factors, including inadequate internet access in rural areas, lack of digital literacy among patients, and varying levels of acceptance among healthcare providers [99]. Moreover, regulatory and reimbursement policies have not always kept pace with the rapid expansion of telehealth services, creating additional hurdles for both patients and providers [100]. For instance, while some regions have successfully integrated tele-rehabilitation into their healthcare systems, others have struggled due to a lack of clear guidelines and support for implementing these technologies effectively. This inconsistency not only affects the quality of care provided but also reinforces existing disparities in access to rehabilitation services [101]. To address these challenges, it is essential for policymakers to develop comprehensive strategies that enhance the infrastructure for telehealth, provide training for both patients and providers, and ensure equitable reimbursement for remote rehabilitation services. By doing so, we can create a more inclusive healthcare environment that meets the diverse needs of individuals recovering from COVID-19 and other chronic conditions.

3.5.3. Coordination Issues in Multidisciplinary Team Collaboration

As depicted in Figure 10, the coordination challenges in multidisciplinary teams require systematic approaches to address communication barriers and role clarification.

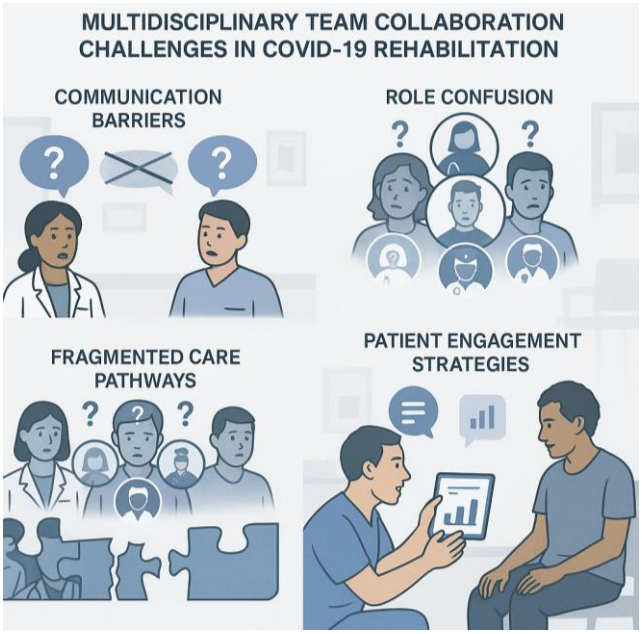

Figure 10. *Coordination challenges and solutions in multidisciplinary team collaboration for COVID-19 rehabilitation. Created with BioRender.com.*

The coordination of multidisciplinary teams (MDTs) in the context of post-COVID-19 rehabilitation presents significant challenges, particularly in terms of interdisciplinary communication barriers and unclear role definitions. Effective collaboration among healthcare professionals from diverse specialties is essential for providing comprehensive care to patients recovering from COVID-19 sequelae. However, the complexity of the clinical picture often leads to misunderstandings and misalignments in treatment approaches. For instance, healthcare providers may have varying interpretations of patient needs based on their professional backgrounds, which can result in fragmented care delivery. Moreover, the absence of a clearly defined role for each team member can exacerbate these issues, leading to inefficiencies and potential gaps in patient management. The literature highlights that the successful implementation of MDTs requires not only a common understanding of patient care goals but also the establishment of clear communication channels and protocols. This is particularly crucial in the

context of post-COVID-19 care, where patients often present with multifaceted symptoms affecting multiple organ systems, necessitating input from various specialists [102, 103]. Additionally, the integration of telemedicine during the pandemic has introduced new dynamics into team collaboration, with virtual meetings becoming the norm. While this has improved accessibility, it has also posed challenges in maintaining effective communication and rapport among team members, which are vital for cohesive teamwork [104]. Therefore, addressing these coordination issues through structured communication strategies and role clarification is essential for enhancing the efficacy of MDTs in managing post-COVID-19 rehabilitation.

Promoting patient adherence and sustained engagement in multidisciplinary rehabilitation programs is another critical aspect that requires strategic intervention. Patients recovering from COVID-19 often experience a range of persistent symptoms that can significantly impact their motivation and ability to participate in rehabilitation activities. To enhance patient compliance, it is essential to implement tailored strategies that address individual patient needs and preferences. Evidence suggests that involving patients in the decision-making process regarding their care can lead to improved adherence, as it fosters a sense of ownership and accountability [34]. Additionally, establishing regular follow-up appointments and utilizing digital health technologies such as telehealth can facilitate ongoing engagement and support for patients, making it easier for them to access care and resources. The use of patient education initiatives to inform individuals about the importance of rehabilitation and the potential benefits of participation can also play a pivotal role in enhancing adherence rates. Furthermore, addressing potential barriers to participation, such as transportation issues or psychological distress, through community support programs can help mitigate challenges that patients may face in their recovery journey [39]. Ultimately, a multifaceted approach that combines patient-centered care, continuous support, and adaptive strategies is necessary to promote sustained engagement in rehabilitation programs, thereby improving outcomes for individuals experiencing post-COVID-19 sequelae.

3.6. Future Prospects and Research Directions

3.6.1. Development of Standardized Rehabilitation Assessment and Intervention Guidelines

As illustrated in Figure 11, the development of standardized rehabilitation guidelines requires a comprehensive framework that integrates multiple assessment and intervention components.

The establishment of standardized rehabilitation assessment and intervention guidelines is critical in addressing the diverse and complex sequelae of COVID-19. Given the multifaceted nature of post-COVID conditions, which can affect various organ systems and manifest as a range of symptoms, it is essential to develop unified assessment tools and rehabilitation pathways that can be universally applied across different healthcare settings. The COVID-19 Rehabilitation Needs Survey (C19-RehabNeS) exemplifies such an effort, combining established metrics like the 36-item Short Form Survey (SF-36) with newly developed questionnaires tailored to the unique needs of post-COVID patients [105]. This comprehensive approach facilitates the identification of functional limitations and rehabilitation needs, while also capturing patient satisfaction with health services, thereby providing a holistic view of recovery trajectories. Additionally, a systematic assessment model proposed by rehabilitation professionals emphasizes the necessity for a structured approach to monitor and manage long-term sequelae, which includes both in-person and telehealth components [106]. This model not only aids in early detection and intervention but also aligns with the urgent need for evidence-based practices that can adapt to the evolving understanding of COVID-19's impact on health.

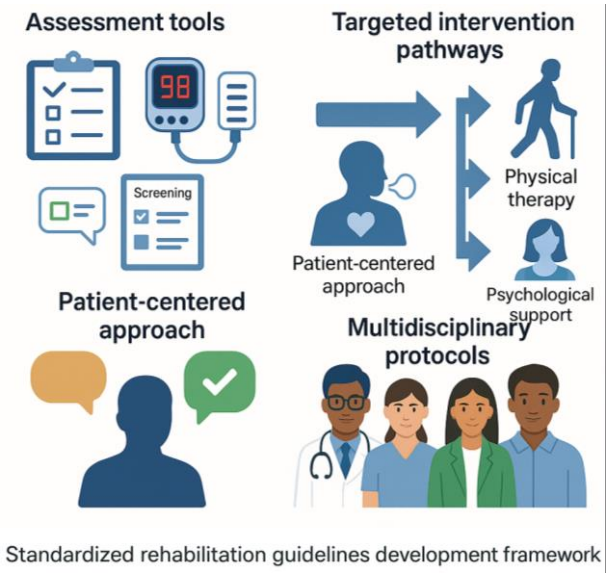

Figure 11. *Improved high-resolution BioRender-style framework for standardized COVID-19 rehabilitation guidelines. Created with BioRender.com.*

Furthermore, developing targeted rehabilitation programs for different types of sequelae is equally important. Research has shown that patients with long COVID often present with distinct symptoms that require tailored rehabilitation strategies, such as pulmonary rehabilitation for those experiencing respiratory difficulties or cognitive rehabilitation for individuals facing neuropsychological challenges [39]. For instance, a multidisciplinary rehabilitation program that incorporates physical training, education, and psychological support has demonstrated significant improvements in physical capacity and quality of life among long COVID patients [107]. This highlights the need for rehabilitation protocols

that are not only symptom-specific but also adaptable to the individual patient's context, including their pre-existing health conditions and the severity of their COVID-19 experience.

The creation of these guidelines must also consider the integration of patient perspectives, as they play a crucial role in shaping effective rehabilitation strategies. Engaging patients in the development of rehabilitation frameworks ensures that their experiences and preferences are reflected in the guidelines, enhancing adherence and outcomes [108]. Moreover, ongoing research into the long-term effects of COVID-19 is essential to refine these guidelines continually. As new data emerges regarding the prevalence and nature of post-COVID sequelae, rehabilitation strategies must evolve to address these findings effectively, ensuring that healthcare providers are equipped to deliver comprehensive and personalized care to COVID-19 survivors.

In conclusion, the establishment of standardized rehabilitation assessment and intervention guidelines is paramount in the effective management of post-COVID sequelae. By integrating comprehensive assessment tools, developing targeted rehabilitation programs, and incorporating patient insights, healthcare systems can enhance recovery outcomes for individuals affected by COVID-19. This multifaceted approach not only addresses the immediate rehabilitation needs but also lays the groundwork for long-term health strategies that are responsive to the complexities of post-COVID conditions.

3.6.2. Long-term Follow-up and Data Sharing Platform Development

Multicenter long-term follow-up studies are critical in understanding the sequelae of COVID-19, particularly as the pandemic has unveiled a spectrum of post-viral complications that can persist long after the acute phase of the illness. These studies allow for the collection of diverse patient data across different demographics and geographical locations, enhancing the generalizability of findings. For instance, a study that followed hospitalized COVID-19 patients for up to 48 weeks reported that a significant proportion continued to experience symptoms such as fatigue and dyspnea, highlighting the long-term impact of the virus on health-related quality of life [109]. Furthermore, multicenter studies facilitate the identification of risk factors associated with long-term outcomes, as demonstrated in a cohort study that revealed higher mortality rates among septic patients with COVID-19 compared to those without, emphasizing the need for tailored follow-up care for this vulnerable population [110]. By pooling resources and expertise, these studies can also address the challenges of data variability and patient heterogeneity, ultimately leading to more robust conclusions regarding the long-term effects of COVID-19 and informing clinical practice guidelines.

The establishment of standardized data-sharing platforms is paramount for advancing scientific research and improving clinical practices in the context of long-term COVID-19 follow-up. Standardization ensures that data collected from various centers can be harmonized, allowing for effective comparisons and analyses across different studies. For example, a systematic review highlighted the need for standardized symptom assessments and follow-up protocols to better understand the long-term health impacts of COVID-19 [111]. Moreover, data-sharing initiatives can enhance collaboration among researchers, enabling them to pool data for larger-scale analyses that can yield more significant insights into the long-term consequences of COVID-19. This collaborative approach is exemplified by the International Severe Acute Respiratory and emerging Infection Consortium (ISARIC), which has developed standardized protocols for COVID-19 follow-up studies, facilitating global data collection and sharing [112]. Such initiatives not only promote scientific inquiry but also ensure that clinical practices are informed by the most comprehensive and up-to-date evidence, ultimately leading to improved patient outcomes and more effective rehabilitation strategies for those affected by long COVID.

3.6.3. Integration of Innovative Technologies

The integration of innovative technologies into healthcare, particularly in the context of COVID-19 rehabilitation, has emerged as a transformative approach to address the complexities of long COVID and its sequelae. Artificial intelligence (AI) has become a pivotal tool in enhancing diagnostic accuracy and personalizing rehabilitation strategies for patients suffering from post-acute sequelae of SARS-CoV-2 infection (PASC). AI-assisted diagnostic systems can analyze vast datasets to identify patterns and predict patient outcomes, thereby facilitating tailored rehabilitation plans that align with individual patient needs. For instance, AI algorithms can process clinical data, including symptoms, comorbidities, and demographic information, to stratify patients based on their risk profiles and recovery trajectories. This personalized approach not only optimizes resource allocation but also enhances patient engagement and adherence to rehabilitation protocols, which is crucial for effective recovery from long COVID [39]. Furthermore, the application of AI in telemedicine platforms has streamlined remote consultations, enabling healthcare providers to offer real-time support and monitoring for patients in their homes. This is particularly vital for individuals who may face barriers to accessing traditional healthcare settings, such as those in rural areas or those with mobility issues.

In addition to AI, the use of telemedicine and virtual reality (VR) technologies has shown immense potential in the rehabilitation of COVID-19 patients. Telemedicine has expanded access to healthcare services, allowing for remote assessments and interventions that mitigate the risks associated with in-person visits during the pandemic. For example, studies have demonstrated that telerehabilitation can effectively improve outcomes in patients with respiratory symp-

toms, such as dyspnea, by providing structured exercise programs and educational resources through digital platforms [113]. This model not only preserves continuity of care but also enhances patient safety by minimizing exposure to potential infections in healthcare settings. Moreover, VR technology offers immersive rehabilitation experiences that can engage patients in their recovery process. By simulating real-world environments, VR can help patients practice functional tasks and improve their physical and cognitive abilities in a controlled setting. This innovative approach has been particularly beneficial for addressing psychological sequelae associated with COVID-19, as it provides a safe space for patients to confront their anxieties and build resilience [76].

The convergence of these technologies—AI, telemedicine, and VR—creates a comprehensive framework for managing long COVID, emphasizing the importance of a multidisciplinary approach to rehabilitation. As healthcare systems continue to adapt to the challenges posed by the pandemic, the integration of these innovative technologies will be essential in shaping the future of rehabilitation services. It not only addresses immediate healthcare needs but also lays the groundwork for a more resilient and responsive healthcare infrastructure capable of managing the long-term consequences of COVID-19 and other emerging health crises. The ongoing research and development in this field will be critical in refining these technologies and ensuring their effective implementation in clinical practice, ultimately improving patient outcomes and quality of life for those affected by long COVID [77].

3.6.4. Health Equity and Policy Support

The COVID-19 pandemic has underscored the critical importance of health equity in public health policy and recovery strategies. Policymakers must prioritize the development of equitable rehabilitation services to ensure that all individuals, regardless of their socioeconomic status, have access to the care they need. This necessitates a comprehensive approach that includes the establishment of policies aimed at reducing barriers to accessing rehabilitation services, particularly for marginalized populations who have been disproportionately affected by the pandemic. For instance, the integration of health equity considerations into COVID-19 mitigation strategies has been shown to enhance community resilience and improve health outcomes. Evidence suggests that health inequities are exacerbated by structural determinants, such as income, education, and access to healthcare resources, which must be addressed through targeted policy interventions [114, 115]. Furthermore, the COVID-19 Health Disparities Grant, which allocated significant funding to health departments across the United States, illustrates the potential for policy-driven initiatives to enhance health equity and address the needs of underserved populations [116]. By fostering collaboration between public health officials, community organizations, and policymakers, we can create a more equitable healthcare system that prioritizes the needs of all individuals, especially those who have been historically marginalized.

In addition to equitable access to rehabilitation services, public health education plays a vital role in promoting health equity and enhancing recovery outcomes. Effective communication strategies are essential to raise awareness about the long-term effects of COVID-19 and the importance of rehabilitation. Public health campaigns should focus on educating individuals about the potential for long COVID and the available resources for recovery, thereby empowering communities to seek the care they need [117, 118]. Moreover, enhancing public awareness of health equity issues can foster a greater understanding of the social determinants of health and their impact on recovery, ultimately leading to more informed and engaged communities. The need for culturally competent health education is paramount, as it ensures that diverse populations receive information that is relevant and accessible to them. By employing community-based participatory research approaches, health educators can collaborate with community members to develop tailored educational interventions that address specific needs and barriers faced by different populations [119, 120]. This collaborative approach not only enhances the effectiveness of health education initiatives but also builds trust and rapport between health systems and communities, which is essential for promoting long-term health equity. As illustrated in Figure 12, achieving health equity in COVID-19 rehabilitation requires a comprehensive framework that integrates policy support, community education, and equitable access.

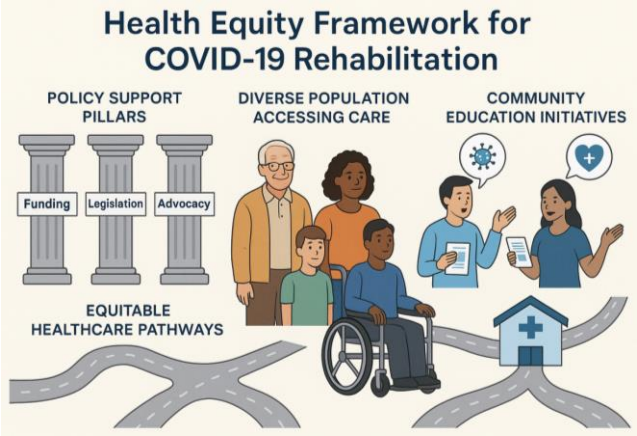

Figure 12. *Health equity and policy support framework for COVID-19 rehabilitation services. Created with BioRender.com.*

The integration of health equity into policy and public health education is not merely a response to the COVID-19 pandemic but a necessary step toward building a more resilient and equitable healthcare system for the future. As we navigate the ongoing challenges of the pandemic and its aftermath, it is imperative that policymakers and public health officials prioritize health equity in their planning and imple-

mentation efforts. This includes not only addressing immediate needs related to rehabilitation and recovery but also fostering a culture of health equity that permeates all aspects of public health practice. By doing so, we can ensure that all individuals have the opportunity to achieve optimal health outcomes, regardless of their background or circumstances, thereby creating a healthier and more equitable society for all [121, 122].

4. Conclusion

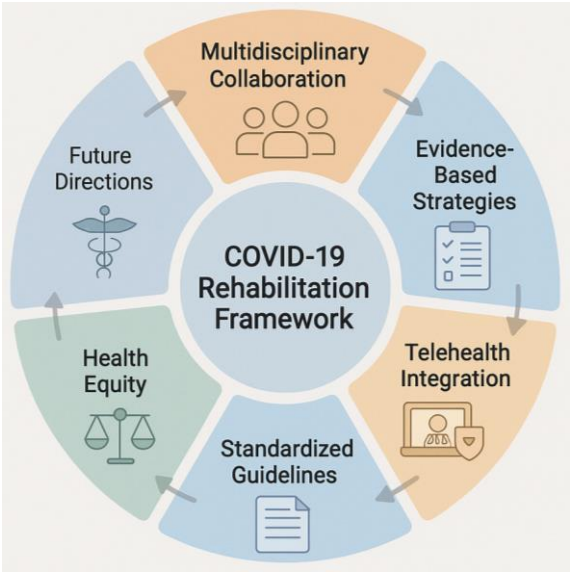

Figure 13. *Integrated approach to COVID-19 rehabilitation and future directions. Created with BioRender.com.*

The multifaceted nature of post-COVID-19 sequelae presents a significant challenge for healthcare systems worldwide. As we have explored throughout this review, the implications of COVID-19 extend far beyond the acute infection phase, affecting multiple organ systems and manifesting in a diverse array of symptoms. This complexity necessitates a comprehensive and nuanced approach to rehabilitation, one that acknowledges the varied needs of patients and the intricate interplay of physical, psychological, and social factors that influence recovery. Figure 13 presents the comprehensive framework for COVID-19 rehabilitation and future development directions. This diagram systematically summarizes the core findings of this review, emphasizing that COVID-19 sequelae rehabilitation requires a multi-dimensional, integrated approach. The core of the framework is a multidisciplinary collaborative model that integrates the synergistic cooperation of multi-professional teams including physicians, physiotherapists, occupational therapists, psychologists, and social workers. The figure demonstrates the coordinated interaction of four key elements: evidence-based rehabilitation strategies (best practices based on multicenter data), hybrid rehabilitation models (combining the advantages of in-person and telerehabilitation), standardized guideline development (ensuring care consistency and quality), and health equity assurance (eliminating disparities in rehabilitation service access). The outer arrows of the figure point to future development directions, including technology innovation integration, continuous research advancement, and policy support strengthening. This comprehensive framework reflects that the field of COVID-19 rehabilitation is rapidly evolving and requires coordinated efforts from all stakeholders to realize its full potential.

From an expert perspective, the development of effective rehabilitation strategies for post-COVID-19 patients hinges on the integration of multidisciplinary collaboration and systematic assessment. The involvement of various healthcare professionals—including physicians, physiotherapists, occupational therapists, psychologists, and social workers—is essential to address the diverse rehabilitation needs that arise from the syndrome. By fostering a collaborative environment, we can ensure that rehabilitation programs are tailored to individual patient profiles, thereby enhancing the overall efficacy of interventions.

Moreover, the combination of in-person and tele-rehabilitation modalities has emerged as a promising strategy to optimize resource utilization while ensuring accessibility for patients. The COVID-19 pandemic has accelerated the adoption of telehealth technologies, which can bridge geographical barriers and provide continuous support to patients in their recovery journey. This hybrid model not only maximizes the reach of rehabilitation services but also allows for ongoing monitoring and adjustment of treatment plans based on real-time patient feedback and progress.

The evidence-based rehabilitation strategies supported by multicenter data play a pivotal role in promoting functional recovery and improving the quality of life for post-COVID-19 patients. By harnessing data from diverse patient populations, we can identify best practices and refine therapeutic approaches that are most effective in addressing the unique challenges posed by long COVID. This evidence-based approach not only enhances clinical outcomes but also fosters a culture of continuous improvement within rehabilitation practices.

Looking ahead, there is a pressing need to strengthen the development of standardized guidelines that can serve as a framework for rehabilitation efforts across different settings. The establishment of clear protocols will facilitate consistency in care and ensure that all patients receive evidence-based interventions that are aligned with current best practices. Additionally, the integration of technological innovations—such as wearable devices and mobile health applications—into rehabilitation programs can enhance patient engagement and provide valuable data for ongoing research and quality improvement initiatives.

Equally important is the commitment to health equity in the rehabilitation of post-COVID-19 patients. As we advance in our understanding of the long-term effects of the virus, it

is crucial to ensure that all individuals, regardless of socio-economic status or access to healthcare resources, have equitable access to rehabilitation services. Addressing disparities in care will not only improve individual outcomes but also contribute to the broader goal of public health equity.

In conclusion, the landscape of post-COVID-19 rehabilitation is rapidly evolving, driven by the need for comprehensive, multidisciplinary approaches that address the complex and varied needs of patients. By fostering collaboration, leveraging evidence-based practices, and prioritizing health equity, we can pave the way for a more effective and inclusive rehabilitation framework. As we continue to navigate the challenges posed by long COVID, it is imperative that we remain committed to advancing research, refining clinical practices, and advocating for policies that support the ongoing development of this critical field. The future of post-COVID-19 rehabilitation holds promise, but it will require concerted efforts from all stakeholders to realize its full potential.

Abbreviations

AI	Artificial Intelligence
ANS	Autonomic Nervous System
ARDS	Acute Respiratory Distress Syndrome
C19-RehabNeS	COVID-19 Rehabilitation Needs Survey
C19-YRS	COVID-19 Yorkshire Rehabilitation Screen
CBT	Cognitive-Behavioral Therapy
CNS	Central Nervous System
CR	Cardiovascular Rehabilitation
CT	Computed Tomography
DLCO	Diffusion Capacity for Carbon Monoxide
FEV1	Forced Expiratory Volume in 1 Second
FVC	Forced Vital Capacity
HRQoL	Health-Related Quality of Life
ICU	Intensive Care Unit
ISARIC	International Severe Acute Respiratory and Emerging Infection Consortium
MDTs	Multidisciplinary Teams
MRI	Magnetic Resonance Imaging
PASC	Post-Acute Sequelae of SARS-CoV-2 Infection
PFTs	Pulmonary Function Tests
POTS	Postural Orthostatic Tachycardia Syndrome
PTSD	Post-Traumatic Stress Disorder
SES	Socioeconomic Status
SF-36	36-item Short Form Survey
VR	Virtual Reality

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Conflicts of Interest

The authors declare no conflicts of interest.

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