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Original Article

Home-Based Rehabilitation Post-COVID-19: A Review of Protocols, Clinical Outcomes, and Lessons Learned.

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Abstract: *The domain of rehabilitation has changed so much, even with the COVID-19 pandemic. Given the high rate of long-term physical, respiratory, and cognitive impairment after SARS-CoV-2 infection, home-based rehabilitation has proved to be an essential alternative to the often-limiting brick-and-mortar rehabilitation. The rationale for home-based rehabilitation in the post-COVID context is reviewed in this review, along with core clinical protocols including physical therapy, respiratory training, and cognitive rehabilitation. Further, such interventions are also explored in regard to their clinical effectiveness, where outpatient, functional outcomes, pulmonary recovery, and improvements in mental health and quality of life are considered. Digital health technologies (i.e., telemedicine, mobile applications, wearable sensors, AI-driven analytics) are identified as key technologies in enabling remote rehabilitation. Also, the review discusses present hurdles in patient selection, digital access disparity, adherence, and the regulatory framework. Based on the evidence presented in high-impact journals, the paper ends with lessons learned and future directions for holistically integrating home-based rehabilitation as a standard, permanent fixture of the post-acute care continuum.*

Keywords: *Cognitive Rehabilitation; COVID-19; Home-Based Rehabilitation; Long COVID; Physical Therapy; Post-Acute Care; Pulmonary Recovery; Telerehabilitation.*

I. INTRODUCTION

The SARS-CoV-2 virus spread across the globe quickly, not only causing a huge health crisis, but also having a gigantic strain on healthcare systems. Initially, the acute phase of COVID-19 received most of the attention because of its dramatic rate of hospitalisations, admissions to critical care, and mortality; however, the focus has now moved to address the impact on the long-term health of survivors. Now an increasing number of patients are experiencing the lingering symptoms weeks, even months, after they originally recovered from an acute infection. Collectively, these are known as Post-Acute Sequelae of SARS-CoV-2 infection (PASC) and more colloquially “long COVID”, characterised by a large variety of physical, cognitive, and psychological impairments.

The most commonly described complications include fatigue, dyspnea, reduced exercise tolerance, joint and muscle pain, and cognitive dysfunction. The limitations in some of these patients are significant enough to distort simple daily activities and to preclude employment. Interestingly, studies have shown that persons who didn’t have any serious symptoms during the acute phase can develop considerable impairments in lung and bodily functioning later [1]. Hence, the requirement for sound rehabilitation interventions has come to be an important consideration in post-pandemic healthcare planning. However, during a pandemic such as COVID-19, which was accompanied by lockdowns, social distancing mandates, and resource constraints, traditional models of rehabilitation involving in-person sessions in either hospital or outpatient settings were significantly disrupted. However, home-based rehabilitation was found as an alternative option to overcome these challenges, as in order to keep continuity of care, the risk of viral transmission was minimised. This model offers the patients the possibility of receiving necessary therapy at home, sometimes based on digital tools and telecommunication platforms. As pandemic-driven rapid deployment and adaptation of home-based rehabilitation protocols is paramount to examine their clinical efficacy, delivery model, technological enablers, and lessons learned to inform future healthcare policies. In this article, a framework of home-based rehabilitation in the post-COVID-19 context is provided through an analysis of its protocol, clinical outcomes, enabling technologies, and the challenges it faces. It also looks back on the main lessons learnt during its implementation and provides suggestions for future directions of rehabilitation delivery in a post-pandemic world.

II. RATIONALE FOR HOME-BASED REHABILITATION IN THE COVID-19 CONTEXT

The issues raised by the COVID-19 pandemic indeed exposed the vulnerabilities in traditional models of healthcare delivery systems, but in a more significant way with the delivery of rehabilitation services. At times of highest infection rates, many outpatient and inpatient rehabilitation units were either turned into emergency care positions or shut down completely at the request of minimising patient exposure and transmission risks. However, for COVID-19 patients recovering with diminished lung capacity, generalised weakness, and cognitive problems, access to timely rehabilitation meant constantly fighting against an increased likelihood of long-term disability. As such, facilities were often prevented from physical access by quarantine regulations and a public fear of contagion, along with transportation issues, access was constrained

In this context, home-based rehabilitation was a solution that could tolerate the clinical need as well as the restriction of access. However, in contrast to the conventional rehabilitation models, home-based approaches are more flexible and can be customized based on a patient's own health status, home environment, and the surrounding social support systems. Although in several cases, these programs built upon existing telehealth infrastructure to allow health professionals to remotely monitor patient progress, give real-time instructions, and modify the therapy according to 'real-time' assessments [2].

Evidence also suggests that rehabilitation interventions are most effective if they start early in the recovery process, and this is the rationale for this model. Early mobilisation and reconditioning decrease the chances of complications of muscle atrophy, venous thromboembolism, and hospital readmission. Immediate post-discharge therapy start-up following rehabilitation is possible by setting exercises for casting up under home-based rehabilitation that may maximise the window for neuroplasticity and physiological recovery [3].

In addition, therapy routines may be positively reinforced by having a certain environment to attend to, as the home may provide psychological comfort that, in turn, increases engagement and compliance with therapy routines. In addition, caregivers or family members are included in the rehabilitation process, allowing for additional social support, which is related to better outcomes in the management of chronic illness. Together with the scalability of digital tools, these advantages make a superior home-based rehabilitation model for the post-COVID era. For further detailing the operating and experiential discrepancies between conventional and home-based rehabilitation models vis-à-vis the post-COVID-19 recovery needs, the following table gives a summarised overview of the same.

Table 1 : Comparative Dimensions of Conventional vs. Home-Based Rehabilitation in Post-COVID Recovery

Dimension	Conventional Rehabilitation	Home-Based Rehabilitation
Location of Care	Hospital or outpatient rehabilitation facilities	Patient's home environment
Accessibility During the Pandemic	Frequently disrupted due to facility repurposing and lockdowns	Maintained continuity through remote and self-managed models
Start Time Post-Discharge	Often delayed due to referral backlog or logistical issues	Can begin immediately after discharge for faster recovery
Customization	Standardised programs with limited individual tailoring	Highly personalised based on patient status and home resources
Cost-Effectiveness	Higher due to facility use, staff overhead	Lower, with potential cost savings from reduced hospital visits
Involvement of Caregivers	Limited to visitor policies and scheduled visits	Facilitated involvement; caregivers can assist with exercises
Patient Comfort and Autonomy	Less familiar environment; less autonomy in scheduling	Familiar setting; greater control over rehabilitation routine
Technology Utilization	Minimal unless integrated in specialised centres	High use of mobile apps, wearables, and telemedicine
Emotional Support	Limited social interaction, especially during restrictions	Greater social support from household members
Scalability	Limited by facility capacity and staff availability	Scalable via digital platforms and remote delivery models

III. CLINICAL PROTOCOLS AND INTERVENTIONS

Among a variety of post-COVID-19 rehabilitation protocols, home-based ones are made up of different and multifaceted protocols that completely differ from one patient to another. Most programs are aimed at physical deconditioning, respiratory impairment, cognitive dysfunction, and psychological distress. Development of these protocols usually requires a multidisciplinary team of physical therapists, respiratory therapists, occupational therapists, psychologists, and sometimes nutritionists. These programs are designed in accordance with clinical assessments that ensure that the interventions are commensurate with the abilities of the patient prior to the injury (baseline goals) or the goals of recovery.

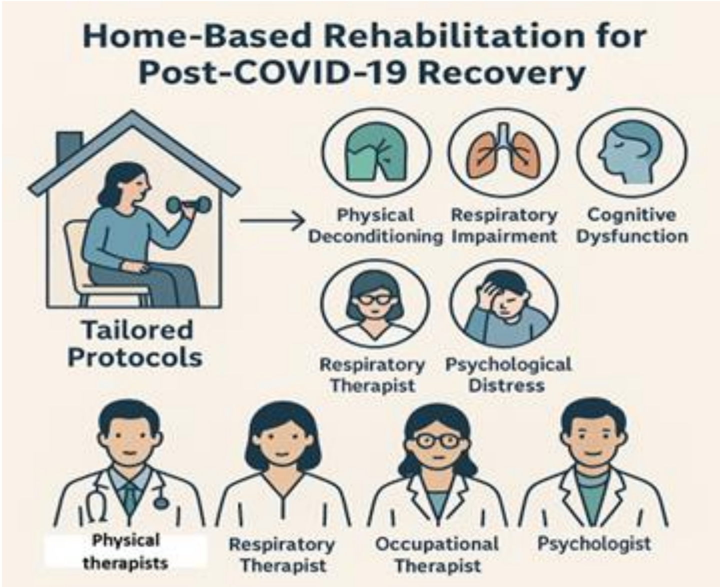

Figure 1: Home-Based Rehabilitation for Post-COVID-19 Recoverythe Figure Illustrates Tailored Rehabilitation Protocols Addressing Physical, Respiratory, Cognitive, and Psychological Issues, Supported By A Multidisciplinary Team Including Physical Therapists, Respiratory Therapists, Occupational Therapists, and Psychologists.

A. Physical Rehabilitation

Most home-based programs include physical rehabilitation as their cornerstone. A typical program consists of some aerobic exercises, resistance training, and a routine of flexibility exercises. One goal is to ward off muscle wasting, increase cardiovascular health, and return functional independence. Generally, exercises are low intensity to begin with, and they are progressed as tolerated by the patient.

Baselines of capacity are assessed and progress monitored by means of functional tests such as the 6-Minute Walk Test (6MWT), the Short Physical Performance Battery (SPPB), and the Barthel Index [4]. Bed exercises are the basic phase of the program; then, standing and walking routines are introduced, usually for patients recovering from severe illness, especially if it means being in the hospital or in the intensive care unit for a prolonged period of time.

B. Respiratory Training

Given the respiratory involvement in COVID-19, pulmonary rehabilitation is a critical component. Techniques such as diaphragmatic breathing, pursed-lip breathing, and inspiratory muscle training help improve lung function and oxygenation. Some protocols use incentive spirometry or handheld resistance devices to guide breathing exercises. In patients with residual hypoxia or reduced lung volumes, daily respiratory exercises have shown improvements in forced expiratory volume (FEV1) and forced vital capacity (FVC) [5]. A structured respiratory rehabilitation program also includes energy conservation strategies to help patients pace themselves through daily activities, especially those experiencing post-exertional malaise or fatigue.

C. Cognitive and Neuropsychological Interventions

A common complaint among post-COVID-19 people is now cognitive impairment, or as it is often called, 'brain fog'. Among common problems are memory lapses, attention deficits, and executive dysfunction. Structured tasks, memory drills, and problem-solving exercises are used to facilitate cognitive rehabilitation protocols, many of which are offered through computer-based tools or mobile applications [6]. It is also well established that psychological support is critical, as many individuals infected with COVID experience anxiety, depression, and post-traumatic stress disorder afterwards. Regular counselling sessions, mindfulness training, and stress reduction techniques are some of the techniques that have been included in some of the home-based models. Telepsychology services have been effective in treating these interventions in several instances while not affecting the therapeutic quality [7].

D. Multidimensional and Personalised Plans

The tertiary prevention programs usually integrate both the areas of physical, respiratory, and cognitive in one comprehensive program with additional components of nutritional counselling, sleep hygiene education, and pain management. The plans are based on individual assessments and patient-reported symptoms, and are changed if they are not working/ not agreed upon. Patients who are comorbid (diabetes/cardiovascular disease/pre-existing mental health condition), however, are in particular need of multidimensional protocols that can be employed in the home.

While the delivery format varies from a printed instruction, video tutorial, live video consultant, to a mobile health app, the delivery of the same is a combination of these multiple things. Some models involve training caregivers to help with exercises and monitoring safety, and in this case, continuity and adherence are ensured.

IV. CLINICAL OUTCOMES AND EFFECTIVENESS

There have been randomised controlled trials, cohort analyses, and observational case series that have evaluated the effectiveness of home-based rehabilitation post-COVID-19. The physical function, respiratory performance, psychological well-being, and quality of life metrics measured were the outcomes.

A. Improvements in Physical Function

Significant improvements in physical endurance and the strength of muscles have also been reported by patients participating in home-based rehabilitation programs. Several studies described a much-increased 6MWT distance after 6–8 weeks of intervention with an increase averaging 20–35% of baseline [8]. The Berg Balance Scale, in addition, has been used to measure the improvement in balance and coordination.

These gains are both statistically and clinically meaningful, often translated as more independence with activities of daily living like bathing, cooking, and household mobility. It has been further related to decreased hospital readmissions and emergency visits, resulting in overall healthcare cost savings [9].

B. Pulmonary Recovery

In addition, recovery of pulmonary function has been well documented. Measured improvements in spirometry indices that include FEV1, FVC, and oxygen saturation have been seen in patients. A study from Italy claimed that this amount of daily home-based respiratory training was able to raise FEV1 by 15% and PEFR by 12%, after four weeks [10].

In particular, home exercises have proven very effective for patients where lung involvement is moderate, after COVID-19, but patients with severe fibrosis or preexisting chronic obstructive pulmonary disease (COPD) may need a hybrid model where they have some clinical supervision, but a lot of that exercise is doable at home.

C. Psychological and Cognitive Benefits

According to several reports, post-COVID anxiety and depression have affected 20% to 40% of recovered people. In addition, home-based rehabilitation with psychological support and cognitive training has shown a considerable decrease in the scores of standardized scales such as the General Anxiety Disorder-7 (GAD-7), the Patient Health Questionnaire-9 (PHQ-9) [11].

Modules of cognitive rehabilitation, particularly with gamified digital tools, have proven to boost memory recall, task switching capacity, and mentality in general. These results highlight the importance for patients of a holistic rehabilitation approach as opposed to an attention only on physical health.

D. Quality of Life Metrics

In all of the studies, general improvement in health-related quality of life (HRQoL) has been a consistent outcome. These patients have more satisfaction with the recovery process, increased confidence to deal with symptoms, and increased autonomy in daily life. Both have been used to measure these parameters with the EQ-5D and SF-36 health surveys, which show statistically significant improvement in home-rehab cohorts [12].

V. TECHNOLOGICAL ENABLERS AND DIGITAL HEALTH INTEGRATION

Home-based rehabilitation has been an inevitable feature of post-COVID rehabilitation, and IoT will be an essential enabler of such rehabilitation. In the current circumstances where healthcare systems are under pressure and physical contact is restricted, digital tools have become the primary channel to deliver, monitor as well and adapt rehabilitation programs remotely. However, the convergence of telemedicine, wearable sensors, mobile applications, and cloud-based platforms has enabled rehabilitation services to be designed and delivered in a far different way.

A. Telemedicine and Remote Consultations

Telemedicine is one of the founding technologies in home rehabilitation and continues to be so, providing healthcare providers a means to consult with their patients through secure video conferencing platforms. Initial assessment of the physical and cognitive status of the patient can be done through teleconsultation, and it can be provided and provide individualised interventions. Real-time exercises can be demonstrated by providers, observed by patients, and then corrected, and the intensity and or duration adjusted based on the observed outcomes [13]. Also, this model supports multidisciplinary collaboration because the physical therapists, psychologists, and pulmonologists work hand in hand and therefore participate in virtual case discussions as well as dynamic treatment adjustment.

Figure 2: Key Technologies in Home-Based Post-COVID-19 Rehabilitationthe Figure Highlights Core Digital Tools Such As Telemedicine, Wearable Sensors, Mobile Applications, and Cloud-Based Platforms, Enabling Remote Delivery and Monitoring of Rehabilitation Services

B. Mobile Applications and Monitoring Tools

Home-based rehabilitation programs have thus become central to mobile technologies found in mobile health (mHealth) applications. Many of these apps feature exercise video libraries, medication reminders, symptom trackers, and progress dashboards. Patients can log their performance metrics/ pain level/energy by following structured routines.

Gamification strategies are then implemented in advanced applications in order to enhance patient engagement and adherence. Real-time feedback and motivational prompts help enable the maintenance of long-term therapy participation. Further, in many cases, such apps also come with feedback loops that tell a therapist when a patient misses' session or reports a worsening of symptoms, allowing timely interventions to be made [14].

C. Wearable Devices and Sensors

Physiological parameters of heart rate, respiratory rate, SpO2 (oxygen rate), and physical activity levels have been tracked in wearable technologies. For example, continuous data that is provided by devices such as smartwatches, chest sensors, and pulse oximeters can be remotely accessed by clinicians. Data streams are easily used for real-time performance of decision making and predictive analytics for the prediction of patients at risk of clinical deterioration. For instance, a steady decrease in daily step count or oxygen saturation is indicative of the need for early intervention in order to avoid exacerbation. It has been shown from several studies that wearable-assisted rehabilitation programs increase compliance as well as the functional outcome [15].

D. Artificial Intelligence and Data Analytics

Applications of artificial intelligence (AI) emerging include. Using large datasets to train the machine learning models will help to personalise the rehabilitation intensity, predict the time taken for recovery, and also help to identify the patients who may be candidates for hybrid (home and facility) programs. Some platforms have even incorporated AI-powered chatbots into them in order to provide educational help, symptom triaging, as well as motivational interviewing techniques. Nevertheless, problems still exist in areas of data privacy, interoperability between devices and electronic health records (EHRs), and patients' digital literacy and literacy of providers. However, to scale these technologies effectively as we go forward and integrate them into future public health strategies, we will need to overcome these barriers.

VI. CHALLENGES AND LIMITATIONS

While home-based rehabilitation appears to be sturdy and has encouraging results, there are still challenges to be taken into account. Instead, these limitations make it clear that such interventions need to be carefully planned, policies developed, and future research conducted to optimise and scale such interventions.

A. Patient Selection and Medical Complexity

Not all patients are able to have home-based rehabilitation. Those with the most severe post-COVID-19 sequelae, usually pulmonary fibrosis, cardiologic complications, or significant neurologic damage, need individual care and continuous overtreatment, beyond the resources of the home. In addition, patients with multiple comorbidities are liable to have their exacerbations complicate remote treatment and thus necessitate hospital readmission. It also needs robust triaging protocols to separate out patients that can be safely managed at home from those patients that will need hybrid or in-facility-based care.

B. Health Inequities and Digital Divide

Digital health infrastructure remains unequal in access between socioeconomic groups. With patients in rural or underserved urban areas, they may not have reliable internet connections, enough devices, or the digital literacy to use the telehealth cloud effectively. These disparities may contribute to magnifying existing health inequities, specifically for the elderly, those with lower income, and people with disabilities. In this gap, programs need to integrate inclusive design principles or alternatively, program new forms of modalities like phone check-in or printed rehabilitation materials.

C. Adherence and Motivation

In unsupervised settings, adherence to rehabilitation regimens may vary. Physical fatigue, mental well-being, and having a caregiver nearby, as well as how relevant the exercises are being perceived, all have an impact on adherence. Some patients may underperform or not complete the program as the accountability of in-person supervision will be lost. To tackle it, one needs to include behavioural interventions in the rehabilitation plan in the form of regular check-ins, goal-setting frameworks, social support groups, and digital gamification.

D. Regulatory and Reimbursement Issues

Telehealth and home-based care are not unattended in the regions; however, regulatory clarity on telehealth and home-based care is generally inconsistent across countries within the region. The ambiguity is from licensing, scope of practice, liability, and data privacy, which vary depending on providers. Policies of reimbursement also fall behind, with many of the insurers still not reimbursing for home-based or virtual rehabilitation services. For home-based rehabilitation to be established as the standard of care, reforms and regulatory harmonisation in the policy sphere are required for its sustainability.

VII. LESSONS LEARNED AND FUTURE DIRECTIONS

Home-based rehabilitation implementation during the COVID-19 pandemic presents a great case to learn from about healthcare innovation under crisis conditions. Several important lessons have emerged that point to how future delivery of rehabilitation can be informed by what has been learned for post-COVID patients, and indeed for larger populations with chronic illness or disability.

A. Decentralisation of Care

None of the most important lessons is the fact that healthcare services can be decentralised. Technology-supported, home-based models of care can deliver outcomes comparable to in-facility rehabilitation when properly overseen. The increased access, mitigated system burden, and patient–centred care are all supported by this model. However, future systems may instead use hybrid models that fuse in-person evaluations at periodic intervals with constant home-based management, achieving the best of both worlds.

B. Integration of Multidisciplinary Teams

Rehabilitation itself will be effective when it involves input from several disciplines. Models of remote multidisciplinary care were created at home and showed that with the right coordination tools, it can be effectively delivered. In particular, this lesson is applicable to the management of other chronic conditions that necessitate an evaluation of the many aspects of the management of patients, such as stroke, congestive heart failure, and COPD.

C. Investment in Digital Infrastructure and Literacy

Key to digital rehabilitation is reliable infrastructure, widespread health care, both in the use of digital tools and by patients and providers. Future healthcare reforms should therefore prioritise the investment in broadband access, in device distribution programs, and in digital literacy training etc.

D. Evidence-Based Protocol Development

With the growing frequency of home-based rehabilitation, there is a requirement for standard protocols based on empirical evidence. Therefore, the development of guidelines defining best practices for the different subgroups of patients should rely on randomised trials, large-scale cohort studies, and meta-analyses to warrant consistency of the use of these guidelines across the regions.

E. Policy and Reimbursement Reform

Only then are the models of care supported by healthcare policies. It involves standardising reimbursement codes for tele-rehabilitation, setting up quality and safety benchmarks and incorporating digital services into national health plans. By learning these lessons, healthcare systems not only become more able to deal with future pandemics but also become better at providing rehabilitation services for elderly people and those with disabilities, as well as people recovering from major surgery or chronic illness.

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