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Digital Therapeutics in Post-COVID Pulmonary Care: A Systematic Review of Tele-Rehabilitation Approaches

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Abstract: The COVID-19 pandemic has left millions with long-term sequelae, with pulmonary impairment emerging as one of the most disabling consequences of long COVID. Conventional pulmonary rehabilitation, though effective, faces barriers of access, scalability, and resources, particularly in low- and middle-income countries. In response, tele-rehabilitation has gained prominence as a digital therapeutic strategy. This review synthesizes evidence on two core models: Daily Structured Respiratory Conditioning (DSRC), emphasizing autonomy and scalability, and Supervised Tele-Pulmonary Exercise (STPE), offering safety and adherence through professional oversight. Hybrid approaches are highlighted as promising for balancing independence with supervision. Drawing on biopsychosocial, behavioral, and technology acceptance frameworks, the review situates tele-rehabilitation within clinical, economic, and policy contexts. Key challenges include equity gaps, adherence, and the need for standardized protocols. LMICs face significant barriers Tele-rehabilitation is presented not merely as a substitute but as a paradigm shift toward patient-centered and resilient post-COVID care.

Introduction

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, has emerged as one of the most significant global health emergencies of the 21st century. Initially detected in Wuhan, Hubei Province, China, in late December 2019, the virus rapidly crossed international borders, leading the World Health Organization (WHO) to declare a global pandemic by March 2020 (Cerfoglio et al., 2023b). The clinical spectrum of COVID-19 is remarkably broad, encompassing asymptomatic and mild cases to severe respiratory distress, multi-organ failure, and, in some instances, death (Salawu et al., 2020b). Severe cases often require intensive care support, including mechanical ventilation and extended hospital stays (Estela-Zape et al., 2025). Although the initial concern was for acute illness management and mortality reduction, the pandemic has since disclosed an evolving long-term health issue: post-COVID syndrome, also known as long COVID—a syndrome described by ongoing symptoms long after the acute phase of the disease.

1.2 Defining Long COVID

Long COVID, or post-COVID-19 syndrome, has proven to be a multifaceted, long-lasting condition characterized by an extensive variety of symptoms persisting far beyond the acute phase of the disease. According to the World Health Organization (WHO), long COVID refers to a condition that impacts people with a confirmed or presumptive history of infection with SARS-CoV-2, usually occurring three months or more after the onset of the first illness. The condition is defined by symptoms that

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persist for at least two months and are not due to any other medical diagnosis (Cerfoglio et al., 2024b). Current estimates from recent studies place as many as 10% to 20% of individuals infected with COVID-19 still suffering from ongoing health effects—also known as long-term sequelae—affecting their physical, cognitive, and emotional health (Calvache-Mateo et al., 2023b). The heterogeneity of long COVID prevalence is influenced by study design, patient population, and healthcare setting. Reports suggest prevalence rates of up to 23% in outpatient cohorts, 35% in non-hospitalized cases, and nearly 87% among hospitalized patients (Calvache-Mateo et al., 2023b). These statistics highlight both the widespread nature of the condition and the urgent need for effective rehabilitation and healthcare strategies.

1.3 Symptomatology and Health Burden

The clinical manifestations of long COVID are broad and affect multiple organ systems. Common symptoms include fatigue, dyspnea, muscle weakness, cognitive impairment ("brain fog"), and psychological disorders such as depression and anxiety (Calvo-Paniagua et al., 2022c; Elyazed et al., 2024b). Patients also report olfactory and gustatory dysfunction, chest pain, palpitations, gastrointestinal disturbances, and neurological symptoms (Cerfoglio et al., 2023b). In some cases, persistent impairments extend to respiratory, cardiovascular, and gastrointestinal systems, while functional challenges such as reduced exercise tolerance and difficulties in daily living are widespread (Cerfoglio et al., 2024b). Notably, even individuals with mild acute infections remain susceptible to post-COVID complications, making this condition particularly complex to manage (Calvo-Paniagua et al., 2022c).

The functional decline associated with long COVID is striking. Studies report that nearly one-third of hospitalized survivors show reduced lung function, exercise capacity, and six-minute walking distance (6MWD) for up to a year post-discharge (Elyazed et al., 2024b). Polese et al. noted that up to 70% of patients exhibited 6MWD values below predicted ranges, underscoring the persistence of impairment. Beyond physical limitations, prolonged immobilization during ICU stays contributes to muscle wasting, loss of aerobic capacity, ventilator-associated complications, and fibrotic lung lesions (Estela-Zape et al., 2025). In addition, comorbidities such as obesity, diabetes, and chronic obstructive pulmonary disease (COPD) are known to significantly increase the risk of severe complications and poorer outcomes among individuals with COVID-19 (Tsutsui et al., 2021). The interplay of these underlying conditions with post-COVID symptoms contributes to a growing burden—both for affected individuals and for already strained healthcare systems.

1.4 Rehabilitation Needs and Rationale

Given the prolonged and multifaceted nature of long COVID, rehabilitation has become a central component of the recovery process. These interventions are designed to restore functional independence, enhance respiratory capacity, and improve the overall quality of life for patients navigating post-COVID challenges (Cerfoglio et al., 2024b). Among the various strategies, pulmonary rehabilitation (PR)—long established as an effective treatment for chronic respiratory conditions like asthma and COPD—has gained renewed relevance for COVID-19 survivors. PR typically combines structured physical activity, respiratory muscle training, and psychological support, offering a comprehensive approach that enhances lung function, exercise tolerance, and mental well-being (Borghi-Silva et al., 2024; Soril et al., 2022). Studies demonstrate that PR leads to significant improvements in pulmonary function parameters, dyspnea, fatigue reduction, and quality of life scores among post-COVID patients (De Lima Martins et al., 2024). Improvements in functional measures, such as the six-minute walking test, lower limb strength, and inspiratory muscle strength, have also been reported (Dalbosco-Salas et al., 2021; Kortianou et al., 2022). Thus, PR and related interventions are not merely supplementary but essential for enabling patients to regain independence and mitigate long-term disability.

1.5 Telemedicine and Telerehabilitation Advances

The COVID-19 pandemic disrupted traditional healthcare delivery models, particularly in rehabilitation services, due to lockdowns,

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physical distancing measures, and overwhelmed hospitals. Consequently, telemedicine and telerehabilitation emerged as critical alternatives to maintain continuity of care (Calvo-Paniagua et al., 2022c; Mohamed et al., 2022b). Telerehabilitation, delivered through videoconferencing, mobile health applications, or structured home-based exercise programs, has shown promise in improving pulmonary function, reducing fatigue, and enhancing psychological well-being (De Lima Martins et al., 2024; Dalbosco-Salas et al., 2021). Evidence highlights the safety, feasibility, and scalability of home-based telerehabilitation, particularly for patients with mild to moderate COVID-19 symptoms (Semphuet et al., 2024b; Rinn et al., 2023). Benefits include reduced healthcare costs, improved accessibility, decreased exposure risks, and better patient engagement. Telerehabilitation also supports multidisciplinary approaches, integrating physiotherapists, psychologists, and nutritionists into coordinated virtual care (Andritoi et al., 2022). However, challenges remain regarding technology access in low-resource settings, patient adherence, and long-term efficacy evaluation (Gloeckl et al., 2023).

1.6 Research Gaps and Unmet Needs

Despite encouraging outcomes, significant research gaps persist. Many telerehabilitation trials suffer from small sample sizes, short follow-up durations, or lack of control groups, limiting the generalizability of findings (Rinn et al., 2023). Moreover, variability in program protocols—duration, intensity, and modality—complicates comparisons across studies (Borghi-Silva et al., 2024). The European Respiratory Society has emphasized the urgent need for standardized rehabilitation frameworks and patient follow-up strategies tailored to long COVID (Antoniou et al., 2022). Similarly, the WHO has issued calls for action highlighting rehabilitation as a critical, yet underutilized, aspect of pandemic response and recovery planning (Gloeckl et al., 2023). Further investigation is necessary to identify patient-specific predictors of rehabilitation success, optimize digital interventions, and evaluate cost-effectiveness in diverse healthcare settings. Moreover, more systematic, large-scale trials are required to establish evidence-based guidelines that can inform public health policy and clinical practice globally.

2. Literature Review

The COVID-19 pandemic had a profound global impact on healthcare, particularly in the modality, delivery, and significance of pulmonary rehabilitation (PR) outcomes. This review evaluated available evidence on PR during the pandemic, emphasizing delivery modes, outcomes, challenges, and adjustments required to maintain rehabilitation services. A systematic search was conducted across the Cochrane Library, MEDLINE, Embase, and Sci ELO databases from December 1, 2019 to August 1, 2023. The results highlight the crucial difficulty in the rehabilitation of patients with severe acute COVID-19, and those affected by long COVID symptoms. Across the world, utilization and access to community based rehabilitation programs are suboptimal, with pulmonary rehabilitation (PR) services underutilized, and especially among low- and middle-income nations. Successful strategies for improving recovery are interdisciplinary integrated care, targeted fitness based therapies, and symptom-specific interventions. While both outpatient rehabilitation and tele-rehabilitation have shown proven benefits in managing conditions like chronic obstructive pulmonary disease (COPD), access to these services is often restricted due to technological limitations and resource constraints in underserved settings. One study conducted during Greece's first nationwide lockdown (April–July 2020) assessed the impact of a home-based tele-rehabilitation program for post-hospitalized COVID-19 patients. The study utilized a pre- and post-intervention design, which included four telehealth sessions supported by a custom-designed e-book, followed by a two-month supervised exercise regimen. Key outcome measures included physical activity (IPAQ-Gr), psychological well-being (HADS), quality of life (SF-36), and functional capacity (3MST, 60-second Sit-to-Stand Test, and SPPB). Out of 74 participants, only 22 completed the program, but no adverse events were reported. Statistically significant improvements were observed in lower-limb strength, anxiety and depression

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levels, and overall quality of life ($p < 0.001$), demonstrating both the safety and efficacy of tele-rehabilitation for COVID-19 recovery.

Similarly, due to the difficulties in delivering traditional in-person rehabilitation during the height of the pandemic, a prospective observational study was implemented across seven primary care centers in Chile. This study evaluated a home-based telerehabilitation program for adult COVID-19 survivors, comprising 24 supervised exercise sessions. Patient outcomes were assessed using the SF-36 questionnaire, the 1-minute sit-to-stand test, and fatigue/dyspnea scoring, further validating the effectiveness of remote rehabilitation in improving post-COVID recovery metrics. Among 115 patients (mean age: 55.6 ± 12.7 years, 55.4% female), significant improvements were observed in exercise performance (20.5 ± 10.2 to 29.4 ± 11.9 repetitions, $p < 0.001$), SF-36 global scores (39.6 ± 17.6 to 58.9 ± 20.5), and symptom relief. Despite the absence of a control group, the study confirmed that telerehabilitation is both feasible and effective in enhancing functional capacity and quality of life in COVID-19 survivors. This meta-analysis assessed the impact of telerehabilitation on physical activity outcomes in COVID-19 patients. Clinical trials were retrieved from major databases including Cochrane Library, PubMed, CINAHL, PEDro, and Web of Science (January 2023). A total of 14 quantitative studies and 24 qualitative studies involving 1,344 patients were analyzed. Findings indicated significant improvements in lower limb strength, endurance (SMD 0.74, $p < 0.00001$), agility (MD −0.69, $p = 0.04$), functional capacity (MD 79.65 m, $p < 0.00001$), dyspnea (SMD −0.94, $p = 0.009$), fatigue, and muscle strength. Inspiratory muscle strength also improved (MD 13.71, $p = 0.001$). However, no significant effects were observed on forced vital capacity. The study concluded that telerehabilitation effectively enhances physical fitness, quality of life, and functional ability while reducing fatigue and dyspnea in COVID-19 survivors. This scoping review investigated the role of digital interventions in supporting patients with post-COVID or long-COVID symptoms. Eight original studies were identified, with interventions ranging from supervised telerehabilitation to online peer-support programs. The interventions primarily combined physical and psychological activities, showing positive outcomes in physical health, fatigue reduction, and psychological well-being. However, not all symptoms (e.g., bowel issues, memory, nightmares) improved consistently. Most studies lacked control groups, limiting generalizability. The authors emphasized the need for larger, systematic studies and recommended integrating digital health interventions into standard care for long-COVID patients. COVID-19 has left millions with long-term sequelae, imposing significant burdens on healthcare systems worldwide. This paper emphasized the importance of rehabilitation for post-COVID patients, aligning with the World Health Organization's Call for Action. The authors proposed a conceptual framework for categorizing post-COVID conditions into non-organ-specific phenotypes, helping clinicians tailor individualized treatment strategies. The study highlighted current unmet rehabilitation needs and provided a roadmap for developing targeted therapeutic approaches. This quasi-experimental study evaluated a telehealth-based physiotherapy intervention program for 60 patients with post-COVID-19 syndrome in Assiut University Hospital, Egypt. Using the Modified Medical Research Council Dyspnea Scale, Chalder Fatigue Scale, and Post-COVID-19 Functional Status Scale, significant improvements were observed in functional capacity, fatigue, and dyspnea at 8 and 12 weeks post-intervention ($p = 0.001$). The study concluded that telehealth physiotherapy significantly benefits post-COVID patients, with nurses playing a crucial role in delivery, particularly in contexts constrained by social distancing measures.

A task force of the European Respiratory Society (ERS) prioritized eight clinical issues related to post-COVID follow-up care. Evidence from a focused literature review suggested that persistent symptoms such as impaired pulmonary function, thromboembolic events, and reduced quality of life were common between 1–6 months after infection. While follow-up care improved patient management, robust evidence for long-term strategies remains limited. This highlights the urgent need for well-structured post-acute COVID-19 management protocols. This rapid review assessed the clinical

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effectiveness of pulmonary rehabilitation (PR) for post-COVID patients. Nine studies (including one RCT) showed consistent improvements in exercise capacity, pulmonary function, quality of life, and psychological well-being (e.g., anxiety and depression). However, most studies were small-scale, low-quality, and short-term. Evidence was lacking for long-term outcomes and for non-hospitalized patients. The review emphasized that PR program design should account for feasibility, capacity, and resource constraints given the current paucity of high-quality evidence. This study evaluated advancements in cardiopulmonary rehabilitation technologies during and after COVID-19. The pandemic accelerated the adoption of telemedicine, remote monitoring, and modern rehabilitation technologies. These innovations enhanced patient access to complex rehabilitation programs globally. The paper highlighted the urgent need for paradigm shifts in rehabilitation delivery, emphasizing how technological adoption has improved flexibility, accessibility, and patient outcomes in cardiopulmonary rehabilitation.

3. Conceptual and Theoretical Framework

The effectiveness of tele-rehabilitation for post-COVID patients with long-term pulmonary impairment cannot be fully understood without grounding it in appropriate conceptual and theoretical frameworks. Rehabilitation in this context is not simply a matter of restoring lung function; it encompasses psychological recovery, social reintegration, technology adoption, and equitable access to care. Accordingly, this section borrows from several frameworks—biopsychosocial, behavioral, technological, and policy-oriented—collectively offering a wide-angle lens for understanding the place of tele-rehabilitation in combating long-COVID.

3.1 The Biopsychosocial Model

Originally developed by George Engel in 1977, the biopsychosocial model has established itself as a staple in chronic disease and rehabilitation literature. This model suggests that outcomes of health are not only determined by biological dysfunction, but by the intricate and dynamic interaction between biological, psychological, and social factors of health. Within the context of post-COVID recovery, this model provides a valuable perspective through which to analyze the multi-dimensionality of long COVID: The biological aspect includes pulmonary function markers like inspiratory pressure, lung diffusion capacity, and oxygen saturation—important measures in evaluating respiratory recovery. The psychological aspect involves symptoms of anxiety, depression, cognitive impairment, and posttraumatic stress, commonly felt by patients who underwent extensive hospitalization or intensive care. The social factor involves the patient's capacity to return to everyday life, including work roles, household responsibilities, and community functions. Tele-rehabilitation translates well to this framework by providing interventions across all three domains. Formed physical activity sessions promote biological recovery; virtual counseling and peer-support group sessions target emotional well-being; and telemonitoring devices aid in maintaining consistent patient–clinician interaction, sustaining ongoing social interaction and accountability. Through the application of a biopsychosocial approach, tele-rehabilitation is not viewed as a narrow clinical intervention for symptom management, but as an integrative and comprehensive model for post-COVID rehabilitation—adapted to the complex nature of recovery.

3.2 Self-Management Theory

Self-management theory focuses on individuals being actively engaged in taking care of their health, encouraging independence, responsibility, and active involvement in daily wellness behaviors. The theory diverges from conventional healthcare paradigms where patients are regarded as recipients of medical care. Rather, self-management empowers individuals to become responsible for their recovery process. In the context of tele-rehabilitation, self-management takes form in treatment forms like Daily Structured Respiratory Conditioning (DSRC) programs. These allow patients to execute respiratory and physical exercises on their own with the assistance of digital platforms, instructional videos, or mobile apps. Devices like wearable sensors and digital progress logs provide immediate feedback, enabling patients to measure their own performance and make

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adjustments accordingly. This degree of participation is particularly beneficial for those with long COVID, whose symptoms can change randomly over the course of several weeks or months. Being able to regulate their rehabilitation independently instills a sense of renewed control and psychological strength throughout recovery. Aside from encouraging patient empowerment, self-management helps make healthcare systems sustainable. By empowering patients to undertake rehabilitation on their own, tele-rehabilitation reduces the strain on stretched healthcare services and fills the ongoing gap of specialized practitioners. This benefits in low-resource or sparsely distributed populations where access to in-person care is in short supply. By doing so, self-management not only raises individual recovery success but also facilitates scalable and cost-effective models of post-COVID care.

3.3 Social Cognitive Theory

Albert Bandura's Social Cognitive Theory (SCT) continues to be an underlying model in behavioral health, focusing on the reciprocal interaction of self-efficacy, observational learning, and reinforcement as they influence and maintain health-related habits

- Self-efficacy: As patients experience improvements in measurable outcomes—such as walking distance, inspiratory muscle strength, or reduced fatigue—they gain confidence in their capacity to manage their recovery.
- Observational learning: Tele-rehabilitation platforms often include instructional videos or group-based virtual sessions, allowing patients to observe peers or professionals and replicate correct techniques.
- Reinforcement: Positive feedback from clinicians during remote sessions, combined with data visualizations that track patient progress, acts as a powerful motivator for continued adherence.

SCT helps explain the variability in patient engagement. Those who perceive themselves as capable and receive consistent encouragement are more likely to sustain participation. Tele-rehabilitation programs that incorporate SCT principles—such as peer modeling, visual progress tracking, and clinician reinforcement—are demonstrably more effective in promoting long-term adherence and behavioral change.

3.4 Behavioral Change Models

Theories of behavioral change, specifically the Transtheoretical Model (TTM), offer further explanation for how patients interact with and move through tele-rehabilitation therapies. TTM defines five major phases of behavior change: precontemplation, contemplation, preparation, action, and maintenance.

Tele-rehabilitation can be strategically matched to each phase:

- Precontemplation & Contemplation: Patients are introduced to the benefits of pulmonary and physical rehabilitation through targeted education—such as motivational videos or one-on-one consultations.
- Preparation: Digital platforms offer structured plans, automated reminders, and initial guided sessions to build readiness and familiarity.
- Action: Patients begin active participation in either DSRC (self-directed modules) or STPE (supervised sessions).
- Maintenance: Sustained engagement is supported through regular feedback, progress reports, and scheduled follow-ups with clinicians to reinforce behavior and reduce risk of dropout or relapse.

By integrating behavior change theory into design, tele-rehabilitation programs become adaptive and patient-focused, enabling tailoring on an individual's readiness and enhancing adherence. In contrast to static interventions, behaviorally

3.5 Technology Acceptance Frameworks

Since Tele-Divin is fundamentally dependent on digital platforms, technology-cope models (TAMS) as frameworks and integrated theory and technology are the acceptance and use of technology important for understanding patient engagement and adoption of patient gallery and technology. According to TAM, two primary factors affect user acceptance: perceived utility - the extent to which technology improves health results, such as an increase in lung capacity or reduced fatigue. Easy use of ease of use - spontaneity and simplicity of platform interface. In the context of Tele-Opinion, these principles direct the design of user-centered digital solutions that are not only clinically effective but also available to patients with different degrees

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of technical knowledge. Mobile applications and web portals must be adapted to easy navigation, accountability, and clarity in order to promote frequent use.

3.6 Health Equity Lens

While the Tele Divin provides scalable and innovative solutions, equity is a significant concern. Digital health equipment may unconsciously increase existing inequalities, especially if the groups of margins, such as the older population, rural residents, or low-income households, have limited access due to limited digital literacy or inadequate infrastructure in homes with less income. It is necessary to use a health capital lens for a telecommunications revolutionary program design. Equity centers may be involved:

- Developing low-bandwidth platforms to ensure affordable and reliable access in underserved regions.
- Incorporating multilingual and culturally sensitive content to enhance relevance and usability.
- Adopting hybrid models that combine digital interventions with in-person or community-based support, especially for those who struggle with full digital autonomy.

Such approaches ensure that tele-rehabilitation evolves into an inclusive healthcare innovation—bridging gaps rather than deepening them—and aligns with global health priorities such as universal health coverage and equitable pandemic recovery.

3.7 Integrated Conceptual Framework for Tele-Rehabilitation

Synthesizing these theoretical perspectives results in an integrated framework where:

- The biopsychosocial model sets the multidimensional outcomes.
- Self-management theory emphasizes patient empowerment.
- Social cognitive and behavioral models explain adherence and motivation.
- Technology acceptance frameworks ensure usability and adoption.
- The equity lens guarantees inclusivity and scalability.

Collectively, these frameworks provide a robust and multidimensional foundation for the implementation of tele-rehabilitation among individuals recovering from long COVID. By integrating clinical, psychological, behavioral, technological, and equity-based perspectives, this approach ensures that rehabilitation is not confined to a purely biomedical model. Instead, it embraces the complex and interconnected nature of post-COVID recovery—addressing the physical symptoms, emotional well-being, digital accessibility, and social reintegration required for truly holistic care.

4. Comparative Models of Tele-Rehabilitation

Tele-rehabilitation has emerged as a versatile approach for addressing post-COVID respiratory impairments, yet its modalities vary in structure, intensity, and level of professional supervision. Among the most popularly discussed models are Supervised Tele-Pulmonary Exercise (STPE) and Daily Structured Respiratory Conditioning (DSRC). Each model is based on different assumptions regarding patient behavior, technological interaction, and clinical supervision, and both have both advantages and disadvantages.

4.1 Structured Respiratory Conditioning (DSRC) daily

Tele-rehabilitation has picked up considerable momentum as an elastic and convenient approach to dealing with post-COVID respiratory dysfunction. Yet, the format and presentation of such treatment differ considerably in terms of organization, frequency, and degree of professional oversight. Two models dominate contemporary discussion: Daily Structured Respiratory Conditioning (DSRC) and Supervised Tele-Pulmonary Exercise (STPE). These models embody different presuppositions regarding patient conduct, digital participation, and clinical participation—and each has unique strengths and weaknesses.

Key Features of DSRC:

- Autonomy and Habit Formation: Through regular, self-directed exercises that are a routine part of their daily lives, patients eventually make rehabilitation a habit. Consistency leads to resilience and behavioral self-regulation, which is essential for long-term recovery. Cost-Effectiveness and Scalability: DSRC is conducted with minimal clinical

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oversight, so it is extremely scalable and especially adaptable for low-resource or geographically remote populations.

- Patient Empowerment through Self-Management: Based on the theory of self-management, DSRC promotes patient responsibility by motivating patients to take charge of their recovery process. This is in tandem with contemporary trends of patient-centric care.

While DSRC does not provide the same degree of real-time clinical feedback as supervised models, it delivers a useful, low-cost solution that facilitates behavioral change and long-term interaction—particularly where healthcare resources are scarce.

4.2 Supervised Tele-Pulmonary Exercise (STPE)

Supervised Tele-Pulmonary Exercise (STPE) is a clinician-directed model of rehabilitation provided through video conferencing or interactive online platforms. During this modality, patients attend live sessions with supervision by physiotherapists, respiratory therapists, or multidisciplinary teams who monitor and modify exercises depending on the patient's needs.

Salient aspects of STPE:

- Professional Monitoring: Clinicians can correct incorrect techniques and observe patient safety during exercise.
- Greater Adherence: Direct monitoring ensures responsibility and positive reinforcement, minimizing dropout.
- Psychosocial Support: Online group sessions allow peer engagement, minimizing loneliness and worry.

Yet, STPE is more resource-demanding. It needs reliable internet access, flexible schedules, and continuous availability of clinicians—factors that might restrict feasibility in low-resource environments or high-patient-demand locations.

4.3 Hybrid and Blended Approaches

In light of the complementary relationships between DSRC and STPE, hybrid models of rehabilitation have been found to be a good solution. The hybrid models mostly involve patients undergoing DSRC every day for everyday self-care and maintenance of function, with biweekly or weekly STPE sessions on structured guidance as well as motivational enhancement. This hybrid strategy provides an adaptable balance between clinical guidance and patient independence that accommodates a wide range of patient populations with different levels of symptoms severity, digital literacy, and motivation. In addition, hybrid models complement behavior change frameworks—such as the Transtheoretical Model—by facilitating support to patients at all levels of engagement, from initial contemplation to extended maintenance. Notably, hybrid models also maximize the distribution of healthcare resources by minimizing clinician workload while allowing patients to continue receiving specialist input at critical points in recovery.

4.4 Comparative Effectiveness: DSRC vs. STPE

Although large-scale comparative studies are only just appearing, early evidence is that each model might have benefits for specific groups of patients:

- DSRC seems particularly well-suited for well-motivated patients with mild-to-moderate impairment, encouraging independence, habit formation, and cost-effective scale-up.
- STPE, conversely, offers more benefits to patients with high symptom severity, low self-efficacy, or high clinical risk due to the real-time professional guidance and psychosocial support it entails.

Instead of seeing these models as competitive, they can be regarded as complementary modalities that can be strategically adapted depending on patient profiles, resources, and health system capacity.

4.5 Each Model's Advantages and Disadvantages

The following table (Table 1) collates the comparative characteristics of DSRC and STPE along major dimensions such as cost, autonomy, safety, compliance, and tech needs. It also identifies the scalability and cost-effectiveness of DSRC in low-resource settings, while noting STPE's clinical severity and compliance advantages in more serious conditions. Hybrid methods are seen as a responsive middle ground incorporating the best aspects of both.

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Table 1. Comparative Advantages and Limitations of DSRC and STPE Models in Post-COVID Tele-Rehabilitation

Aspect	DSRC (Daily Structured Respiratory Conditioning)	STPE (Supervised Tele-Pulmonary Exercise)
Cost	Low, highly scalable	Moderate–High, dependent on clinician time
Patient Autonomy	High	Moderate
Clinical Safety	Limited oversight	High due to real-time supervision
Adherence	Risk of decline over time	Typically higher due to accountability
Technology Needs	Low–Moderate	High (video conferencing, stable bandwidth)
Best Suited For	Mild/moderate impairments, motivated patients	Severe impairments, low self-efficacy patients

The contrast outlined in Table 1 emphasizes that while Daily Structured Respiratory Conditioning (DSRC) and Supervised Tele-Pulmonary Exercise (STPE) are different and complementary, both have their place in the telerehabilitation context. DSRC trains patients efficiently and cost-effectively, with high levels of autonomy and scalability, and is thus suited to wider application—especially in low-resource environments. Yet, its absence of real time supervision can result in lower adherence and poorer technique, notably among lower-motivation or higher-risk patients. By contrast, STPE offers greater clinical management, safety, and psychosocial care through real-time engagement with health workers. However, its reliance on stable digital infrastructure, availability of clinicians, and increased resource intensity may restrict accessibility and scalability, especially in underserved or high-burden settings. These findings reinforce the importance of viewing tele-rehabilitation not just through a clinical lens, but within a comprehensive conceptual framework—one that integrates psychological, behavioral, technological, and equity considerations. Such a multidimensional approach is critical to designing patient-centered, context-sensitive, and sustainable rehabilitation solutions in the post-COVID era. To capture these interlinked domains, a conceptual framework is presented in **Figure 1**, which positions tele-rehabilitation as a central intervention influencing multidimensional outcomes.

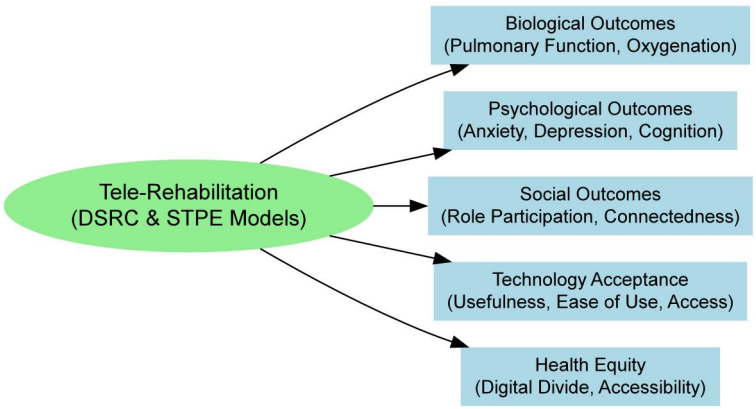


Figure 1. Conceptual framework for tele-rehabilitation in post-COVID recovery.

Figure 1 illustrates how tele-rehabilitation, encompassing DSRC and STPE models, serves as a central intervention influencing multiple outcome domains. The framework integrates biological outcomes (e.g., pulmonary function), psychological outcomes (e.g., anxiety and cognition), social outcomes (e.g., connectedness, role participation), technology acceptance factors (ease of use and perceived usefulness), and health equity considerations (digital divide

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and accessibility). Together, these elements position tele-rehabilitation as a multidimensional strategy for holistic recovery.

5. Global Perspectives and Policy Implications

The global adoption of tele-rehabilitation as a therapeutic strategy for long-COVID reflects both opportunities and challenges shaped by healthcare infrastructure, socio-economic context, and policy priorities. While the pandemic accelerated digital health integration across nations, the pace, reach, and sustainability of tele-rehabilitation programs vary widely between high-income and low- to middle-income countries (LMICs). Understanding these variations is critical to developing scalable and equitable tele-rehabilitation frameworks.

5.1 High-Income vs. Low-Income Countries Implementation

In HICs, strong digital infrastructures, increased patient digital literacy, and fully developed insurance systems have supported the rapid uptake of STPE. Numerous hospitals and rehabilitation centers in resource-rich environments have been able to integrate video consultations, wearable monitoring devices, and AI-driven feedback systems into tele-rehabilitation service models. Such developments have allowed for more customized, data-driven care and improved clinical supervision. Conversely, the low- and middle-income countries (LMICs) remain with significant barriers to digital health adoption. Low internet penetration, poor smartphone availability, and the cost are all deterring factors that slow down the implementation of technology-intensive rehabilitation interventions. In these settings, the more accessible and scalable solution is Daily Structured Respiratory Conditioning (DSRC). DSRC can be implemented on low-tech, low-cost platforms such as simple mobile applications, SMS-based reminders, or even printed teaching materials—making it a viable option for resource-poor environments.

5.2 WHO Digital Health Strategy (2020–2025)

The global strategy of the World Health Organization on Digital Health (2020-2025) has highlighted telemedicine and digital health solutions as essential components of universal health coverage. Tele-Pole vas matches this vision:

- Expanding healthcare access beyond hospitals into community and home settings.
- Reducing geographical and socio-economic disparities in rehabilitation delivery.
- Enabling resilience in healthcare systems during pandemics, disasters, or crises.

Policymakers are therefore encouraged to institutionalize tele-rehabilitation within national healthcare systems, ensuring its integration into reimbursement frameworks, digital health platforms, and workforce training programs.

5.3 Equity and Accessibility Challenges

Despite the global political support, stock challenges remain:

- Digital Divide: Inadequate broadband access excludes millions, particularly in rural LMICs.
- Cultural and Linguistic Barriers: Programs often lack localized content, reducing patient engagement.
- Age and Disability: Older adults and patients with cognitive impairments struggle with digital interfaces.
- Gender Disparities: Women, especially in low-income contexts, face cultural barriers in accessing digital rehabilitation resources.

These inequalities require versatile strategies to address these inequalities: providing grants to digital units, offering multilingual interfaces, community-based supports for digital on board, and developing hybrid models that combine telecommunications hearts with local search.

5.4 Cost-Effectiveness and Health Economics

Economic evaluation of tele-rehabilitation indicates substantial cost savings for both patients and health systems. By reducing the need for hospital readmissions, transportation, and long-term in-person consultations, tele-rehabilitation alleviates financial burdens. STPE models may incur higher operational costs due to clinician time and infrastructure, but these are offset by reductions in emergency visits and complications. DSRC, being low-cost and scalable,

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presents the greatest economic advantage for resource-limited settings. Nevertheless, policymakers must balance cost-effectiveness with equity. If only DSRC is promoted due to cost concerns, severely impaired patients who need STPE risk being underserved. Hybrid models offer a pragmatic middle ground, combining affordability with clinical safety.

5.5 Public Health Integration and Insurance Coverage

For tele-rehabilitation to transition from experimental programs to sustainable healthcare delivery models, it must be institutionalized within public health systems. This includes:

- Establishing reimbursement policies for digital rehabilitation sessions.
- Training healthcare professionals in digital communication and monitoring tools.
- Incorporating tele-rehabilitation into national COVID-19 recovery strategies.
- Engaging insurers and government agencies to cover costs under universal health coverage schemes.

Without policy alignment, tele-rehabilitation risks being a fragmented, short-term solution. With proper integration, however, it can become a cornerstone of global post-pandemic recovery and future chronic disease management.

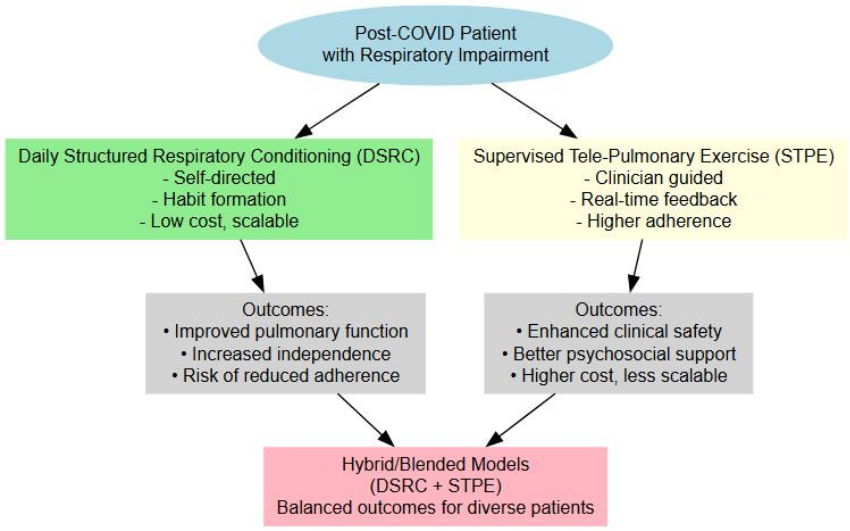


Figure 2. Comparative flow of DSRC and STPE models in tele-rehabilitation pathways.

Figure 2 compares patient rehabilitation trajectories under DSRC and STPE. DSRC emphasizes daily self-directed routines that promote independence and habit formation, while STPE provides real-time clinician guidance and psychosocial support. The figure also depicts how outcomes diverge—DSRC offers scalability but risks adherence decline, whereas STPE enhances safety and motivation but requires greater resources. The diagram concludes with hybrid models, demonstrating their potential to integrate both approaches for balanced, patient-centered outcomes.

6. Discussion

Tele-rehabilitation has proven to be a feasible and scalable response to the rehabilitation demands of long-COVID. Its strengths lie in accessibility, continuity of care, and cost-effectiveness. DSRC empowers patients through autonomy and daily engagement, while STPE ensures clinical safety and stronger adherence. Hybrid models combine these benefits and appear promising for future adoption. However, challenges remain. Equity gaps caused by the digital divide, variable adherence, and lack of standardized protocols hinder widespread implementation. Privacy, data protection, and clinician workload also require attention. Lessons from the pandemic highlight that tele-rehabilitation is not just a substitute for conventional programs but a paradigm shift

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toward patient-centered and technology-integrated recovery pathways.

7. Conclusion

The COVID-19 pandemic has shifted the global health landscape, causing chronic conditions and straining healthcare systems. Pulmonary rehabilitation is crucial, but conventional models face geographical, financial, and infrastructural barriers. Tele-rehabilitation, through DSRC and STPE, offers a viable solution. Hybrid models, combining strengths of both approaches, hold promise. However, long-term sustainability requires standardized protocols, cross-country guidelines, and policy integration. Emerging technologies like AI and wearables expand its applicability beyond COVID-19.

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