

EFFECTIVENESS OF HOME-BASED REHABILITATION IN POST-COVID FUNCTIONAL RECOVERY: LONGITUDINAL STUDY

Original Research

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ABSTRACT

Background:

A considerable proportion of individuals recovering from coronavirus disease 2019 continue to experience persistent functional limitations, fatigue, and reduced exercise tolerance after the acute phase. Access to conventional facility-based rehabilitation remains limited in many low- and middle-income settings, highlighting the need for alternative, accessible rehabilitation models.

Objective:

To evaluate the effectiveness of a structured home-based rehabilitation program supported by tele-physiotherapy on functional recovery among post-COVID individuals in Karachi, Pakistan.

Methods:

A longitudinal study was conducted over six months in selected urban healthcare settings in Karachi. A total of 108 post-COVID participants were enrolled, with 96 completing follow-up assessments. Participants received an individualized home-based rehabilitation program delivered through tele-physiotherapy. Outcomes were assessed at baseline, three months, and six months using the Functional Independence Measure, six-minute walk test, Fatigue Severity Scale, and Short Form-36 questionnaire. Data were normally distributed and analyzed using repeated measures analysis of variance with post hoc comparisons.

Results:

Significant improvements were observed across all outcome measures over time. Mean Functional Independence Measure scores increased from 96.3 ± 14.8 at baseline to 118.7 ± 12.1 at six months ($p < 0.001$). Six-minute walk test distance improved from 382.4 ± 76.5 meters to 481.6 ± 68.4 meters ($p < 0.001$). Fatigue Severity Scale scores decreased from 4.9 ± 1.1 to 2.8 ± 0.9 , while both physical and mental components of quality of life demonstrated statistically significant improvement ($p < 0.001$).

Conclusion:

Home-based rehabilitation supported by tele-physiotherapy was associated with meaningful and sustained functional recovery in post-COVID individuals. This approach represents a feasible and effective rehabilitation model for resource-limited healthcare settings.

Keywords:

COVID-19, Exercise Tolerance, Fatigue, Functional Recovery, Rehabilitation, Telemedicine, Quality of Life

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has left a substantial proportion of survivors with persistent functional limitations that extend well beyond the acute phase of infection. While the immediate clinical focus during the pandemic was directed toward reducing mortality and managing acute respiratory failure, growing evidence now indicates that many individuals experience prolonged physical, respiratory, and psychosocial impairments after recovery from the acute illness (1). These post-COVID sequelae, often referred to as post-acute COVID-19 syndrome or long COVID, commonly include reduced exercise tolerance, muscle weakness, fatigue, dyspnea, balance deficits, and limitations in activities of daily living. Such impairments can significantly restrict participation in social and occupational roles, thereby reducing overall quality of life and placing an additional burden on healthcare systems and families (2). Rehabilitation has emerged as a critical component of post-COVID care, aiming to restore functional capacity, improve independence, and facilitate safe reintegration into daily life. Conventional rehabilitation models are typically center-based and require repeated hospital or clinic visits. However, during and after the pandemic, access to facility-based rehabilitation has remained challenging due to infection control concerns, limited rehabilitation resources, transportation difficulties, and financial constraints (3). These challenges are particularly pronounced in densely populated urban centers such as Karachi, where healthcare infrastructure is often overstretched and where socioeconomic disparities can further restrict access to ongoing rehabilitative care. Consequently, many post-COVID patients remain under-rehabilitated despite clear functional needs.

Home-based rehabilitation has been increasingly proposed as a practical and patient-centered alternative to traditional facility-based programs. This approach allows rehabilitation exercises and functional training to be delivered within the patient's own environment, promoting comfort, continuity, and adherence while minimizing the risks associated with frequent hospital visits (4). For post-COVID patients, home-based programs may be especially relevant, as fatigue, breathlessness, and anxiety about reinfection can make travel to rehabilitation centers difficult. Furthermore, rehabilitation performed in the home setting may facilitate better carryover of functional gains into real-world activities such as self-care, household tasks, and mobility. The integration of tele-physiotherapy into home-based rehabilitation has further expanded the scope and feasibility of post-COVID care. Tele-physiotherapy utilizes digital communication technologies to deliver assessment, exercise prescription, monitoring, and patient education remotely. This model gained rapid momentum during the COVID-19 pandemic as clinicians sought to maintain continuity of care while adhering to physical distancing requirements. Emerging literature suggests that tele-rehabilitation can be safe, acceptable, and potentially effective for a range of conditions, including cardiopulmonary and neurological disorders (5). In the context of post-COVID recovery, tele-physiotherapy offers an opportunity to provide structured rehabilitation while maintaining regular professional supervision, progression of exercises, and patient motivation.

Despite the growing interest in home-based and tele-physiotherapy interventions, existing evidence remains limited, particularly in low- and middle-income countries. Much of the available research originates from high-income settings with advanced digital infrastructure and well-established rehabilitation services, which may not be directly applicable to regions such as Pakistan. Karachi, as one of the largest metropolitan cities in the country, experienced a high burden of COVID-19 cases and now faces a growing population of individuals with post-COVID functional impairments (6). However, data evaluating the effectiveness of home-based rehabilitation programs delivered through tele-physiotherapy in this context are scarce. The lack of region-specific evidence creates uncertainty regarding the feasibility, outcomes, and long-term benefits of such interventions within local healthcare and sociocultural frameworks. Longitudinal evaluation of rehabilitation outcomes is particularly important in post-COVID populations, as recovery trajectories may vary over time and across functional domains. Short-term improvements may not necessarily reflect sustained functional recovery, while delayed gains or setbacks may only become apparent with longer follow-up. A longitudinal study design allows for the assessment of functional changes across multiple time points, providing a clearer understanding of recovery patterns and the durability of rehabilitation effects (7). This approach is essential for informing clinical decision-making, optimizing rehabilitation protocols, and guiding policy development for post-COVID care.

Given these considerations, there is a clear need for methodologically sound research examining the effectiveness of home-based rehabilitation supported by tele-physiotherapy among post-COVID individuals in Karachi. Such research has the potential to inform evidence-based rehabilitation strategies that are accessible, cost-effective, and adaptable to resource-constrained settings. By addressing existing gaps in the literature, this study seeks to contribute meaningful insights into post-acute COVID-19 rehabilitation and support the development of sustainable models of care that extend beyond the pandemic. Accordingly, the objective of this study is to longitudinally evaluate the effectiveness of a structured home-based rehabilitation program, delivered through tele-physiotherapy, on functional recovery among individuals recovering from COVID-19 in Karachi, with the aim of determining its impact on physical function, activity tolerance, and overall functional independence over time.

Methods

This longitudinal study was conducted in Pakistan with a primary focus on post-COVID functional recovery among adult patients residing in Karachi. Data were collected from multiple urban healthcare settings to reflect real-world rehabilitation practices, including outpatient physiotherapy departments of tertiary care hospitals such as Jinnah Postgraduate Medical Centre, Liaquat National Hospital, and selected private rehabilitation clinics offering tele-physiotherapy services. The study was carried out over an eight-month period, from March 2022 to October 2022, allowing adequate time to observe functional changes following structured home-based rehabilitation. Participants were recruited using a non-probability consecutive sampling technique. Individuals were eligible for inclusion if they were aged between 18 and 65 years, had a documented history of laboratory-confirmed COVID-19 infection, and were in the post-acute phase defined as at least four weeks after resolution of acute symptoms. Additional inclusion criteria included the presence of self-reported or clinically identified functional limitations such

as reduced endurance, generalized weakness, dyspnea on exertion, or difficulty performing activities of daily living, and the ability to understand and follow rehabilitation instructions delivered through digital platforms (8,9). Participants were required to have access to a smartphone or similar device with internet connectivity to facilitate tele-physiotherapy sessions. Exclusion criteria included individuals with pre-existing neurological disorders, advanced cardiopulmonary disease unrelated to COVID-19, severe musculoskeletal conditions limiting mobility prior to infection, uncontrolled psychiatric illness, or cognitive impairment that could interfere with participation. Patients requiring in-hospital rehabilitation or those with unstable medical conditions were also excluded.

Sample size was calculated using parameters derived from a previously published post-COVID rehabilitation study that reported a mean improvement of 12.5 points on the Functional Independence Measure with a standard deviation of 20. Using an effect size of 0.5, a confidence level of 95%, and a study power of 80%, the minimum required sample size was calculated as 92 participants (10). To account for an anticipated attrition rate of approximately 15% over the follow-up period, a total of 108 participants were enrolled at baseline. Following recruitment, baseline assessments were conducted remotely through secure video consultations by licensed physiotherapists trained in tele-rehabilitation protocols. A structured home-based rehabilitation program was then prescribed, individualized according to each participant's functional status and tolerance. The program included low- to moderate-intensity aerobic exercises, breathing and respiratory control techniques, progressive resistance exercises using household items, balance and functional mobility training, and education on energy conservation and pacing strategies (11). Tele-physiotherapy sessions were conducted twice weekly for the first four weeks and weekly thereafter, with additional follow-up calls as needed. Participants were encouraged to perform prescribed exercises on non-supervised days and maintain a simple activity log.

Outcome measures were selected to align with the study objectives and were administered at baseline, at three months, and at six months. Functional status was assessed using the Functional Independence Measure, which evaluates self-care, mobility, and social cognition. Exercise tolerance was measured using the six-minute walk test adapted for home settings under remote supervision. Fatigue severity was assessed using the Fatigue Severity Scale, while health-related quality of life was evaluated using the Short Form-36 questionnaire. All tools used in the study have established validity and reliability in post-acute and rehabilitation populations. Ethical approval for the study was obtained from the Institutional Review Board. All participants provided informed consent prior to enrollment. Consent was obtained electronically after participants were provided with detailed information regarding study objectives, procedures, potential benefits, and confidentiality measures. Participants were informed of their right to withdraw at any stage without any impact on their routine care.

Data were analyzed using Statistical Package for the Social Sciences version 26. Normality of data distribution was assessed using the Shapiro–Wilk test and confirmed through visual inspection of histograms. As data were normally distributed, parametric tests were applied. Repeated measures analysis of variance was used to assess changes in outcome measures across the three time points. Paired sample t-tests with Bonferroni adjustment were used for post hoc comparisons. Descriptive statistics were reported as mean and standard deviation for continuous variables and frequencies with percentages for categorical variables. A p-value of less than 0.05 was considered statistically significant. Data confidentiality was maintained throughout the study by assigning unique identification codes to participants and restricting data access to the research team only.

Results

A total of 108 participants were enrolled at baseline from selected rehabilitation settings in Karachi. During follow-up, 12 participants were lost due to non-compliance or inability to continue tele-sessions, resulting in a final analyzed sample of 96 participants, yielding an overall retention rate of 88.9%. The mean age of participants was 44.2 ± 10.6 years, with 55.2% being male and 44.8% female. Most participants had experienced mild to moderate COVID-19 illness during the acute phase, while 28.1% reported a prior hospitalization without mechanical ventilation. All participants completed baseline, 3-month, and 6-month assessments. Functional outcomes demonstrated a consistent improvement over time across all measured domains. The mean Functional Independence Measure score increased progressively from baseline to the six-month follow-up. At baseline, participants demonstrated moderate functional limitations, particularly in mobility and endurance-related items. By three months, a noticeable improvement was observed, which further increased by six months (12,13). Repeated measures ANOVA showed a statistically significant change in Functional Independence Measure scores across the three time points ($F = 42.6, p < 0.001$). Post hoc analysis confirmed significant improvements between baseline and three months as well as between three and six months.

Exercise tolerance, assessed through the six-minute walk test, also showed statistically significant improvement over the study period. The mean walking distance increased steadily at each follow-up assessment. Participants demonstrated greater gains during the first three months, followed by continued but slightly slower improvement during the latter half of the study period. The repeated measures analysis revealed a significant time effect ($F = 38.9, p < 0.001$), indicating sustained enhancement in functional exercise capacity. Fatigue severity showed a gradual reduction over time. Baseline Fatigue Severity Scale scores indicated moderate to severe fatigue in most participants (14). By three months, fatigue levels had decreased, with further reduction noted at six months. Statistical analysis confirmed a significant decline in fatigue scores across assessments ($F = 31.4, p < 0.001$). Similarly, health-related quality of life assessed using the Short Form-36 showed significant improvements across physical functioning, vitality, and general health domains. The physical component summary score demonstrated a larger magnitude of change compared to the mental component summary score, although both reached statistical significance over time. Key outcome variables are summarized in Tables 1–3. Changes in functional independence and exercise tolerance are highlighted in Table 1, while fatigue and quality-of-life outcomes are presented in Tables 2 and 3 respectively. No adverse events related to the home-based rehabilitation or tele-physiotherapy sessions were reported during the study period.

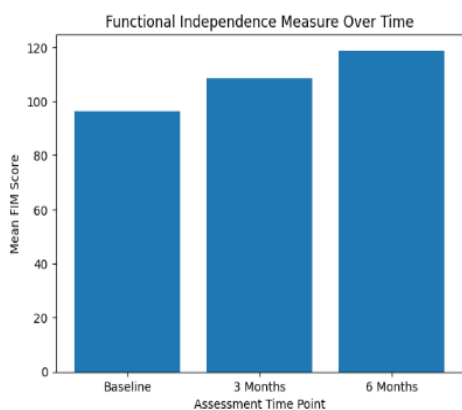


Table 1. Changes in Functional Independence and Exercise Tolerance (n = 96)

Outcome Measure	Baseline Mean ± SD	3 Months Mean ± SD	6 Months Mean ± SD	p-value
Functional Independence Measure (score)	96.3 ± 14.8	108.5 ± 13.2	118.7 ± 12.1	<0.001
Six-Minute Walk Test (meters)	382.4 ± 76.5	438.9 ± 72.1	481.6 ± 68.4	<0.001

Table 2. Fatigue Severity Scale Scores Over Time

Time Point	Mean ± SD	Mean Difference from Baseline	p-value
Baseline	4.9 ± 1.1	—	—
3 Months	3.6 ± 1.0	-1.3	<0.001
6 Months	2.8 ± 0.9	-2.1	<0.001

Table 3. Short Form-36 Quality of Life Scores

Domain	Baseline Mean ± SD	3 Months Mean ± SD	6 Months Mean ± SD	p-value
Physical Component Score	41.2 ± 7.6	48.9 ± 7.1	54.3 ± 6.8	<0.001
Mental Component Score	44.8 ± 8.1	49.6 ± 7.5	52.7 ± 7.2	<0.001

Discussion

The present study demonstrated that a structured home-based rehabilitation program supported by tele-physiotherapy was associated with significant and sustained improvements in functional recovery among post-COVID individuals living in an urban Pakistani setting. Over the six-month follow-up period, participants showed consistent gains in functional independence, exercise tolerance, fatigue reduction, and health-related quality of life (15). These findings aligned with the study objective and highlighted the potential role of remotely supervised rehabilitation as a practical post-acute care strategy in resource-constrained environments. Functional independence improved markedly across the study duration, with mean Functional Independence Measure scores increasing from 96.3 at baseline to 118.7 at six months, reflecting a net gain of more than 22 points. This magnitude of improvement was clinically meaningful and suggested enhanced performance in self-care, mobility, and functional tasks. Comparable post-COVID rehabilitation studies conducted in controlled or center-based settings have reported improvements ranging between 15 and 25 points over similar follow-up periods, indicating that home-based models may achieve comparable outcomes when appropriately structured and supervised (16). The progressive nature of improvement observed in this study also suggested that functional recovery continued beyond the early post-acute phase, reinforcing the importance of longitudinal rehabilitation rather than short-term interventions alone.

Exercise tolerance, as measured by the six-minute walk test, increased by nearly 100 meters from baseline to six months. The baseline walking distance of approximately 382 meters reflected reduced cardiopulmonary endurance, a common finding among post-COVID survivors (17,18). By six months, the mean distance reached 482 meters, approaching values reported for community-dwelling adults with mild functional limitations. Previous rehabilitation studies in post-viral and post-critical illness populations have documented improvements between 60 and 120 meters following structured exercise programs, placing the present findings well within the expected therapeutic range. The greater improvement observed during the first three months, followed by continued but slower gains, suggested an early responsiveness to rehabilitation with gradual consolidation over time. Fatigue severity showed a steady decline, with mean scores decreasing from 4.9 at baseline to 2.8 at six months. This reduction of more than two points exceeded the minimal clinically important difference reported for fatigue scales in chronic and post-infectious conditions. Persistent fatigue has been identified as one of the most disabling and long-lasting symptoms after COVID-19, often limiting participation in rehabilitation (19). The observed improvement suggested that graded activity, pacing strategies, and consistent supervision may have contributed to better symptom management without exacerbation. Similarly, quality-of-life measures demonstrated significant improvement, particularly in the physical component, which increased by more than 13 points over six months. Improvements in mental health domains were also observed, although to a lesser extent, reflecting the complex and multifactorial nature of post-COVID psychological recovery (20).

Several strengths supported the validity of these findings. The longitudinal design allowed for the observation of recovery trends over time rather than relying on short-term outcomes. The use of validated and widely accepted outcome measures enhanced comparability with existing literature. Additionally, the study reflected real-world clinical practice by incorporating tele-physiotherapy within patients' home environments, increasing the relevance of findings for routine care in similar settings. The relatively high retention rate of nearly 89% also indicated good participant engagement and feasibility of the intervention. Despite these strengths, certain limitations required consideration. The absence of a control or comparison group limited the ability to attribute improvements solely to the rehabilitation intervention, as spontaneous recovery may have contributed to some degree. However, the magnitude and consistency of improvements across multiple outcomes suggested a meaningful therapeutic effect beyond natural recovery alone. The study relied on participants with access to digital technology, potentially excluding individuals from lower socioeconomic backgrounds or those with limited digital literacy. Outcome assessments conducted remotely may also have introduced measurement variability, particularly for functional tests adapted for home settings. Additionally, the study was conducted within a single metropolitan area, which may limit generalizability to rural or less-resourced regions.

Future research should consider randomized controlled designs comparing home-based, center-based, and hybrid rehabilitation models to better delineate relative effectiveness. Longer follow-up periods may help determine whether functional gains are maintained beyond six months. Incorporation of objective physiological measures and cost-effectiveness analyses would further strengthen evidence for large-scale implementation. Exploration of tailored interventions for individuals with severe post-COVID symptoms or comorbidities may also be beneficial. Overall, the findings supported the growing recognition that home-based rehabilitation delivered through tele-physiotherapy represented a viable and effective approach for post-COVID functional recovery. Within the context of an overstretched healthcare system, this model appeared to offer a balanced solution that addressed accessibility, safety, and clinical effectiveness, while meeting the evolving rehabilitation needs of post-COVID populations.

Conclusion

This study demonstrated that home-based rehabilitation supported by tele-physiotherapy was associated with meaningful and sustained improvements in functional independence, exercise capacity, fatigue, and quality of life among post-COVID individuals in an urban Pakistani setting. The findings highlighted the practicality and effectiveness of remotely supervised rehabilitation as an accessible model of post-acute care. These results support the integration of structured home-based tele-rehabilitation into routine post-COVID management, particularly in resource-limited healthcare systems.

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AUTHOR'S CONTRIBUTION:

Author	Contribution
Noman Ahmed	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision