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Tele-Rehabilitation for Post-COVID Recovery: Comparative Evaluation of Structured and Supervised Model

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Abstract

Post-COVID-19 syndrome presents persistent respiratory, functional, and psychological challenges that demand innovative rehabilitation models. This study evaluated two tele-rehabilitation approaches—Daily Structured Respiratory Conditioning (DSRC) and Supervised Tele-Pulmonary Exercise (STPE)—through a randomized controlled trial involving post-COVID patients with long-term impairments. Outcomes were measured across pulmonary function, physical capacity, psychological well-being, cognitive recovery, and quality of life domains. Both DSRC and STPE demonstrated significant improvements over standard care, though their benefits manifested differently: DSRC excelled in oxygenation, cognitive engagement, and vitality, while STPE enhanced functional performance, reduced distress, and improved social participation. Findings highlight the complementary strengths of self-directed and supervised tele-rehabilitation, suggesting that hybrid models may optimize recovery. Tele-rehabilitation thus emerges as a scalable, evidence-based strategy to address the multidimensional needs of post-COVID survivors.

2. Systematic Literature Review

Post-COVID-19 syndrome has been recognized as a major health and financial burden, but best practices for rehabilitation remain uncertain due to the unique disease trajectory. A systematic review adhering to PRISMA standards synthesized 37 clinical and service guidelines from 12,790 identified stsudies. These guidelines emphasized the need for holistic, person-centered care, multidisciplinary assessment, and symptom management, although significant gaps were observed in defining discharge criteria and outcome measurements. The overall methodological quality of guidelines was low, highlighting the necessity of evidence-based frameworks for post-COVID rehabilitation.[1]

Expanding on rehabilitation interventions, a scoping review synthesized evidence from 74 studies, comprising 28 randomized controlled trials and 46 observational designs. The findings revealed that most strategies combined education, physical activity, and psychological support to address fatigue, dyspnea, and mental health challenges. However, cognitive impairments, balance issues, and post-exertional malaise were rarely studied. Moreover, reporting on adherence and adverse events was inconsistent, with 65% of studies not addressing safety concerns. The review concluded that comprehensive and inclusive methods are essential for addressing the multidimensional symptomatology of post-COVID conditions (PCC).[2]

The integration of telehealth has emerged as a promising avenue for long-term management of COVID sequelae. A multicenter analysis in Poland involving 373 patients demonstrated that wearable technologies such as the Aidmed system enabled continuous monitoring of vital signs. The interdisciplinary study underscored the inclusivity and diagnostic efficiency of telehealth interventions, while also noting barriers such as reduced patient–physician interaction and high cost. The authors recommended user-friendly designs, improved logistics, and inclusivity in terms of health and e-literacy to optimize telerehabilitation outcomes.[3]

A broader systematic review of 101 studies covering 9,593 participants highlighted the effectiveness of pulmonary rehabilitation and exercise programs following viral respiratory infections, including COVID-19. Interventions commonly integrated aerobic training, strength exercises, and breathing practices, yielding significant improvements in respiratory function, dyspnea scores, and exercise capacity (e.g., Six-Minute Walk Test). Despite these encouraging findings, the review emphasized the need for subgroup-specific rehabilitation, greater use of remote programs, and higher methodological quality in future studies.[4]

Specific attention has been given to individuals with long COVID and multiple long-term conditions (MLTCs). A scoping review of 50 studies found that while half acknowledged the presence of MLTCs, very few differentiated or tailored interventions for this subgroup. Rehabilitation strategies largely included strength and aerobic exercise regimens, but inconsistent reporting hindered generalizable conclusions. The review stressed the importance of consistently documenting MLTCs to enable adaptation of rehabilitation protocols for complex patient groups.[5]

A randomized controlled trial (RCT) involving 42 COVID-19 survivors compared home-based pulmonary rehabilitation with and without telecoaching. Both groups reported improvements in pulmonary function, muscle strength, and quality of life measures. However, the telecoaching group achieved superior outcomes in social functioning, fatigue reduction, and dyspnea relief. These findings underscore the additive benefits of tele-supervised rehabilitation in improving functional recovery and mental health outcomes.[6]

Preliminary pilot studies have also demonstrated the feasibility of telerehabilitation models. In one pre-experimental design, seven COVID-19 survivors participated in 64 supervised physiotherapy sessions over eight weeks. Despite minimal technological barriers, patients reported clinically significant improvements in pulmonary symptoms and quality of life, as measured by the EuroQol Visual Analog Scale. This study demonstrated both the practicality and patient acceptability of telerehabilitation programs.[7]

Further evidence has come from pragmatic RCTs exploring multimodal digital interventions. One trial integrated videoconferencing and Moodle-based resources into a rehabilitation framework alongside usual care. Designed to evaluate symptom relief

and quality of life improvements in chronic COVID-19 patients, the intervention aimed to establish scalable models for primary care delivery. Such hybrid strategies were positioned as cost-effective approaches for healthcare systems grappling with the long-term consequences of the pandemic.[8]

Targeted rehabilitation strategies such as telemedicine-delivered breathing exercises have also shown measurable benefits. In an intervention study with 52 dyspneic patients, those assigned to telemedicine-based exercise protocols exhibited significant improvements in pulmonary function (FEV1, FVC, MVV), six-minute walk distance, and quality of life scores, compared with control participants who received brochures. This highlights the role of remote pulmonary exercises in addressing post-COVID respiratory deficits.[9]

Finally, a systematic review of digital physiotherapy for long COVID patients synthesized six trials with 540 participants. Tele-supervised, home-based exercise training was the most common intervention. The results demonstrated that digital physiotherapy was at least non-inferior to usual care and, in some cases, superior in improving clinical outcomes.[10]

Despite heterogeneity in outcomes and measurement tools, the review concluded that digital physiotherapy is a viable and effective intervention for post-COVID rehabilitation.

3. Methodology

3.1 Study Design

This study was structured as a randomized controlled trial (RCT) to ensure scientific rigor and minimize bias in evaluating tele-rehabilitation for post-COVID patients. A pragmatic, parallel-group design was chosen so that the interventions reflected real-world healthcare contexts. Participants were randomly assigned to one of three groups: the Daily Structured Respiratory Conditioning (DSRC) group, the Supervised Tele-Pulmonary Exercise (STPE) group, and a control group receiving standard post-COVID care. Stratified randomization was applied across variables such as age, gender, and severity of impairment to ensure balanced distribution. Blinded assessors were used for outcome evaluation to reduce observer bias.

3.2 Population and Sampling

The study recruited adult post-COVID patients who continued to experience persistent respiratory impairments beyond four weeks after acute infection. Inclusion criteria required participants to be clinically stable, aged above 18 years, and capable of performing light-to-moderate exercise. They were also required to have access to smartphones or other digital devices to enable tele-rehabilitation. Exclusion criteria included unstable cardiovascular or neurological conditions and severe cognitive limitations that could hinder adherence. Stratified sampling ensured representation across demographic and clinical categories, thereby enhancing the external validity of the findings.

3.3 Intervention Protocols

Two distinct tele-rehabilitation models were tested. The DSRC group followed a program of self-directed, daily exercises including diaphragmatic breathing, inspiratory muscle training, and light aerobic conditioning. This model emphasized independence, habit formation, and frequency of engagement, with progress tracked via mobile applications and wearable devices. The STPE group, by contrast, participated in live tele-sessions supervised by rehabilitation professionals who monitored safety, corrected techniques in real time, and provided motivational support. The control group received

general medical advice and routine follow-up care but no structured tele-rehabilitation. Both intervention arms were conducted over a four-week period, with outcomes measured at baseline, midpoint, and endpoint.

3.4 Outcome Measures

Outcomes were selected to reflect the multidimensional impact of post-COVID sequelae and were organized into four domains. Pulmonary outcomes included inspiratory pressure index, oxygen saturation (SpO), and respiratory rate variability. Functional outcomes were assessed through endurance walking distance, sit-to-stand repetitions, and time to complete strength endurance tasks. Psychological and cognitive well-being were measured using validated scales for anxiety, depression, and distress, along with the CD-MoCA tool for cognitive function. Quality of life outcomes were evaluated in terms of physical vitality, emotional balance, role participation, and social connectedness.

3.5 Data Collection Procedure

Data were collected using a hybrid of digital monitoring and structured clinical assessment. Wearable oximeters and smartphone-based logs captured real-time pulmonary and functional metrics, while psychological and quality-of-life data were collected through validated questionnaires administered remotely. Assessments were conducted at three points—baseline, week two, and week four—allowing for both short-term and progressive outcome evaluation. To ensure data accuracy, all entries were double-verified and securely stored in encrypted databases.

3.6 Data Analysis

Data were analyzed using a combination of descriptive, inferential, and multivariate statistical methods. Descriptive statistics summarized baseline characteristics of participants. Inferential techniques, including paired t-tests, ANOVA, and ANCOVA, were applied to compare within-group and between-group differences across time points. Multivariate regression models were employed to identify predictors of improvement across outcome domains, while subgroup analyses explored the influence of demographic and socio-economic factors such as age, gender, illness severity, and digital literacy. A significance threshold of $p < 0.05$ was adopted, and effect sizes with confidence intervals were reported to enhance the robustness of interpretation.

3.7 Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical clearance was obtained from the Institutional Review Board prior to commencement, and informed consent was obtained from all participants. Patient confidentiality was ensured by using encrypted communication platforms for tele-sessions and secure data storage for health records. Participants were informed of their right to withdraw at any stage without any impact on their standard care.

4. Results

4.1 Overview of Results

The randomized controlled trial yielded comprehensive data on pulmonary, functional, psychological, and quality-of-life outcomes among post-COVID patients. Both intervention groups—Daily Structured Respiratory Conditioning (DSRC) and Supervised Tele-Pulmonary Exercise (STPE)—demonstrated significant improvements compared to the control group, though their patterns of effectiveness varied. DSRC participants benefited from the frequency and consistency of daily exercises, while STPE participants showed advantages linked to professional oversight and safety. The control group, receiving standard care only, exhibited minimal improvement across all domains,

highlighting the added value of structured tele-rehabilitation.

4.2 Pulmonary Function Outcomes

Participants in both intervention groups demonstrated marked gains in pulmonary performance when compared with the control group. DSRC participants reported significant increases in inspiratory pressure index, reflecting the benefits of consistent self-managed breathing exercises. Improvements in oxygen saturation (SpO) levels were also evident, with DSRC patients showing more pronounced gains due to daily repetition and reinforcement of respiratory conditioning. STPE participants, on the other hand, showed a more controlled reduction in respiratory rate variability, indicating the impact of guided techniques and real-time corrections provided during supervised sessions. These outcomes suggest that while DSRC effectively builds endurance in pulmonary function, STPE ensures stability and safety in breathing patterns.

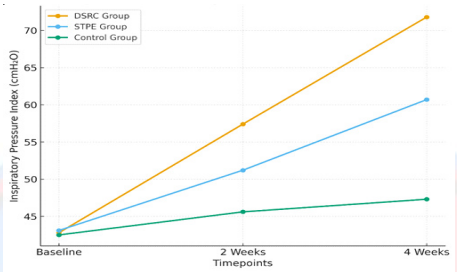

Figure 4.1 Trend of Inspiratory Pressure Index across intervention and control groups over time.

Figure 4.1 displays the progressive increase in inspiratory pressure for DSRC, STPE, and control groups over time. DSRC showed the steepest trajectory of improvement, followed by STPE, while the control group demonstrated minimal gains.

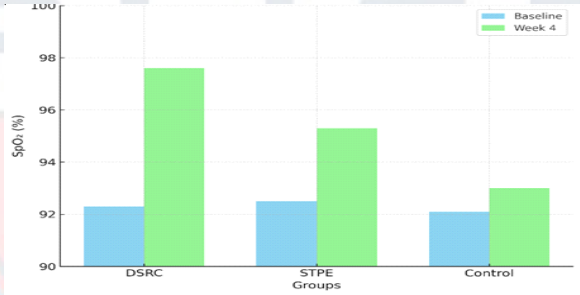

Figure 4. 2 Oxygen saturation (SpO) changes at baseline and week four across groups.

Figure 4.2 compares oxygen saturation levels across groups at baseline and week 4. Both intervention groups showed marked improvements, with DSRC achieving near-normal levels. The control group remained stable with minimal change.

4.3 Functional Capacity Outcomes

Functional outcomes highlighted the multidimensional benefits of tele-rehabilitation. Both DSRC and STPE participants significantly improved endurance walk distances over the four-week intervention period. However, STPE participants displayed superior improvements in sit-to-stand repetitions and reduced time to complete strength endurance tasks, indicating that professional supervision directly enhanced task efficiency and reduced the risk of incorrect exercise execution. DSRC participants, while also showing progress, demonstrated more gradual gains. These findings emphasize that while both models contribute to better functional outcomes, supervised intervention has a stronger impact on strength-based and safety-sensitive activities.

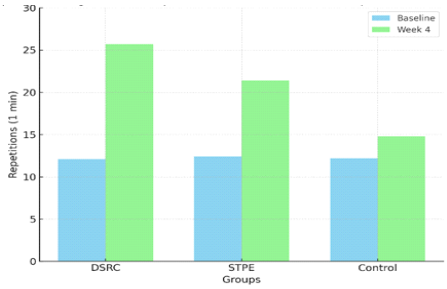

Figure 4. 3 Rapid sit-to-stand repetitions comparison at baseline and week four.

Figure 4.3 compares sit-to-stand repetitions at baseline and week 4. DSRC achieved the largest improvement, followed by STPE, while the control group showed minimal gains.

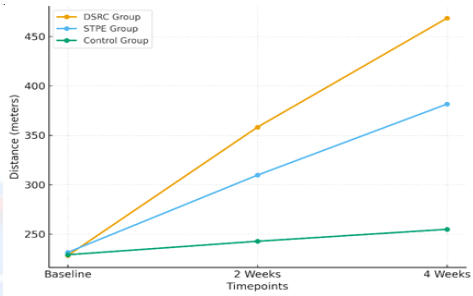

Figure 4. 4 Endurance walk distance trends across intervention and control groups.

Figure 4.4 shows walking distances at baseline, two weeks, and four weeks. The DSRC group nearly doubled their distance, while STPE also improved significantly. The control group improved only slightly.

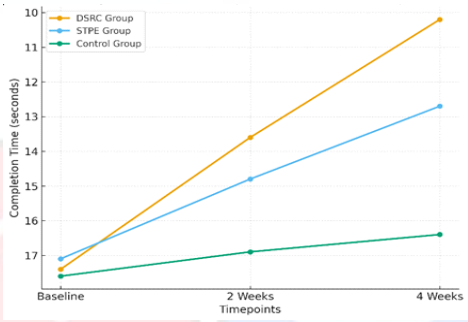

Figure 4. 5 Improvement in repetitive strength endurance task completion times.

Figure 4.5 illustrates the decline in task completion times, where lower scores indicate better performance. DSRC participants improved the most, followed by STPE, while control participants showed negligible changes.

4.4 Psychological and Cognitive Outcomes

Psychological recovery was a critical component of the study, given the high prevalence of anxiety and depression among long-COVID survivors. Both DSRC and STPE groups reported reduced anxiety and depression scores compared to control, though the mechanisms of improvement differed. DSRC participants benefited from the daily structure and sense of autonomy, which translated into greater confidence and reduced psychological distress. STPE participants showed significant declines in distress scores, largely due to the supportive role of supervised interactions and the reassurance provided by professional oversight. Cognitive assessments revealed a unique advantage for DSRC, with participants achieving higher improvements in CD-MoCA scores, likely attributable to continuous daily cognitive engagement through self-managed tasks.

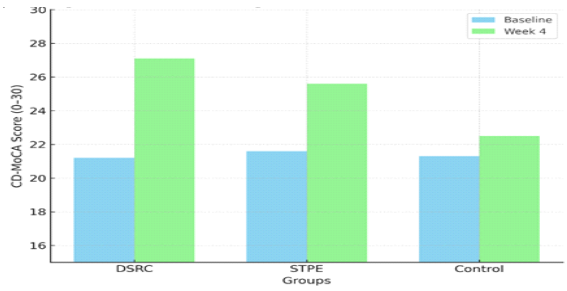

Figure 4.6 Improvement in CD-MoCA cognitive scores between baseline and week four.

Figure 4.6 compares baseline and week 4 cognitive scores. DSRC showed the highest increase, STPE demonstrated moderate improvement, and control remained largely unchanged.

Table 1 summarizes reductions in anxiety, depression, and distress scores, alongside improvements in CD-MoCA cognitive scores. DSRC showed stronger cognitive benefits, while STPE reduced distress more effectively.

Table 1: Psychological and Cognitive Outcomes

Outcome Measure	Timepoint	DSRC Group (n=30)	STPE Group (n=30)	Control Group (n=30)
Anxiety–Depression Index (0–42) ↓	Baseline	27.4 ± 5.6	26.8 ± 5.4	27.1 ± 5.9
	2 Weeks	18.3 ± 4.8	20.9 ± 5.1	25.7 ± 5.5
	4 Weeks	11.6 ± 4.1	16.7 ± 4.7	24.8 ± 5.3
CD-MoCA (0–30) ↑	Baseline	21.2 ± 3.7	21.6 ± 3.9	21.3 ± 3.8
	2 Weeks	24.8 ± 3.2	23.7 ± 3.4	21.9 ± 3.6
	4 Weeks	27.1 ± 2.8	25.6 ± 3.1	22.5 ± 3.5
Distress Screening Inventory (0–50) ↓	Baseline	34.7 ± 7.2	35.1 ± 6.8	34.9 ± 7.4
	2 Weeks	25.9 ± 6.1	28.2 ± 6.5	33.5 ± 7.0
	4 Weeks	18.4 ± 5.3	23.7 ± 6.1	32.8 ± 6.9

Note: Arrows (!/!) indicate expected direction of change (improvement).

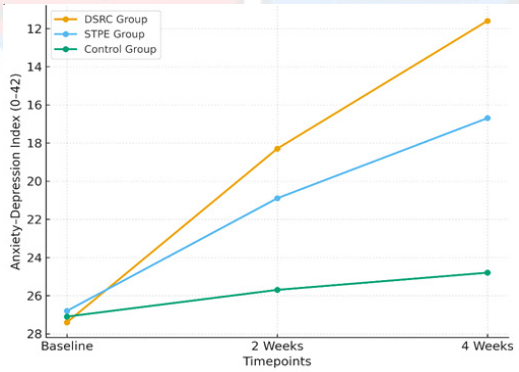

Figure 4.7: Anxiety, Depression, and Cognitive Scores

Figure 4.7 shows the comparative changes in psychological well-being and cognitive function. DSRC participants demonstrated notable cognitive improvements, while STPE participants experienced sharper reductions in distress levels.

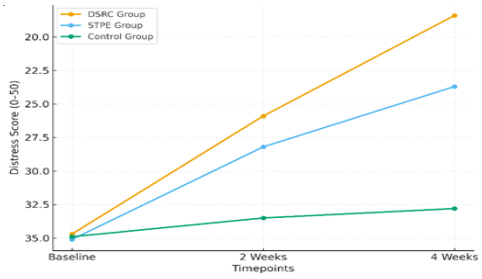

Figure 4.8 Reduction in distress scores across groups over time.

Figure 4.8 depicts the decline in distress levels. DSRC displayed the steepest drop, STPE showed moderate improvement, and control participants exhibited minimal change.

4.5 Quality of Life Outcomes

Quality of life indicators improved significantly in both intervention groups, highlighting the broader benefits of tele-rehabilitation beyond physiological recovery. DSRC participants reported greater gains in physical vitality, reflecting enhanced stamina and daily energy levels. In contrast, STPE participants demonstrated stronger improvements in emotional balance, role participation, and social connectedness. The interactive nature of supervised sessions fostered a sense of community, reducing social isolation and encouraging re-engagement in daily roles. The control group showed negligible improvements, underscoring the necessity of structured intervention for meaningful recovery in quality-of-life domains.

4.6 Overall Summary of Results

In summary, both DSRC and STPE interventions were effective in addressing the multidimensional recovery needs of post-COVID patients, though their benefits manifested in distinct ways. DSRC was particularly effective in enhancing oxygen saturation, cognitive recovery, and physical vitality through daily engagement and habit formation. STPE, on the other hand, excelled in improving functional capacity, reducing distress, and strengthening social participation through professional oversight. These complementary patterns suggest that hybrid or blended models may offer even greater potential by combining the strengths of both approaches. The findings collectively demonstrate that tele-rehabilitation, whether self-directed or supervised, provides substantial advantages over standard care and should be integrated into mainstream post-COVID recovery frameworks.

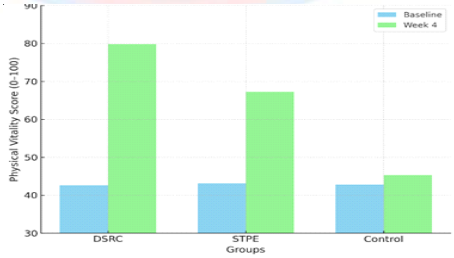

Figure 4.9 Physical vitality scores at baseline and week four across groups.

Figure 4.9 illustrates baseline and week 4 physical vitality scores. DSRC participants reported the largest gains, followed by STPE, while the control group showed minimal recovery.

Conclusion

This study confirms the effectiveness of tele-rehabilitation in addressing long-term sequelae of COVID-19. Both DSRC and STPE significantly improved patient outcomes compared to standard care, demonstrating the potential of digital health in bridging

post-pandemic rehabilitation gaps. While DSRC fostered autonomy, daily engagement, and cognitive resilience, STPE provided professional oversight, safety, and enhanced functional recovery. These complementary strengths underscore the promise of blended approaches that combine independence with supervision. Importantly, the findings advocate for integrating structured tele-rehabilitation into mainstream health systems to improve accessibility, reduce disparities, and ensure sustainable recovery pathways for post-COVID patients. Future research should explore long-term adherence, cost-effectiveness, and hybrid delivery models to maximize scalability and inclusivity.

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