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A Mobile App–Delivered Pulmonary Rehabilitation Model for Chronic Respiratory Disease: Clinical Outcomes from A Prospective Study

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Abstract:
Background: *Chronic respiratory diseases (CRDs) significantly impair quality of life and functional capacity. While pulmonary rehabilitation (PR) is an established treatment, access to traditional programs remains limited. This study evaluated the effectiveness of a digitalized home-based PR program using a mobile application.*
Methods: *A prospective cohort study was conducted on 80 adults with stable CRDs who completed an 8-week digital PR program. The mobile app included educational modules, exercise guidance, and virtual consultations. Pre- and post-intervention assessments included spirometry, the Six-Minute Walk Test (6MWT), and validated clinical scales such as the SGRQ and MMRC.*
Results: *Post-intervention, participants showed significant improvements in FEV1 (from 41.3% to 50.6%, p=0.0003) and FEV1/FVC ratio (p=0.0106). The mean 6MWT distance increased by 69 meters (p<0.0001). Quality-of-life scores, dyspnoea scales, and CAT scores also improved significantly. No major adverse events were reported.*
Conclusion: *Digitalized home-based PR is a clinically effective and accessible intervention for improving pulmonary function, exercise capacity, and quality of life in patients with CRDs. It offers a scalable alternative to conventional PR, especially in resource-limited settings.*
Keywords: *chronic respiratory disease, pulmonary rehabilitation, mobile health, telerehabilitation, digital health*

INTRODUCTION:

Chronic respiratory diseases (CRDs), including chronic obstructive pulmonary disease (COPD), asthma, and interstitial lung diseases, are leading causes of morbidity and mortality worldwide (1). These conditions are associated with persistent respiratory symptoms, airflow limitation, and progressive functional decline, significantly impairing patients' quality of life (2). Globally, CRDs continue to pose a major public health challenge, driven by factors such as tobacco use, environmental pollutants, and occupational exposures (3, 4).

Pulmonary rehabilitation (PR) has been established as a cornerstone in the management of CRDs. It is a structured, evidence-based intervention that combines supervised exercise training, patient education, and psychosocial support to reduce symptoms, enhance functional capacity, and improve health-related quality of life (1, 2). Numerous studies have demonstrated the efficacy of PR in reducing exacerbation frequency, decreasing hospital admissions, and lowering healthcare costs (5-7). Despite these benefits, access to traditional, facility-based PR remains limited due to barriers including geographic inaccessibility, transportation difficulties, and time constraints (8, 9).

The emergence of digital health platforms offers a promising solution to overcome these challenges. Digitalized pulmonary rehabilitation, delivered via mobile applications or telehealth interfaces, enables patients to receive personalized, guided rehabilitation remotely. This model is particularly relevant in the post-COVID-19 era, where minimizing face-to-face interactions while maintaining care continuity is crucial (10). Recent studies suggest that home-based and digital PR interventions are not only feasible but also produce comparable outcomes to conventional centre-based models in improving exercise capacity and dyspnoea (11-13).

Key advantages of digital PR include enhanced accessibility for patients in rural or underserved areas, improved adherence through app-based reminders and monitoring, and cost-effectiveness by reducing the need for frequent hospital visits (8, 14, 15). However, despite growing interest, the evidence base for digital PR remains limited, especially in the Indian healthcare context. Challenges such as variable digital

literacy, inconsistent internet access, and lack of integration into existing care pathways hinder widespread adoption (16).

Given this background, the present study aimed to evaluate the effectiveness of an eight-week digitalized home-based pulmonary rehabilitation program in improving the functional capacity and quality of life in patients with CRDs. Using validated tools such as the Six-Minute Walk Test (6MWT) and the St. George's Respiratory Questionnaire (SGRQ), the study also explored changes in pulmonary function, symptom burden, and patient engagement. By assessing both clinical and operational outcomes, this research seeks to strengthen the evidence supporting digital PR as a scalable, sustainable model for chronic respiratory care in real-world settings.

MATERIALS AND METHODS:

Study Design and Setting:

This prospective cohort study was conducted at Saveetha Medical College, Chennai, over a period of 18 months. The objective was to assess the effectiveness of a digitalized home-based pulmonary rehabilitation (PR) program in improving the quality of life and functional capacity in patients with chronic respiratory diseases (CRDs).

Ethical clearance:

Ethical approval for the study was obtained from the Institutional Ethics Committee of Saveetha Medical College and Hospital (IEC Reference Number: 013/09/2024/IEC/SMCH), in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment, ensuring that they were fully aware of the study's purpose, procedures, potential risks, and their right to withdraw at any stage without consequence.

Sample Size and Study Population:

A total of 80 patients aged ≥18 years with a confirmed diagnosis of CRDs (including asthma, COPD, bronchiectasis, or interstitial lung disease) were enrolled using convenience sampling. The minimum required sample size was calculated to be 80 based on assumed proportions ($p1 = 0.2$, $p2 = 0.4$) with a confidence level of 95% and power of 80%.

Eligibility Criteria:

Participants included in the study were adults aged 18 years or older with clinically stable chronic respiratory diseases (CRDs) who were willing to adhere to the home-based pulmonary rehabilitation program. Patients were excluded if they were critically ill, required ventilator support, or had comorbidities such as recent myocardial infarction, cerebrovascular accident, active tuberculosis, or heart failure with an ejection fraction below 40%. Individuals who were unwilling to participate were also excluded.

Intervention: Digitalized Home-Based PR Program

Participants followed an 8-week digitalized PR program delivered through a custom-built mobile application, which included educational content, exercise regimens, and virtual consultations.

Mobile Application Features:

The mobile application featured a user-friendly interface available in both Tamil and English, designed to support patient engagement and clinical monitoring. It included a Patient Profile section with condition-specific educational videos and training materials (Supplementary Figure 1). Patients could schedule real-time video consultations through the Appointment Booking feature (Supplementary Figure 2). Interactive elements such as chat support, push notifications, and reminders enhanced adherence. The app also integrated quality-of-life assessment tools, including the St. George's Respiratory Questionnaire in both languages (Supplementary Figure 3). Clinicians accessed a dedicated provider dashboard to manage appointments, update patient records, and monitor progress (Supplementary Figures 4, 4, and 6).

Measurement Tools and Outcomes:

Pre- and post-intervention assessments were conducted using standardized tools to evaluate clinical effectiveness. Pulmonary function was measured using spirometry, capturing Forced Expiratory Volume in one second (FEV1), Forced Vital Capacity (FVC), and the FEV1/FVC ratio. Functional exercise capacity was assessed through the Six-Minute Walk Test (6MWT). Symptom severity and quality of life were evaluated using validated clinical scales, including the Modified Medical Research Council (MMRC) Dyspnoea Scale, St. George's Respiratory Questionnaire (SGRQ), Modified Borg Dyspnoea Scale, COPD Assessment Test (CAT), Epworth Sleepiness Scale (ESS), and the STOP-BANG Questionnaire.

Study Workflow:
At baseline, demographic, clinical, and functional data were collected for all participants. This was followed by an eight-week structured home-based pulmonary rehabilitation program delivered via the mobile application. Upon completion, post-intervention assessments were conducted using the same tools to evaluate changes in clinical outcomes.

Statistical Analysis:
All data were analysed using standard statistical software. Pre- and post-intervention comparisons were performed using paired Student's t-tests for continuous variables. A p-value < 0.05 was considered statistically significant. Descriptive statistics summarized baseline demographics and clinical characteristics.

RESULTS:

Baseline Characteristics:
A total of 80 patients with chronic respiratory diseases were enrolled in the study. The cohort was predominantly male (85%, n=68), with the most common age group being 61–70 years (41.25%, n=33). Smoking history revealed that 40% were current smokers, 35% were former smokers, and 25% were non-smokers. Hypertension (15%) and diabetes mellitus (10%) were the most frequent single comorbidities, while 26.25% of patients had both diabetes and hypertension. Notably, 35% of participants reported no comorbid conditions (Table 1).

Pulmonary Function and Exercise Capacity:
Following the 8-week digitalized home-based pulmonary rehabilitation program, significant improvements were observed in key pulmonary function parameters. Mean Forced Vital Capacity (FVC) increased from 54.84% to 60.34% (p=0.0176), and Forced Expiratory Volume in one second (FEV1) rose from 41.3% to 50.6% (p=0.0003). The FEV1/FVC ratio improved significantly from 77.53% to 83.29% (p=0.0106). Although changes in FVC and FEV1 lung volumes, and FEF25-75% were observed, they did not reach statistical significance (Table 2).
Exercise tolerance, measured by the Six-Minute Walk Test (6MWT), demonstrated a significant increase in mean walking distance from 181.9 meters to 250.9 meters post-intervention ($p<0.0001$) (Table 2).

Arterial Blood Gas Status:
Improvements in arterial blood gas (ABG) profiles were noted after the intervention. As shown in Figure 1, 23.46% of patients achieved normal ABG levels post-intervention compared to none at baseline. The proportion of patients with two risk factors (2 RF) decreased markedly from 49.38% to 13.58%.

Clinical Symptom and Quality-of-Life Scales:
There were statistically significant improvements across all clinical scales used to evaluate symptom severity and quality of life (Table 3). The Modified Medical Research Council (MMRC) dyspnoea scale scores improved from a mean of 2.938 to 1.713 ($p<0.0001$), and the St. George's Respiratory Questionnaire (SGRQ) scores dropped from 31.83 to 22.66 ($p<0.0001$), indicating enhanced health-related quality of life.
Similarly, the Modified Borg Dyspnoea Scale and COPD Assessment Test (CAT) scores significantly improved ($p<0.0001$). The Epworth Sleepiness Scale (ESS) also showed a modest but significant improvement (p=0.0048). No significant change was observed in the STOP-BANG score (p=0.3204), suggesting minimal effect on sleep apnoea risk screening.

DISCUSSION:

This study demonstrates that a digitalized, home-based pulmonary rehabilitation (PR) program effectively improves exercise capacity, pulmonary function, and quality of life in patients with chronic respiratory diseases (CRDs). Delivered via a bilingual mobile application, the program combined structured exercise regimens, educational content, and virtual consultations—offering a flexible and patient-centred alternative to traditional facility-based PR.
One of the most significant outcomes was the improvement in the six-minute walk test (6MWT), with participants showing a mean increase of 69 meters after the intervention. This finding is consistent with previous studies by Fatma Arslan et al. (17), who emphasized the 6MWT's utility in assessing submaximal exercise tolerance, and Palmira Bernocchi et al. (18), who reported a 60-meter improvement through telerehabilitation in older adults with COPD and CHF. Michele Vitacca et al. (19) reported a slightly

higher gain in hospital-based settings (81.9 meters), suggesting that digital PR offers comparable improvements in functional capacity.

The program also led to a significant reduction in dyspnoea, a major symptom limiting daily activities in CRD patients. Improvements in MMRC scores mirror those reported by Busaba ChuatraKoon et al. (20), who found reduced dyspnoea in COPD patients undergoing home-based PR with balance training. Lin-Yu Liao et al. (21) similarly demonstrated symptom relief in elderly patients following structured rehabilitation, reinforcing the broader applicability of such interventions.

Pulmonary function, as measured by Forced Expiratory Volume in one second (FEV1) and FEV1/FVC ratio, improved significantly post-intervention, indicating better airflow and lung mechanics. These results align with findings by Nicole Marquis et al. (22), who reported similar outcomes using in-home telerehabilitation, and Naoki Ijiri et al. (23), who linked improved FEV1 to reduced exercise-induced desaturation in COPD patients.

Patient-reported outcomes, particularly on the St. George's Respiratory Questionnaire (SGRQ), showed meaningful reductions in symptom burden and psychosocial impact. These changes are in line with improvements documented by Ignacio A. Gaunaurd et al. (24) in idiopathic pulmonary fibrosis patients and Narelle S. Cox et al. (25), who found that telerehabilitation was as effective as centre-based PR in enhancing quality of life.

A core strength of this study was the use of a mobile application that enabled personalized care, real-time monitoring, and bilingual content access. These features likely contributed to high engagement and adherence, echoing the conclusions of Atsuyoshi Kawagoshi et al. (26), who demonstrated improved physical activity through digital feedback, and Janet McDowell et al. (27), who reported enhanced quality of life via telemonitoring.

Three key takeaways emerge. First, digital PR significantly improves exercise tolerance, lung function, and quality of life in patients with CRDs. Second, mobile platforms improve accessibility and adherence, especially for those in remote or resource-limited settings. Third, digital PR presents a scalable, sustainable model that reduces the strain on healthcare infrastructure.

Clinically, these findings support the integration of digital PR into standard management protocols for CRDs. Horton et al. (28) highlighted its cost-effectiveness, while Zanaboni et al. (29) demonstrated long-term reductions in hospitalizations and emergency visits. To ensure successful adoption, clinicians should tailor programs to individual needs, promote digital literacy, and offer ongoing support. As Cox et al. (30) recommend, systemic integration of telerehabilitation into clinical pathways is crucial for long-term sustainability.

CONCLUSION:

Digitalized home-based pulmonary rehabilitation is a clinically effective and patient-centric intervention that significantly enhances functional capacity, lung function, and health-related quality of life in patients with chronic respiratory diseases. By leveraging technology to overcome logistical, financial, and geographic barriers, this model enables broader access to care while supporting long-term adherence and self-management. The results of this study support the integration of digital PR into routine practice and health policy, particularly in settings where traditional PR access is limited.

Moving forward, expanding the scope of digital PR through AI-based personalization, wearable sensor integration, and multilingual content delivery could further optimize patient outcomes and program scalability. While limitations such as digital access and adherence monitoring must be addressed, the findings provide a compelling case for reimagining chronic disease management through digital innovation.

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Tables and Figures:

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population

Category	**Subcategory**	**Number of Patients (n)**	**Percentage** (%)
Gender	Male	68	85
	Female	12	15

Age Group	21–30	1	1.25
	31–40	2	2.5
	41–50	7	8.75
	51–60	18	22.5
	61–70	33	41.25
	71–80	12	15
	>80	7	8.75
Smoking History	Current Smoker	32	40
	Former Smoker	28	35
	Non-Smoker	20	25
Co-Morbidities	None	28	35
	Hypertension (SHTN)	12	15
	Diabetes Mellitus (T2DM)	8	10
	Tuberculosis (TB)	4	5
	Coronary Artery Disease (CAD)	1	1.25
	Obstructive Sleep Apnoea (OSA)	1	1.25
	SHTN + TB	2	2.5
	T2DM + SHTN	21	26.25
	T2DM + CAD	1	1.25
	T2DM + SHTN + CAD	2	2.5
	Nil	28	35

Table 2: Comparison of Pre and Post Spirometry and Pulmonary Function Tests

Measure	Stage	Mean	SD	t-value	p-value
FVC (%)	**Pre**	54.84	14.25	2.399	0.0176
	Post	60.34	14.75		
FVC Lung Volume (L)	**Pre**	1.76	0.4801	1.57	0.1183
	Post	1.883	0.5131		
FEV1 (%)	**Pre**	41.3	14.42	3.656	0.0003
	Post	50.6	17.6		
FEV1 Lung Volume (L)	**Pre**	1.151	0.4773	1.87	0.0633
	Post	1.296	0.5056		
FEF25-75 (%)	**Pre**	27.51	25.2	0.9171	0.3605
	Post	31.28	26.68		
FEF25-75 Lung Volume (L)	**Pre**	0.7031	0.7281	1.177	0.2411
	Post	0.8468	0.8135		
PFT: FEV1/FVC (%)	**Pre**	77.53	16.03	2.586	0.0106
	Post	83.29	11.84		
6MWT (m)	**Pre**	181.9	48.73	7.112	<0.0001
	Post	250.9	71.8		

Table 3: Comparison of Pre- and Post-Intervention Scores Across Six Clinical Scales Following 8 Weeks of Treatment

Measure	Stage	Mean	SD	t-value	p-value
MMRC	**Pre**	2.938	0.7521	19.12	<0.0001
	Post	1.713	0.6787		
ST George Questionnaire	**Pre**	31.83	8.647	13.99	<0.0001
	Post	22.66	6.923		
Modified Borg Dyspnoea Scale	**Pre**	6.275	1.432	19.85	<0.0001

	Post	3.3	1.513		
(CAT)	**Pre**	22.71	4.876	16.8	<0.0001
	Post	17.48	4.231		
(ESS)	**Pre**	1.125	3.509	2.904	0.0048
	Post	0.9	2.844		
Stop-Bang	**Pre**	2.363	0.7334	1	0.3204
	Post	2.35	0.7309		

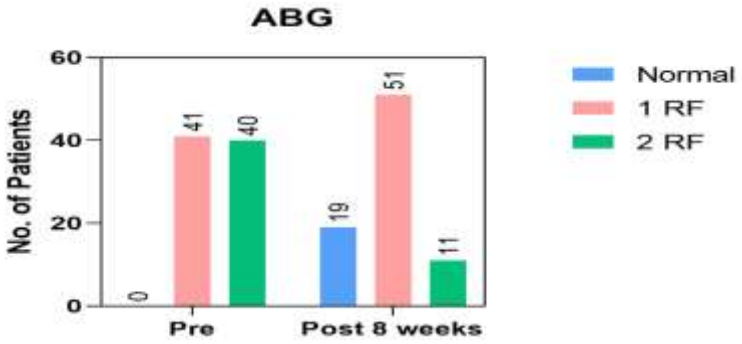

Figure 1: ABG comparison between Pre- and Post-Intervention Scores Across Six Clinical Scales Following 8 Weeks of Treatment

Abbreviations:

ABG – Arterial Blood Gas
AI – Artificial Intelligence
CAT – COPD Assessment Test
CHF – Congestive Heart Failure
COPD – Chronic Obstructive Pulmonary Disease
CRDs – Chronic Respiratory Diseases
ESS – Epworth Sleepiness Scale
FEF25-75% – Forced Expiratory Flow at 25–75% of the pulmonary volume
FEV1 – Forced Expiratory Volume in One Second
FVC – Forced Vital Capacity
IEC – Institutional Ethics Committee
MMRC – Modified Medical Research Council (Dyspnoea Scale)
PR – Pulmonary Rehabilitation
SGRQ – St. George's Respiratory Questionnaire
STOP-BANG – Snoring, Tiredness, Observed apnoea, high blood Pressure, BMI, Age, Neck circumference, Gender (Sleep apnoea Screening Tool)
6MWT – Six-Minute Walk Test