

Evaluation of the Effects of Hospital-Community-Home (3H) Digital Management on Self-Management Behaviors among Patients with Chronic Obstructive Pulmonary Disease

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Abstract

Objective: This study aimed to evaluate the clinical efficacy of a Hospital-Community-Home (3H) digital management platform in improving self-management behaviors of patients with chronic obstructive pulmonary disease (COPD), identify deficiencies and bottlenecks encountered during real-world implementation, and provide evidence-based references for optimizing digitalized management strategies for COPD.

Methods: A COPD digital management platform was constructed based on 5G information technology to establish the integrated 3H service model, supported by a joint management team consisting of respiratory specialists and community general practitioners. A single-group pre-post self-controlled trial was conducted. A total of 1,000 patients meeting the diagnostic criteria outlined in the Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2019 were recruited on a voluntary basis and stratified into GOLD A, B, C, and D subgroups. All participants received standardized continuous management for 14 months. The platform dynamically collected baseline demographic data, medication adherence indicators (regular refill frequency and duration of continuous medication), histories of acute exacerbations, and responses to a disease awareness questionnaire. Retrospective statistical analyses were performed using SPSS 26.0 software.

Results: Ultimately, 985 patients completed the full 14-month digital management program. Patients classified as GOLD A and B accounted for 86.93% of the total cohort, substantially exceeding the proportion of GOLD C and D patients (13.07%). In terms of age distribution, 84.67% of participants were aged 50 - 79 years, 6.19% were younger than 50 years, and 9.14% were aged ≥80 years; the 60-69-year age bracket dominated the GOLD A subgroup. Urban residents constituted 69.04% of the study population versus 30.96% rural patients, with urban patients demonstrating a markedly higher monthly regular medication refill rate (90.29% vs. 12.79%). Only 30.86% of all participants maintained standardized continuous medication for more than 12 months, with subgroup proportions of 15.86% (A), 35.26% (B), 69.50% (C), and 57.14% (D), respectively. Following implementation of the digital platform intervention, patients' medication adherence rose significantly from 23.35% to 66.29%, median disease awareness scores increased from 2 to 6 points, and the total number of patients experiencing acute exacerbations declined from 20 to 11 (all $P < 0.01$).

Conclusion: COPD patients enrolled in digitalized management exhibit significant disparities in disease severity stratification, urban-rural distribution, and long-term regular medication compliance. The 3H integrated digital management platform effectively standardizes patients' self-management behaviors, enhances medication adherence and disease cognition, and reduces the risk of COPD acute exacerbations.

Keywords: Chronic Obstructive Pulmonary Disease; 3H Digital Management Platform; Self-Management Behaviors; Effectiveness Evaluation

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Introduction

Chronic obstructive pulmonary disease (COPD) affects over 400 million individuals globally and ranks among the world's top three leading causes of mortality [1,2]. Sustained exposure to risk factors coupled with population aging is projected to drive a persistent rise in COPD-related disease burden over the coming decades, posing a severe global public health crisis. The World Health Organization estimates that China bears the world's highest COPD mortality rate, with new cases and COPD-associated deaths expected to surge by approximately 1.5-fold within the next 25 years [3,4]. Against this backdrop of worsening respiratory chronic disease prevention and control, the Chinese State Council has prioritized chronic respiratory disease management and incorporated it into the Healthy China 2030 Outline.

Conventional chronic disease management models predominantly rely on outpatient follow-up and offline health education, which are hampered by low follow-up efficiency, fragmented care continuity, and insufficient patient disease awareness and self-management capacity. The deep integration of 5G, big data, Internet of Things and digital technologies with healthcare has catalyzed transformative changes in chronic disease management. In 2018, the General Office of the State Council issued a policy document encouraging medical institutions to leverage internet technology to build integrated online-offline medical service systems covering pre-consultation, in-consultation, and post-consultation care [5]. In the same year, Ningxia Hui Autonomous Region was designated China's first national demonstration zone for Internet Plus Healthcare. Despite intelligent and digital management emerging as a core developmental direction for respiratory chronic disease care, real-world implementation frameworks, sustainable operation mechanisms, and optimization experience remain scarce, requiring further refinement of management workflows and intervention protocols. While mature remote monitoring and self-management systems for COPD supported by internet technology have been established internationally, domestic research lacks sufficient real-world data on long-term digital management outcomes. In response to relevant national policies and unmet clinical needs, our hospital launched a dedicated COPD digital management platform in 2019, enrolling 1000 clinically diagnosed COPD patients and delivering long-term standardized care assisted by wearable monitoring devices.

Aim of the Study

This study aimed to quantify the intervention effects of the 3H digital management platform on COPD patients' self-management behaviors, generating regional practical evidence to inform optimized nationwide digitalized respiratory chronic disease management models.

Subjects and Methods

Study population and stratification

Between October 2020 and December 2021, 1000 patients diagnosed with COPD per the Global Initiative for Chronic Obstructive Lung Disease 2019 (GOLD 2019) criteria were consecutively recruited and stratified into GOLD A, B, C, and D subgroups based on pulmonary function testing. All participants provided written informed consent and received standardized digital management for a 14-month follow-up period. All analytical data were extracted from the COPD digital management platform and on-site project records.

Inclusion criteria:

1. Confirmed COPD diagnosis consistent with GOLD 2019 clinical guidelines [6];
2. Preserved clear consciousness and intact verbal communication ability, capable of completing online follow-up, wearable device monitoring, and questionnaire assessments;
3. Voluntary provision of informed consent and commitment to full 14-month longitudinal follow-up.

Exclusion criteria: Patients unable to complete questionnaire surveys, wearable device fitting and data transmission, or scheduled periodic follow-up were excluded.

GOLD stratification standards

Subgroup assignment was determined by the modified Medical Research Council (mMRC) dyspnea scale, COPD Assessment Test (CAT), number of acute exacerbations within the preceding year, and pulmonary function staging [6]:

- Group A: Minimal symptoms (mMRC 0-1 or CAT < 10), ≤ 1 acute exacerbation in the prior year without hospitalization;
- Group B: Severe symptoms (mMRC ≥ 2 or CAT ≥ 10), ≤ 1 acute exacerbation in the prior year without hospitalization;
- Group C: Minimal symptoms, ≥ 2 acute exacerbations annually, or ≥ 1 exacerbation requiring hospital admission;
- Group D: Severe symptoms, ≥ 2 acute exacerbations annually, or ≥ 1 exacerbation requiring hospital admission.

Data collection indicators

Baseline demographic and clinical data

Collected variables included gender, age, residential registration type (urban/rural), pulmonary function metrics (predicted FEV₁%, FEV₁/FVC ratio), disease duration, and frequency of acute exacerbations in the preceding 12 months.

Process monitoring indicators during management

1. Medication behaviors: Inhaler regimen (ICS+LABA, LABA+LAMA, triple ICS+LABA+LAMA), prescription refill cycle (1-month, 2-month, 3-month, irregular), duration of uninterrupted standardized medication (< 3 months, 3 - 6 months, 6 - 12 months, > 12 months), and overall medication adherence;
2. Remote real-time monitoring data: Peripheral blood oxygen saturation (SpO₂), heart rate, respiratory rate captured via wearable sensors; predefined abnormal alert threshold (SpO₂ < 90%) and corresponding clinical intervention records;
3. Healthcare service delivery metrics: Number of home visits, valid telephone follow-ups lasting ≥ 3 minutes, scheduled outpatient appointments and attendance rates, utilization volume and daily data upload compliance of Clip-On/Ellipta smart inhaler monitoring devices, and participation statistics for online/offline COPD health education sessions;
4. Disease awareness: Total scores and stratified grading from a self-designed COPD knowledge questionnaire.

Intervention protocols

Digital platform construction

Leveraging 5G communication infrastructure, a hospital-based COPD digital management platform was established within the Department of Respiratory and Critical Care Medicine, alongside an interconnected hospital-community data sharing system enabling real-time synchronization of pulmonary function reports and personalized therapeutic regimens. Integrated monitoring hardware included remote sleep apnea screening devices, portable fingertip pulse oximeters, ambulatory spirometers, and home non-invasive ventilators. The collaborative 3H care framework was formalized through partnerships between tertiary hospital respiratory departments, grassroots community health service centers, and patients' home-based self-monitoring systems. The three-tier framework is defined as: tertiary hospital respiratory diagnosis and treatment centers (Hospital), primary community medical service institutions (Hospital), and COPD patient self-management at home (Home).

Multidisciplinary management team

The integrated care team consisted of tertiary hospital respiratory specialists and community general practitioners. Specialists were responsible for remote telemedicine consultations, individualized therapeutic adjustment, and personalized pulmonary rehabilitation

plan formulation, while community general practitioners delivered routine follow-up, on-site medication guidance, and continuous physiological index monitoring. Standardized training covering spirometry operation and comprehensive COPD clinical management was provided to all community general practitioners prior to program initiation.

Standardized 3H digital management interventions

1. **Pharmacotherapy management:** Hands-on inhaler technique training and real-time remote video guidance were provided to ensure patients mastered correct inhaler administration techniques;
2. **Remote physiological monitoring:** All participants were equipped with wearable finger pulse oximeter rings to continuously record SpO₂, heart rate, and respiratory rate, with data auto-synchronized to the central digital platform. Clinicians delivered targeted intervention recommendations within one hour upon detection of abnormal SpO₂ values (< 90%);
3. **Individualized pulmonary rehabilitation:** Customized rehabilitation training regimens were assigned to each patient, with monthly efficacy assessments and regimen adjustments conducted by certified respiratory rehabilitation therapists;
4. **Monthly comprehensive patient evaluations:** All participants received integrated clinical assessments every 30 days, with immediate clinical intervention triggered for any out-of-threshold monitoring parameters.

Assessment of COPD disease awareness

A self-designed 31-item questionnaire was administered to all participants pre- and post-intervention to quantify COPD-related knowledge, with a total maximum score of 30 points. The questionnaire covered five core domains: (1) disease fundamentals (COPD definition, pathogenesis, risk factors); (2) symptom recognition (typical and atypical manifestations, warning signs of acute exacerbation); (3) treatment adherence awareness (clinical value of inhaled medication, long-term oxygen therapy, and rehabilitation); (4) daily self-management (tobacco cessation, breathing training, nutritional and physical activity regulation); (5) emergency management of exacerbations (alarm symptoms, appropriate timing for hospital presentation, home first aid protocols).

Scoring rubrics: Full points awarded for correct single-choice and true/false responses, zero points for incorrect or unanswered items; partial points assigned for partially correct multiple-choice responses, zero points for fully incorrect or blank submissions. Awareness levels were stratified into three tiers: low cognition (total score < 15, insufficient core disease knowledge requiring foundational health education), moderate cognition (15 - 24 points, adequate basic knowledge with targeted gaps requiring supplementary training), high cognition (≥ 25 points, comprehensive disease mastery with primary intervention focused on sustaining long-term self-management adherence). Uniform questionnaire administration training was completed by all platform nurses to eliminate inter-rater measurement bias.

Data collection and statistical analysis

All baseline demographics, medication refill records, continuous medication compliance, COPD knowledge questionnaire scores, and acute exacerbation frequency data were extracted from the integrated COPD digital management platform. Statistical analyses were performed using SPSS 26.0 software. Count data were presented as case numbers and percentages, with intergroup comparisons conducted via Pearson's χ^2 test; Fisher's exact test was applied for contingency tables with expected frequencies < 5. Pre-post paired binary outcomes were analyzed using the McNemar test, with continuity correction for discordant pairs ($b+c < 40$) and exact binomial two-tailed tests for discordant pairs < 10. Measurement data were subjected to Shapiro-Wilk normality testing; normally distributed variables were reported as mean $\pm$ standard deviation (Mean $\pm$ SD), with paired t-tests for pre-post within-group comparisons and one-way analysis of variance (ANOVA) for multi-group comparisons. Non-normal data were expressed as median (interquartile range, $M(P_{25}, P_{75})$), with Wilcoxon signed-rank tests for paired comparisons and Kruskal-Wallis H tests for multiple independent group comparisons. All statistical hypothesis tests were two-tailed with a significance threshold of $\alpha = 0.05$; $P < 0.05$ was defined as statistically significant.

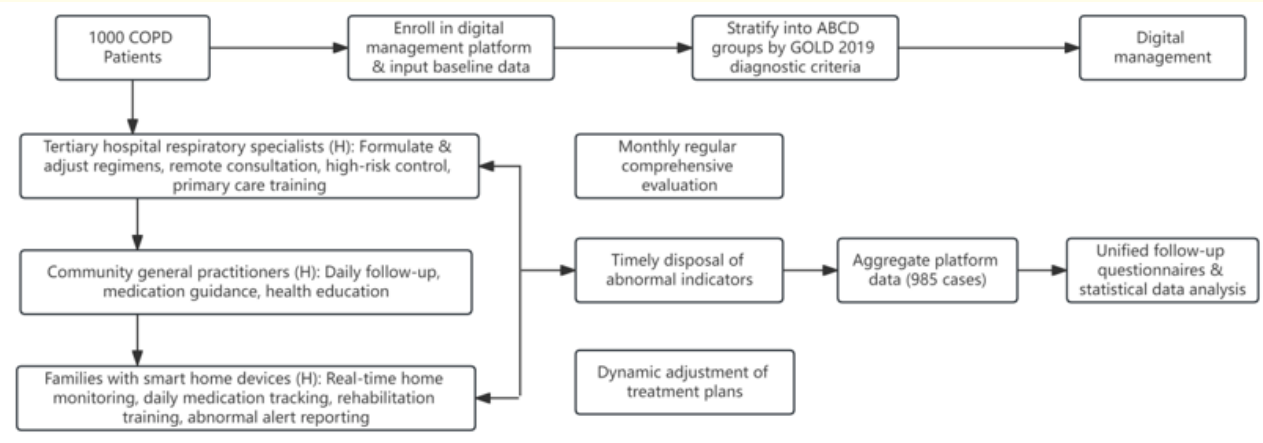


Figure 1: Implementation flowchart.

Results

Baseline clinical characteristics of study participants

A total of 1000 COPD patients were initially enrolled. Fifteen participants withdrew from the study during follow-up (1 death, 3 voluntary withdrawals, 11 lost to follow-up), leaving 985 patients who completed the full 14-month standardized digital management program. Subgroup distribution was as follows: Group A (n = 454, 46.10%), Group B (n = 397, 40.30%), Group C (n = 127, 12.89%), Group D (n = 7, 0.71%). The cohort contained marginally more male patients (n = 528) than female patients (n = 457), with a male-to-female ratio of 1.16:1. Age distribution was dominated by participants aged 50 - 79 years (n = 834, 84.67%), followed by patients aged ≥ 80 years (n = 90, 9.14%) and those younger than 50 years (n = 61, 6.19%). Age stratification differed across GOLD subgroups: the 60-69-year bracket predominated in Group A, while patients aged 70 - 79 years constituted the largest proportion of Groups B, C, and D (Table 1).

Indicator	Group A (n = 454)	Group B (n = 397)	Group C (n = 127)	Group D (n = 7)	Test Statistic	P Value
Gender (n)						
Male	218	222	82	6	$\chi^2 = 15.60$	0.017
Female	236	175	45	1		
Height (cm)	164.6 ± 7.88	164.3 ± 7.21	163.7±7.99	164.8 ± 7.27	F = 0.118	0.946
Age						
< 50	43	18	0	0	Fisher's exact test	<0.001
50~59	87	40	11	1		
60~69	161	138	49	1		
70~79	133	158	52	3		
≥80	30	43	15	2		
Residential area						
Urban	254	294	125	7	Fisher's exact test	<0.001

Rural	200	103	2	0		
Smoking status (n)						
Active smoking	65	37	9	3	Fisher's exact test	<0.001
Passive smoking	46	23	7	2		
No smoking history	343	337	111	2		
Pre-intervention disease awareness score	2 (1,2)	2 (1,2)	2 (1,3)	2 (1,3)	H = 2.31	0.511

Table 1: Baseline demographic and clinical characteristics of participants.

Medication refill patterns across all participants

All patients received standardized inhaled maintenance regimens (dual ICS+LABA, dual LABA+LAMA, or triple ICS+LABA+LAMA). Among the total cohort, 653 patients (66.29%) refilled prescriptions monthly, 29 (2.94%) refilled every two months, 17 (1.73%) refilled every three months, and 286 (29.04%) exhibited irregular refill schedules (Table 2).

Subgroup	Total Patients	Monthly Refill	Bi-monthly Refill	Tri-monthly Refill	Irregular Refill
Group A	454	250	7	10	187
Group B	397	287	13	5	92
Group C	127	111	8	2	6
Group D	7	5	1	0	1
Total	985	653	29	17	286

Table 2: Medication refill frequency by GOLD subgroup (n).

Stratified medication refill patterns: Urban vs. rural patients

The study cohort included 680 urban residents (69.04%) and 305 rural residents (30.96%). Urban patients demonstrated a vastly higher monthly regular refill rate relative to rural counterparts (90.29% vs. 12.79%) (Table 3).

Subgroup	Urban Patients				Rural Patients			
	Monthly Refill	Bi-monthly Refill	Tri-monthly Refill	Irregular Refill	Monthly Refill	Bi-monthly Refill	Tri-monthly Refill	Irregular Refill
Group A	233	7	8	6	17	0	2	181
Group B	266	13	5	10	21	0	0	82
Group C	110	8	2	5	1	0	0	1
Group D	5	1	0	1	0	0	0	0
Total	614	29	15	22	39	0	2	264

Table 3: Medication refill frequency stratified by urban and rural residence.

Long-term continuous standardized medication compliance

Of the 985 participants, only 304 (30.86%) maintained uninterrupted standardized inhaled therapy for more than 12 months; 138 (14.01%) persisted for 6 - 12 months, 156 (15.84%) for 3 - 5 months, and 387 (39.29%) for less than 3 months. The proportion of patients maintaining > 12 months of consistent medication across subgroups was 15.86% (Group A), 35.26% (Group B), 68.50% (Group C), and 57.14% (Group D) (Table 4 and figure 2).

Subgroup	< 3 Months	3 - 5 Months	6 - 11 Months	> 12 Months
Group A	221	122	39	72
Group B	149	30	81	140
Group C	16	6	18	87
Group D	1	0	2	4
Total	387	156	138	304

Table 4: Duration of continuous standardized medication by GOLD subgroup.

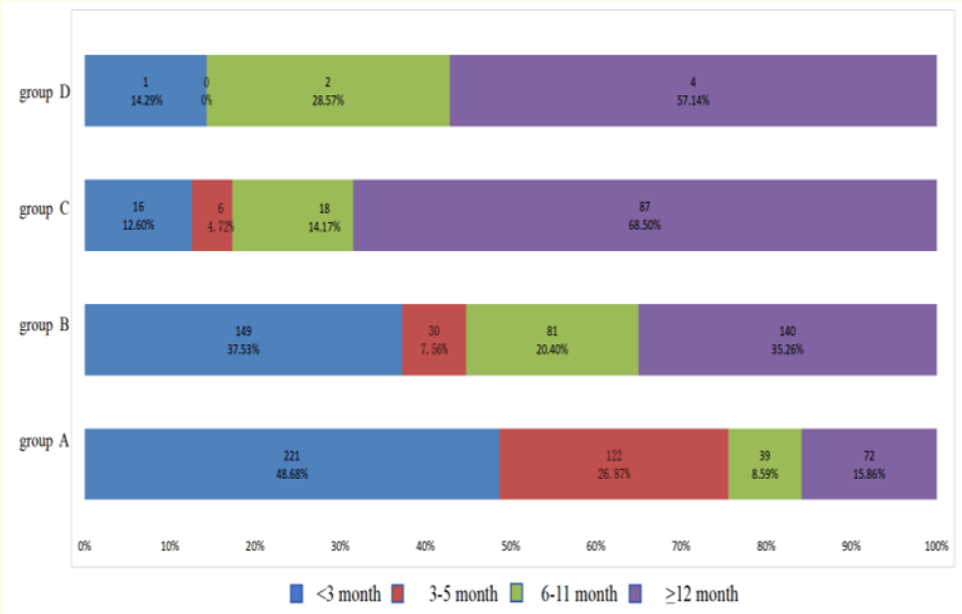


Figure 2: Standard long-term medication adherence of patients in different groups.

Pre- vs. post-intervention clinical outcomes

Changes in overall medication adherence

After 14 months of digital platform-based management, the number of patients achieving standardized regular medication increased significantly relative to baseline, with statistically significant inter-temporal differences ($P < 0.01$) (Table 5).

	Pre-Intervention	Post-Intervention	P
Regular standardized medication	230	653	<0.01
Irregular medication adherence	755	332	

Table 5: Comparison of standardized medication adherence pre- and post-intervention.

Reduction in acute exacerbations

Acute exacerbation counts declined across Groups B, C, and D following digital intervention, though inter-subgroup differences did not reach statistical significance. Aggregate analysis of the full cohort demonstrated a statistically significant reduction in total acute exacerbation events ($P = 0.008$) (Table 6).

Subgroup	Total Cases	Pre-intervention Exacerbations (n, %)	Post-intervention Exacerbations (n, %)	Statistical Test	X ² Statistic	P Value
Group A	454	0 (0.00%)	0 (0.00%)	-	-	-
Group B	397	8 (2.02%)	3 (0.76%)	Exact binomial test	-	0.0625
Group C	127	8 (6.30%)	5 (3.94%)	Exact binomial test	-	0.250
Group D	7	4(57.14%)	3(42.86%)	Exact binomial test	-	1.000
Overall Cohort	985	20 (2.03%)	11 (1.12%)	Corrected McNemar test	7.11	0.008

Table 6: Pre-post comparison of acute exacerbation incidence.

Note: The McNemar test was used for paired binary outcome analysis; continuity correction was applied for discordant pairs ($b+c < 40$), while exact two-tailed binomial tests were adopted for discordant pairs <10 . Significance threshold $\alpha = 0.05$, two-tailed testing.

Improvements in COPD disease awareness

Statistically significant elevations in disease knowledge scores were observed across all participants post-intervention ($P < 0.01$). Stratified score improvements: 775 patients (78.68%) gained 4-6 points, 176 (17.87%) gained 1-3 points, and 34 (3.45%) gained more than 6 points (Table 7).

Population	n	Pre-intervention Score (Median, IQR)	Post-intervention Score (Median, IQR)	Z Statistic	P Value
Entire cohort	985	2 (1, 2)	6 (5, 6)	-27.586	< 0.01
Urban subgroup	680	2 (1, 2)	6 (5, 6)	-23.214	< 0.01
Rural subgroup	305	2 (1, 2)	5 (4, 5)	-15.327	< 0.01

Table 7: Pre-post comparison of median COPD disease awareness scores.

Discussion

COPD is characterized by progressive disease trajectories and recurrent acute exacerbations, necessitating long-term continuous patient management. Conventional offline care models suffer from critical limitations including insufficient human and material

resources, disrupted post-discharge follow-up, and inability to implement cyclic patient reassessment and seamless longitudinal care. The integrated 3H care framework establishes a closed-loop continuum of respiratory chronic disease services, facilitates tiered diagnosis and treatment, and optimizes cross-tier medical resource allocation, representing a core model for standardized COPD management [7]. Nevertheless, high-quality real-world clinical evidence validating its comprehensive efficacy remains limited. This 14-months longitudinal digital management study of 985 COPD patients demonstrated significant improvements in medication adherence, disease awareness, and reduced acute exacerbation frequency following implementation of the 3H digital platform, consistent with findings from multiple domestic and international clinical investigations [8-13]. The present research supplements critical real-world longitudinal data on digital respiratory chronic disease management and identifies actionable limitations to guide future intervention optimization.

Compared with traditional offline care pathways, the digital management platform delivers superior efficiency, accessibility, and population coverage, particularly in standardized inhaler technique training and structured health education. Multimodal educational interventions were deployed via the platform, including embedded video tutorials on inhaler operation, COPD pathophysiology, and home pulmonary rehabilitation, alongside offline patient forums, knowledge competitions, and hands-on inhaler technique workshops. These interventions substantially improved patients' proficiency in inhaler administration and rehabilitation training, deepened disease understanding, slowed functional decline, and enhanced overall quality of life.

The digital intervention successfully corrected the pervasive misconception that "absence of symptoms indicates disease remission". Individualized medication regimens and streamlined outpatient scheduling were formulated based on each patient's clinical profile. Scheduled remote follow-up and real-time physiological monitoring delivered consistent reminders to maintain regular medication, reducing exacerbation risk. Multimodal integrated interventions—including tobacco cessation counseling, standardized pulmonary rehabilitation, and personalized nutritional guidance—were embedded within the platform to optimize holistic physical and psychological health, alleviate disease-related anxiety, and strengthen patient self-efficacy. Collectively, the platform established a complete closed-loop intervention workflow covering disease education, personalized pharmacotherapy guidance, continuous remote monitoring, and patient self-management empowerment, substantially boosting the overall effectiveness of digitalized COPD care.

Several notable disparities in patient engagement and compliance were identified within the cohort.

First, GOLD A and B patients accounted for 86.40% of enrollees, indicating that mild-to-moderate COPD patients exhibit higher willingness to participate and comply with digital remote management, making this population the optimal target for scaled program dissemination. In contrast, GOLD D patients constituted merely 0.71% of participants, likely attributable to severe symptomatic burden, impaired physical function, and diminished social participation in advanced COPD. The study therefore contains limited evidence regarding optimal digital management strategies for severe and very severe COPD subgroups, highlighting the need for targeted tailored protocols (e.g. institutionalized elderly COPD patient integrated care) to achieve full-spectrum standardized management across all disease severities.

Second, rural patients demonstrated an extremely high rate of irregular inhaler refills (86.56%) versus urban counterparts (3.24%). Potential contributing factors include insufficient primary medical resources in rural regions, poor baseline disease literacy, cost barriers to long-term inhaled therapy, and incomplete grassroots chronic disease management infrastructure. Targeted health education and capacity-building for rural COPD patients are therefore paramount to shift patient mindsets from passive medical treatment to proactive self-management, actualizing the national "prevention-first" chronic disease control strategy. Future research should develop unified urban-rural integrated COPD management protocols, supplemented by grassroots clinician training, real-time specialist remote guidance, and targeted medication support policies to mitigate urban-rural disparities and advance population-wide COPD prevention and control.

Baseline data revealed that only 30.86% of all participants maintained uninterrupted standardized medication for over 12 months prior to digital intervention, underscoring the urgent need for nationwide scaled long-term COPD management programs to meet the Healthy China 2030 target of $\geq 70\%$ standardized grassroots management coverage for hypertension, diabetes, and COPD [14]. Non-compliance was disproportionately concentrated among GOLD A and B subgroups. Qualitative post-hoc patient interviews revealed that Groups C and D consistently maintained regular medication due to persistent symptomatic burden and prior hospitalization history, which heightened their awareness of exacerbation risks. In contrast, mild-symptom A and B patients frequently underestimate the progressive nature of COPD and discontinue or reduce inhaled therapy once symptoms abate—a frequently overlooked clinical risk factor. Even mild COPD patients experience irreversible progressive pulmonary function decline, and inconsistent medication accelerates disease progression. The digital platform mitigated this risk through targeted educational campaigns dispelling the “asymptomatic equals cured” misconception, paired with automated medication reminders via remote monitoring. Future research should refine stratified personalized management workflows based on GOLD severity staging to deliver differentiated long-term care and improve prognosis across all disease stages, fulfilling the primary objective of preemptive chronic disease prevention outlined in Healthy China 2030.

Study Limitations

This research possesses several inherent limitations: single-center study design, relatively short 14-month observation window, voluntary enrollment without balanced stratified random matching, and incomplete capture of long-term endpoints including serial pulmonary function changes and all-cause mortality. The primary objective of this analysis was to quantify changes in patient self-management behaviors under the 3H digital model and summarize implementation challenges during early-stage program deployment. The findings provide foundational data to support future multi-center, large-sample, long-term prospective trials and generate robust evidence to guide nationwide scaled implementation of digital respiratory chronic disease management systems.

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