Digital Health Strategies for Early Detection of COPD Exacerbations in Rural Areas: A Narrative Review

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Abstract. Exacerbations of chronic obstructive pulmonary disease (COPD) are often recognized only after symptoms become severe enough to require urgent care. Digital approaches may support earlier detection through symptom reporting, home physiological monitoring, mobile decision support, and wearable activity data, although most evidence comes from settings unlike rural communities. This narrative review examined digital strategies for COPD screening, clinical deterioration, and pre-exacerbation periods, including requirements for rural implementation. Literature published from 2020 to 2025 was searched in PubMed, SAGE, Scopus, ProQuest, ScienceDirect, ClinicalKey, and Google Scholar using PICO-based terms. Seven original studies covered telemedicine, telemonitoring, mobile expert systems, electronic diaries, wearable devices, smartphone self-management, and app-based pulmonary rehabilitation. Early detection included identifying probable COPD, detecting worsening symptoms or physiological changes before escalation, and recognizing periods preceding a documented exacerbation or hospital visit. Definitions and purposes varied across studies. Continuous respiratory monitoring identified some pre-exacerbation periods, whereas mean daily respiratory rate alone performed less well. Electronic diaries and wrist accelerometers detected symptom and activity changes around exacerbations. A mobile expert system matched expert diagnoses in 86 of 100 medical-record cases but did not report sensitivity or specificity. Telemedicine and smartphone interventions mainly supported adherence, self-monitoring, self-efficacy, and rehabilitation access rather than automated prediction. Only one study involved a rural telemonitoring project. Digital health may strengthen COPD screening and follow-up, but evidence remains insufficient to show that automated prediction reduces hospitalization or mortality. Rural implementation requires reliable connectivity, device and literacy support, data governance, and services able to respond to alerts.

Keywords: COPD, Digital health, Exacerbation detection, Rural health, Telemonitoring.

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1 Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous respiratory condition in which chronic symptoms are accompanied by persistent, and often progressive, airflow limitation caused by airway and/or alveolar abnormalities. The Global Initiative for Chronic Obstructive Lung Disease grades airflow limitation using post-bronchodilator forced expiratory volume in one second (FEV1), from GOLD 1 (FEV1 ≥80% predicted) to GOLD 4 (FEV1 <30% predicted) [1]. COPD remains an important cause of illness and death, with tobacco exposure as a major risk factor. Indonesia has a high level of tobacco use. Rural communities may face additional problems, including fewer health facilities, limited access to respiratory specialists, long travel times, and low recognition of COPD symptoms [2]–[4].

Delay can occur at more than one stage of COPD care. One problem is that COPD itself may not be diagnosed promptly in people who have long-standing respiratory symptoms or known risk factors. A separate problem is failure to recognize an acute exacerbation early in someone with established COPD. These situations are related but should not be treated as the same outcome. In this review, the term "early detection" was therefore used for three purposes: preliminary identification of probable COPD before formal confirmation; recognition of worsening symptoms or physiological change before urgent deterioration; and identification of a period preceding a documented exacerbation or hospital presentation. Because the included studies used different time windows and reference standards, their definitions are presented separately.

Digital health covers several types of technology, including telemedicine, remote physiological monitoring, mobile applications, wearable sensors, and computerized decision support [5], [6]. These tools are attractive when distance makes regular face-to-face care difficult. Their usefulness in a rural area, however, cannot be inferred from technical performance alone. A system tested in an urban hospital or rehabilitation center may function differently where internet access is unstable, devices are shared, technical assistance is limited, or referral services are slow. This review therefore describes what each technology was designed to do and discusses its possible transfer to rural care without assuming that all interventions were directly tested in rural populations.\

2 Methods

Articles published from 2020 through 2025 were sought in PubMed, SAGE, Scopus, ProQuest, ScienceDirect, ClinicalKey, and Google Scholar. The search was structured around PICO concepts: people with COPD or individuals undergoing COPD screening; digital health, telemedicine, telemonitoring, mobile applications, wearable devices, or expert systems; usual care, face-to-face care, a clinical reference assessment, or within-person baseline; and outcomes related to early diagnosis, symptom deterioration, pre-exacerbation detection, adherence, self-monitoring, or rehabilitation access. The terms were combined using AND and OR.

Original research was eligible when it evaluated a digital approach relevant to COPD screening, monitoring, exacerbation recognition, self-management, or remote care. Rural location was not required because few rural-specific studies were available, but the setting of each study was identified during synthesis. Seven studies were retained [7]–[13]. The technologies, study designs, populations, and outcome definitions differed substantially. For this reason, the findings were summarized narratively rather than pooled statistically.

3 Results

Seven original studies met the review criteria. The HIS2R feasibility pilot was the only study that explicitly examined home telemonitoring as part of a rurality project [9]. The remaining studies were conducted in clinical, rehabilitation, community, or multicenter settings. They were included because their technologies might be adapted for rural care, not because they demonstrate effectiveness in rural populations. The studies also addressed different stages of care: one tested preliminary diagnostic support, two examined patterns before or around exacerbations, and four focused mainly on remote follow-up, self-management, adherence, or pulmonary rehabilitation.

Telemedicine and remote follow-up. Dogan and Kokturk compared telemedicine follow-up with face-to-face follow-up and reported better treatment adherence, inhaler technique, and quality-of-life outcomes after three months [7]. The study is relevant to continuity of care, but it did not test an algorithm intended to identify an exacerbation before symptoms were reported. Its contribution to early detection is therefore indirect. More frequent remote contact could create an opportunity for patients to report worsening symptoms sooner and for clinicians to review them promptly.

Continuous physiological telemonitoring. Alves Pegoraro et al. used TeleOx® to capture oxygen-therapy duration, breathing rate, and inspiratory amplitude at five-minute intervals. The target outcome was a four-day period before a documented exacerbation. The analysis included 16 recordings associated with an exacerbation and 23 without an exacerbation. At 50% specificity, the hidden Markov model detected about 73% of pre-exacerbation periods. Mean daily breathing rate detected about 56%, while daily oxygen-therapy use reached about 77% sensitivity [8]. The results suggest that time-series patterns or therapy-use data may be more informative than a single daily respiratory-rate average. The 50% specificity, however, indicates that false alerts would be frequent. The study was also conducted in a rehabilitation center rather than in rural homes.

Rural home telemonitoring. The HIS2R pilot followed body weight, temperature, heart rate, blood pressure, and oxygen saturation in a rural telemonitoring context [9]. The system helped clinicians recognize deterioration and supported decisions about care. Hospitalizations and deaths occurred during the six-month pilot, but there was no control group or baseline comparison. Those events should therefore be reported descriptively and cannot be attributed to either failure or success of the intervention. The main contribution of the study was evidence about feasibility and implementation in a rural setting, not proof that telemonitoring reduced hospitalization or mortality.

Table 1. Characteristics and relevance of the included studies.

Study	Design/setting	Digital strategy	Primary purpose	Rural-specific
Dogan and Kokturk (2025) (8)	Randomized controlled trial; COPD follow-up	Telemedicine follow-up	Treatment adherence, inhaler technique, and quality of life; not an automatic exacerbation-detection study	No
Alves Pegoraro et al. (2025) (9)	Observational monitoring in a respiratory rehabilitation center; 16 recordings with exacerbation and 23 without exacerbation used in analysis	TeleOx® respiratory monitoring and hidden Markov model	Classification of stable versus pre-exacerbation periods	No
Schoevaerdts et al. (2024) (10)	Six-month feasibility pilot in a smart-rurality project	Home telemonitoring of physiological variables	Feasibility and recognition of clinical deterioration in rural care	Yes
Pambudi et al. (2025) (11)	System-development study; 100 medical-record test cases	Mobile expert system using decision tree and Dempster-Shafer methods	Preliminary COPD diagnostic decision support	Not stated
Finney et al. (2023) (12)	Feasibility study in people with COPD	Electronic symptom diary and wrist-worn accelerometer	Detection of symptom and activity changes around exacerbations	No
Glynn et al. (2025) (13)	Randomized controlled trial; 12-month follow-up	Smartphone COPD self-management application	Self-monitoring, self-efficacy, communication, and clinical outcomes	No
Gloeckl et al. (2025) (14)	Multicenter randomized controlled trial	Smartphone-based pulmonary rehabilitation	Access to and outcomes of pulmonary rehabilitation; indirect relevance to exacerbation prevention	No

Mobile expert system for COPD screening. Pambudi et al. created a mobile expert system using a decision tree and Dempster-Shafer method. In 100 medical-record cases, the application diagnosis matched the expert diagnosis in 86 cases [10]. The expert diagnosis recorded in the medical record served as the reference. Sensitivity, specificity, positive predictive value, and negative predictive value were not provided. Accordingly, the reported 86% agreement does not show how many COPD cases could be missed or incorrectly classified. The system is best viewed as preliminary decision support and not as a substitute for spirometry and clinical evaluation.

Electronic diaries and wearable activity monitoring. Finney et al. paired an electronic symptom diary with a wrist-worn accelerometer [11]. Their definition of early detection relied on changes in reported symptoms and physical activity near an exacerbation. Step counts declined during the seven days before an exacerbation and remained lower during the first seven days of recovery. A decision-tree model identified sputum-color change, reduced step count, cold symptoms, previous exacerbations, and rescue-medication use as relevant features. This combination may provide an individualized warning pattern. Even so, a feasibility study in a selected sample cannot establish that the same approach will work in all older adults or in all rural patients.

Smartphone self-management and pulmonary rehabilitation. Glynn et al. tested a smartphone program that included symptom entry, step counting, educational material, goal setting, communication with health professionals, and extended follow-up [12]. Its main effects concerned self-monitoring and self-efficacy rather than automated prediction. Gloeckl et al. evaluated smartphone-delivered pulmonary rehabilitation in a multicenter randomized trial [13]. That intervention addressed access to rehabilitation and disease management, not direct detection of an impending exacerbation. Both approaches could reduce travel for rural patients, but only when users have suitable devices, connectivity, support, and access to clinicians who can respond.

4 Discussion

The reviewed technologies should not be discussed as though they represent one intervention or one definition of early detection. They served at least three different functions. The mobile expert system assisted with preliminary identification of probable COPD. TeleOx®, electronic symptom diaries, and wearable activity data were used to recognize changes before or around an exacerbation. Telemedicine follow-up, smartphone self-management, and digital pulmonary rehabilitation mainly supported access, adherence, and continuity of care. This distinction is important because a supportive-care tool should not be presented as a validated diagnostic or predictive system.

The studies that directly examined exacerbation-related change point toward the value of longitudinal and combined data. TeleOx® performed better when time-series or oxygen-therapy-use patterns were considered than when a single mean daily breathing rate was used [8]. Finney et al. likewise found that symptom data and step-count changes together described deterioration more clearly than either source alone [11]. These findings favor individualized trends over isolated cut-off values. Direct comparison of performance is not appropriate, however, because the studies used different monitoring periods, outcomes, settings, and reference standards.

Different technologies may suit different patients. A person who can recognize and report symptoms may benefit from telemedicine or a self-management application. A patient with frequent exacerbations, limited symptom awareness, or greater clinical risk may require structured telemonitoring. No included study directly compared these approaches, so this remains a clinical interpretation rather than a proven hierarchy. A practical service could begin with routine self-management support for stable patients, add monitoring for those at higher risk, and arrange rapid clinical review when symptoms or alerts change.

Rural relevance must be interpreted carefully because only one study was explicitly rural [9]. The possible usefulness of the other technologies is based on their capacity to deliver care remotely. In practice, an alert is valuable only when someone receives it, interprets it, and can act. Internet access, device compatibility, technical support, referral arrangements, and trained staff are therefore part of the intervention rather than background conditions. Collecting more data will not improve outcomes when the health service cannot respond in time.

Digital literacy also cannot be reduced to age. The electronic diary and wearable study showed that some people with COPD can use these tools when support is available [11], but this does not mean that all older adults will find them easy to use. Vision, cognition, language, motivation, caregiver involvement, interface design, and technical reliability may influence continued use. Rural programs should include initial training, simple interfaces, low-bandwidth or offline options where possible, and a non-digital route for patients unable to use the technology independently.

Current evidence does not establish that digital detection reduces hospitalization or mortality. The rural feasibility pilot had no comparator, the continuous-monitoring model had limited specificity, and the expert system did not report complete diagnostic-performance measures. Future studies should define the alert period in advance, use a clear clinical reference standard, report sensitivity and specificity together with false-alert rates, include diverse rural populations, and determine whether an alert actually leads to earlier treatment and better outcomes.

This review has limitations. The search and study-selection procedures followed a narrative rather than systematic-review approach, and no formal risk-of-bias assessment was performed. The seven studies differed in design, population, technology, clinical purpose, and definition of early detection. Only the HIS2R pilot was explicitly embedded in a rurality project, so most conclusions about rural use rely on transferability and contextual reasoning. Several interventions focused on self-management or rehabilitation instead of direct prediction. Diagnostic-performance measures, comparator outcomes, and long-term effects on hospitalization and mortality were also reported inconsistently.

5 Conclusion

Digital health may contribute at several points in COPD care: preliminary screening, recognition of worsening symptoms or physiological change, remote follow-up, self-management, and pulmonary rehabilitation. The studies most directly related to exacerbation detection suggest that repeated, combined data are more useful than a single daily measurement. Their performance is not yet strong enough to support independent clinical decisions. Telemedicine and smartphone programs can improve access and continuity but should not be described as validated early-warning systems unless prediction has been tested directly. For rural services, technology must be linked with reliable connectivity, technical and literacy support, data-protection procedures, and clinicians who can respond promptly. More comparative studies conducted in rural populations are needed before effects on hospitalization, mortality, or health-system burden can be concluded.

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