



Association Between Mobile-Based Remote Monitoring and Chemotherapy Adherence Among Lung Cancer Patients in Aceh Province

Ferry Dwi Kurniawan,¹ Fajar Tara Winanda,¹ Teuku Zulfikar,¹ Budi Yanti,¹ Irmaini,¹ Liza Salawati²

¹Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Syiah Kuala University, Dr. Zainoel Abidin Hospital, Banda Aceh, Indonesia

²Department of Public Health, Faculty of Medicine, Syiah Kuala University, Banda Aceh, Indonesia

Abstract

Background: Chemotherapy adherence is essential for optimizing treatment outcomes in patients with lung cancer, yet maintaining adherence remains challenging because of treatment-related adverse effects and limited opportunities for continuous monitoring. Mobile-based remote monitoring applications may improve adherence by facilitating symptom reporting, treatment reminders, and communication between patients and healthcare providers. This study aimed to evaluate the association between the use of a mobile-based remote monitoring application and chemotherapy adherence among patients with lung cancer.

Methods: A case-control study was conducted at the Pulmonology Clinic of Dr. Zainoel Abidin Hospital between October 2025 and January 2026. A total of 62 patients with lung cancer undergoing chemotherapy were enrolled, including 31 patients who used a mobile-based remote monitoring application (case group) and 31 patients who received standard care (control group). Chemotherapy adherence was assessed using the Indonesian version of the 8-item Morisky Medication Adherence Scale (MMAS-8). Data analysis used the chi-square test, with $P < 0.05$ is significantly statistic.

Results: Baseline demographic and clinical characteristics, including age, sex, smoking history, histopathological subtype, and disease stage, showed no association between the two groups ($P > 0.05$). High chemotherapy adherence was observed in 22 patients (71.0%) in the application group compared with 7 patients (22.6%) in the control group, whereas low adherence was more frequent in the control group (61.3% vs. 12.9%). The use of the mobile-based remote monitoring application was significantly associated with improved chemotherapy adherence ($P = 0.001$).

Conclusion: The use of a mobile-based remote monitoring application was significantly associated with higher chemotherapy adherence among patients with lung cancer. By integrating treatment reminders, symptom monitoring, laboratory follow-up, and direct communication with healthcare providers, the application may improve patient engagement and support continuity of care. Mobile-based remote monitoring represents a promising strategy for enhancing chemotherapy adherence and should be further evaluated in larger multicenter studies with longer follow-up.

Keywords: adherence, chemotherapy, lung cancer, mobile-based application

Corresponding Author:

Ferry Dwi Kurniawan | Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Syiah Kuala University, Dr. Zainoel Abidin Hospital, Banda Aceh, Indonesia | ferrydwikurniawan@usk.ac.id

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INTRODUCTION

Lung cancer is the most common malignancy worldwide, with approximately 2,480,675 new cases annually, accounting for 23.6% of all cancer cases. It is also the leading cause of cancer-related mortality, with 1,817,469 deaths (16.8% of total cancer deaths). In Indonesia, lung cancer ranks as the second most common cancer, with 66,271 cases (9.5%) and 38,904 new cases annually (9.5%). However, it remains the leading cause of cancer-

related mortality, with 34,339 deaths (14.1%).¹

Current medical approaches to cancer treatment focus on prevention, cure, prolongation of survival, and improvement of patients' quality of life. Quality of life is often affected by cancer-related symptoms as well as treatment-related adverse effects, particularly chemotherapy.² As most antineoplastic treatments are administered in outpatient settings to minimize disruption to patients' daily lives and reduce hospitalizations, patients are frequently required to manage treatment-related side

effects independently without direct clinical supervision. This condition may negatively impact adherence to chemotherapy.^{3,4}

In recent years, the internet and digital technologies have become essential resources for both patients and clinicians in the oncology community. The World Health Organization defines telemedicine as the delivery of healthcare services at a distance using information and communication technologies.⁵ One implementation of telemedicine is mobile-based applications, which facilitate secure information exchange and enable patients to communicate health-related concerns, including prevention, diagnosis, treatment, and follow-up remotely.⁶ These strategies also allow patients and healthcare providers to adopt interactive tools that complement routine hospital visits and outpatient follow-up, which often present challenges in terms of treatment monitoring and continuity of care.⁷

One of the primary purposes of mobile-based remote monitoring applications is to support patients in self-management of their health conditions. Self-management refers to an individual's ability to manage symptoms, treatment, and physical and psychosocial side effects based on guidance and recommendations from healthcare professionals, aimed at improving lifestyle or serving as complementary care.⁸

Mobile-based remote monitoring applications have demonstrated several benefits, including healthcare cost optimization through reduced hospital visits and improved symptom control. Additionally, these applications have been shown to enhance quality of life across emotional, cognitive, and social domains.⁸ One example is the Advanced Symptom Management System (ASyMS), which has been developed to monitor and manage chemotherapy-related toxicity using the Daily Chemotherapy Toxicity Self-Assessment Questionnaire, covering ten primary symptoms.⁹

The use of ASyMS has been associated with significant symptom reduction compared with standard care, highlighting the potential of such applications in optimizing symptom control.⁹ Furthermore, the use of mobile-based remote

monitoring applications has been shown to improve treatment adherence.¹⁰

Despite the growing development of mobile-based remote monitoring applications, most are available only in English. Meanwhile, Indonesia ranks 80th out of 116 countries, indicating low English proficiency.¹¹ This limitation may hinder the effective use of such applications among Indonesian patients. Therefore, the development and utilization of Indonesian-language applications are essential to improve accessibility and monitoring for chemotherapy patients.

Based on that issue, mobile-based remote monitoring applications represent a promising modality to improve quality of life, reduce symptoms, and enhance treatment adherence. However, there is still limited evidence regarding the tools for chemotherapy monitoring. Therefore, this study aims to analyze the association between the use of mobile-based remote monitoring applications and chemotherapy adherence among lung cancer patients.

METHODS

This study was an analytic observational study with a case-control design conducted at the Pulmonology Clinic of Dr. Zainoel Abidin Hospital, Banda Aceh, from October 2025 to January 2026. The study population consisted of all lung cancer patients undergoing chemotherapy at Dr. Zainoel Abidin Hospital in 2025. Samples were selected using a random sampling method based on inclusion and exclusion criteria.

The case group included adult patients (aged >18 years) with newly diagnosed lung cancer undergoing at least three cycles of chemotherapy and using a mobile-based remote monitoring application, while the control group consisted of similar patients who did not use the application. Patients without compatible mobile devices, without stable internet access, or those who refused to participate were excluded.

The sample size was calculated using the Slovin formula with a 5% margin of error, resulting in

a minimum of 28 participants, which was increased by 10% to 31 to account for potential dropouts. A total of 62 participants were divided equally into case and control groups (1:1). Participants were assigned using identification numbers, with odd numbers assigned to the case group and even numbers to the control group.

The independent variable was the use of a mobile-based remote monitoring application, and the dependent variable was chemotherapy adherence, defined as completing chemotherapy according to the prescribed cycles and schedule. Data collection used interviews that utilized the Morisky Medication Adherence Scale (MMAS-8) as primary data, while secondary data were collected from medical records, including demographic characteristics, family history, and treatment-related side effects.

The MMAS-8 is a simple and reliable self-report instrument that assesses behaviours associated with medication-taking, including forgetfulness, carelessness, treatment discontinuation when feeling better or worse, and difficulty maintaining a prescribed regimen. The MMAS-8 categorizes adherence into three levels: high (score=8), moderate (score 6 to 7), and low (score <6), allowing standardized assessment and comparison, including in chemotherapy adherence. The MMAS-8 questionnaire was translated into Indonesian and underwent linguistic validation before its use in this study, with a Cronbach's alpha of 0.731. The MMAS-8 questionnaire was answered with "Yes" or "No", with the question list following:

1. Have you ever forgotten to undergo chemotherapy?
2. Have you ever missed a scheduled session for any of the three chemotherapy cycles?
3. Have you ever skipped chemotherapy without informing your doctor because you felt your condition worsened after the treatment?
4. When traveling, do you ever forget to undergo chemotherapy according to schedule?
5. Did you undergo chemotherapy in the previous cycle?

6. When you felt your symptoms were under control, did you ever try to stop chemotherapy?
7. Have you ever felt that adhering to the scheduled chemotherapy sessions is difficult?
8. Do you often forget to undergo chemotherapy according to the schedule?

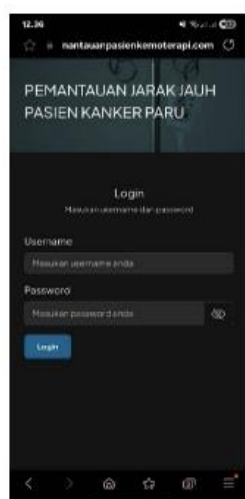
The mobile-based remote monitoring application was developed in-house to accommodate patient complaints, laboratory result monitoring, and chemotherapy schedule alarms. The participants were socialized on how to input, how to upload the laboratory result, how to contact the administrator, and how to get notified regarding the chemotherapy schedule. A step-by-step guide on how to use the app is as Figure 1 and 2.

The application allowed offline data storage with automatic synchronization when internet access was available. All data can be accessed only by the administrator; thus, confidential data are restricted.

Descriptive analysis was used to present frequencies and percentages, while bivariate analysis using the chi-square test was performed to assess the association between application use and chemotherapy adherence, with a value of $P \leq 0.05$ considered statistically significant. All data were collected after ethical approval (No. 286/ETIK-RSUDZA/2025), and informed consent was obtained.

RESULTS

A total of 62 patients with lung cancer undergoing chemotherapy were included in this study, with 31 patients in each of the case and control groups. In the case group and control group, males were dominant, with 22 patients (71.0%) and 23 patients (74.2%), respectively, without a significant difference in sex distribution ($P=0.776$). The mean age in the case group was 53.7 ± 11.6 years, while in the control group it was 58.5 ± 11.5 years ($P=0.107$). A history of smoking was reported in 21 patients (67.7%), while 10 patients (32.3%) were non-smokers in both the case and control groups ($P=1.000$).



1. Log in



2. Windows page



3. Lung cancer general information and therapy



4. Consultation page



5. Consultation link to officer



6. Identity information



7. Follow-up data



8. Chemotherapy protocol



9. Last visit summary including side effects

Figure 1. Lung Cancer Patients App

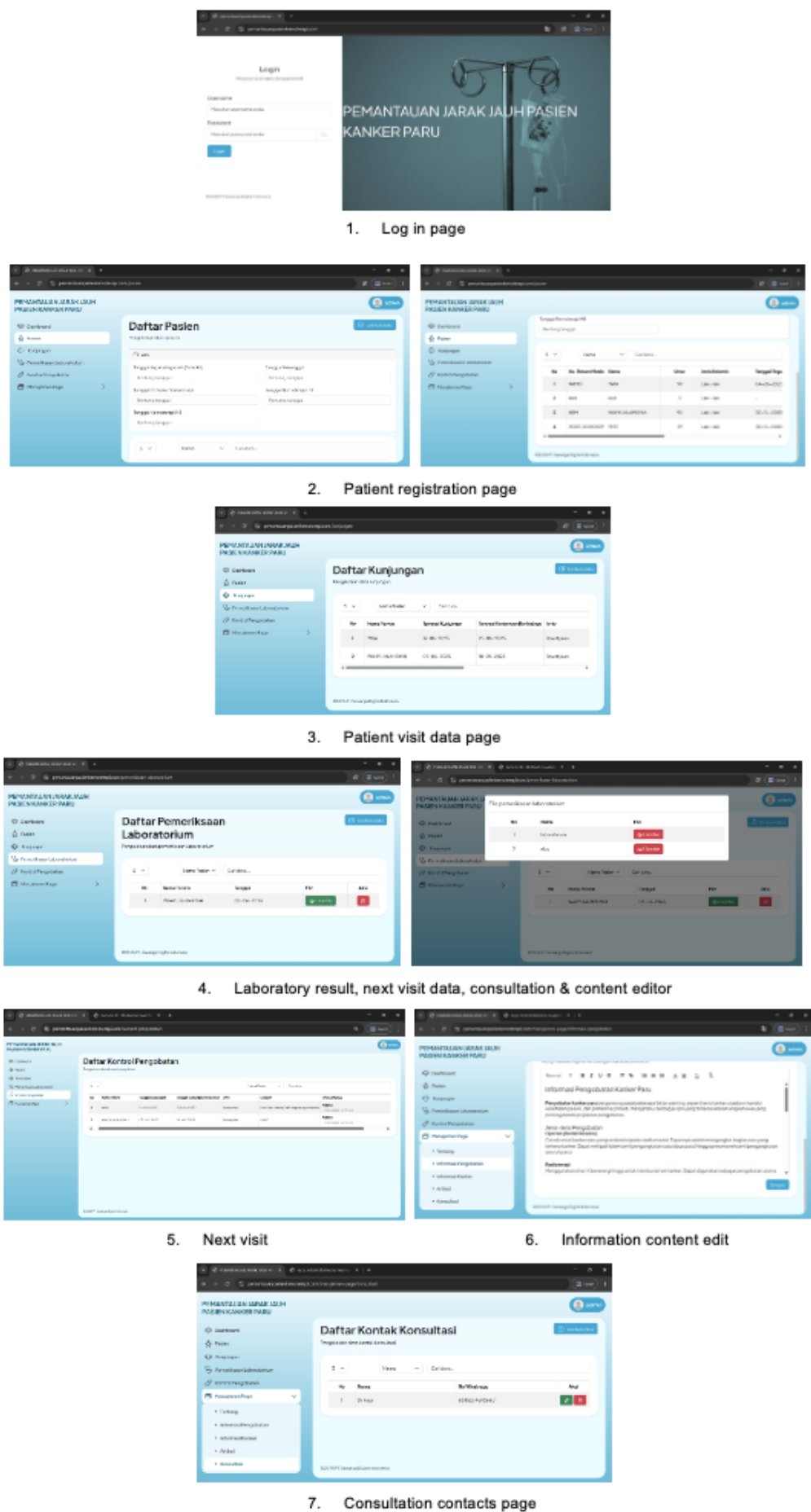


Figure 2. Administrator App

Table 1. Baseline demographic and clinical characteristics

Characteristics	Case (n=31)	Control (n=31)	P
Gender			
Male	22 (71.0%)	23 (74.2%)	0.776
Female	9 (29.0%)	8 (25.8%)	
Age, years (mean±SD)	53.7±11.6	58.5±11.5	0.107
History of smoking			
Smokers	21 (67.7%)	21 (67.7%)	1.000
Non-smokers	10 (32.3%)	10 (32.3%)	
Histopathological subtype			
SCC	23 (74.2%)	21 (67.7%)	0.57
Adenocarcinoma	8 (25.8%)	10 (32.3%)	
Stage			
III	6 (19.4%)	5 (16.1%)	0.747
IIIA	4 (12.9%)	4 (12.9%)	
IIIB	1 (3.2%)	0 (0.0%)	
IIIC	1 (3.2%)	1 (3.2%)	
IV	15 (80.6%)	26 (83.9%)	
IVA	18 (58.1%)	13 (41.9%)	
IVB	7 (22.6%)	13 (41.9%)	

Note: SCC=Squamous cell carcinoma; SD=standard deviation

Squamous cell carcinoma (SCC) was the predominant histopathological subtype in the case and control groups, occurring in 23 patients (74.2%) and 21 patients (67.7%), respectively. But, there was no significant difference in histopathological subtype distribution between the two groups ($P=0.57$). Based on stage, stage IV was predominant in the case and control groups was predominant with 25 patients (80.6%) and 26 patients (83.9%), respectively, with no statistically significant difference in disease stage ($P=0.747$).

High adherence was observed in 22 patients (71.0%) in the case group compared with 7 patients (22.6%) in the control group, whereas low adherence was more common in 19 patients (61.3%) in the control group than in 4 patients (12.9%) in the case group, as shown in Table 2.

Table 2. Chemotherapy Adherence Levels

Adherence Level	Case (n=31)	Control (n=31)
Low	4 (12.9%)	19 (61.3%)
Moderate	5 (16.1%)	5 (16.1%)
High	22 (71.0%)	7 (22.6%)

Among patients who used the application, 22 (71.0%) demonstrated high adherence. In contrast, among patients who did not use the application, low adherence was observed in 19 patients (61.3%). The use of the mobile-based remote monitoring application was significantly associated with

chemotherapy adherence ($P=0.001$), as shown in Table 3.

Table 3. Association Between Application Use and Chemotherapy Adherence

Application Use	Chemotherapy Adherence			P
	Low	Moderate	High	
Yes	4 (12.9%)	5 (16.1%)	22 (71.0%)	0.001
No	19 (61.3%)	5 (16.1%)	7 (22.6%)	

DISCUSSION

This study found that lung cancer predominantly affected male patients in both the case and control groups. This finding is consistent with epidemiological evidence from Indonesia, where the incidence of lung cancer is higher among men. Largely attributable to the greater prevalence of cigarette smoking and increased occupational exposure to carcinogens, including asbestos, industrial dust, and diesel exhaust.¹² In addition to these environmental risk factors, biological mechanisms may also contribute to the observed sex disparity. For example, increased methylation of the RASSF1A tumor suppressor gene has been reported more frequently in men and may play a role in enhancing susceptibility to lung carcinogenesis.¹³

The mean age of patients was 53.7±11.6 years in the case group and 58.5±11.5 years in the control group. This indicates that the risk of cancer increases with advancing age as a result of cumulative exposure to carcinogens, age-related immune dysfunction, and progressive impairment of DNA repair mechanisms.^{13,14}

Smoking was the predominant behavioural risk factor in both groups, further supporting its well-established role as the most important modifiable risk factor for lung cancer.^{13,15} This observation is in agreement with previous studies demonstrating a higher prevalence of smoking among patients with lung cancer than among individuals without the disease.¹⁶

All baseline demographics and clinical characteristics show $P>0.05$. Its mean no statistically significant differences in baseline characteristics between the case and control groups, indicating that the two groups were well balanced and suggesting a low risk of selection bias.

Adherence to chemotherapy is a key determinant of treatment success, as suboptimal adherence may compromise therapeutic efficacy, increase the risk of disease progression or recurrence, and adversely affect patients' quality of life. In the present study, patients who used the mobile-based remote monitoring application exhibited significantly higher levels of chemotherapy adherence than those who did not use the application.

Communication between patients and the healthcare team was facilitated through the consultation feature of the mobile application. Most patients actively used this feature to report chemotherapy-related adverse effects, seek medical advice, and communicate laboratory follow-up results, enabling timely clinical assessment and intervention when necessary.

The mobile-based remote monitoring application likely improved chemotherapy adherence by serving as a treatment reminder, a platform for symptom reporting, and a communication tool between patients and healthcare providers. These integrated features may enhance patient engagement, strengthen motivation, and increase patients' perceived support throughout the course of treatment. In contrast, patients who did not have access to the application were more likely to demonstrate low adherence, highlighting the potential value of digital health interventions in supporting continuity of cancer care.

These findings are consistent with previous studies demonstrating the benefits of mobile health interventions in supporting treatment adherence among patients with cancer. For example, Krukowski et al reported that cancer survivors using symptom-monitoring applications achieved medication adherence rates exceeding 80%.¹⁷

Similarly, Shi et al demonstrated that mobile health-based self-management programs significantly reduced symptom burden and improved physical well-being among patients with breast cancer undergoing chemotherapy.¹⁸ Furthermore, other studies have shown that digital health interventions, including medication reminder systems

and self-management tools, can enhance treatment adherence and improve clinical outcomes, particularly during the early phases of follow-up.¹⁹

However, chemotherapy adherence is a multifactorial behaviour influenced by patients' beliefs and perceptions, health literacy, understanding of the disease and its treatment, healthcare system support, and social and family support.^{20,21} Therefore, although digital health applications can substantially improve adherence, their effectiveness is likely to be maximized when integrated with patient education, behavioural interventions, and continuous clinical support to promote sustained long-term adherence.

This study demonstrated a significant association between the use of a mobile-based remote monitoring application and chemotherapy adherence. Patients who used the application were predominantly classified as having high adherence, whereas those who did not use the application were more frequently categorized as having low adherence. These findings suggest that the observed association is unlikely to have occurred by chance and support the potential effectiveness of the mobile-based remote monitoring application in improving chemotherapy adherence. Remote monitoring systems enable real-time assessment of patients' clinical status and facilitate the early identification of treatment-related complications or changes in health condition, thereby supporting treatment continuity and improving adherence.²²

Furthermore, these applications help overcome geographical and logistical barriers to healthcare access, an important advantage in regions where access to oncology services is limited. By enabling timely communication between patients and healthcare providers, remote monitoring may also promote prompt clinical intervention and optimize the delivery of cancer care.²³

These findings are consistent with previous evidence supporting the effectiveness of mobile health interventions in improving treatment adherence among patients with cancer. For example, Eser reported that reminder-based mobile applications significantly improved medication adherence in patients with cancer.²⁴ Similarly, Yu et

al stated that the use of mobile applications was associated with greater adherence to multidisciplinary treatment recommendations.²⁵ These findings reinforce the potential of digital health technologies to enhance treatment adherence and support the delivery of comprehensive cancer care.

Nevertheless, the evidence regarding the effectiveness of digital health interventions remains inconsistent. For example, Graetz et al reported no significant improvement in adherence to endocrine therapy over a one-year follow-up period, suggesting that the impact of digital interventions may depend on factors such as intervention duration, application design, patient characteristics, and baseline adherence levels.²⁶ Moreover, sustained user engagement is essential to maximize the benefits of these technologies. Without consistent application use, key features such as medication reminders, symptom reporting, and patient-provider communication are less likely to translate into meaningful improvements in treatment adherence.⁹

Overall, mobile-based remote monitoring applications appear to have a beneficial impact on chemotherapy adherence. By integrating treatment reminders, patient education, symptom monitoring, and real-time communication with healthcare providers, these applications can help overcome common barriers to adherence and promote continuity of care. Nevertheless, successful implementation and sustained long-term effectiveness depend on addressing several challenges, including digital literacy, equitable access to mobile technology, internet connectivity, user engagement, and data privacy and security. Future efforts should focus on integrating these digital health interventions into routine oncology practice while ensuring that they remain accessible, secure, and responsive to patients' needs.

LIMITATION

One limitation of this study is the potential influence of social and family support, which was not comprehensively assessed. Variations in the availability and quality of social support may have

affected patients' motivation and consistency in adhering to chemotherapy, as social support is a well-established determinant of treatment adherence and other positive health behaviours. In addition, limited digital literacy among some participants may have reduced the effectiveness of the mobile-based remote monitoring application, as difficulties in using digital technologies can hinder user engagement and limit the benefits of remote monitoring. These unmeasured factors may have contributed to the variability in chemotherapy adherence observed in this study.

CONCLUSION

The use of a mobile-based remote monitoring application was significantly associated with higher chemotherapy adherence among patients with lung cancer. Patients who used the application demonstrated substantially greater adherence than those receiving standard care alone, suggesting that digital health interventions incorporating treatment reminders, symptom monitoring, laboratory follow-up, and direct communication with healthcare providers may enhance patient engagement and support continuity of care. Mobile-based remote monitoring applications represent a promising adjunct to conventional oncology services for improving chemotherapy adherence.

Further multicenter studies with larger sample sizes and longer follow-up periods are warranted to confirm these findings and evaluate their impact on clinical outcomes, including treatment completion, disease progression, survival, and quality of life. Also, future studies should comprehensively evaluate social support and digital literacy and incorporate interventions aimed at enhancing patient education, strengthening support systems, and improving digital competencies to maximize the effectiveness and long-term sustainability of mobile health interventions in oncology.

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CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study or manuscript preparation.

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