

Optimizing Non-Communicable Disease Health Promotion Through Medical Informatics Systems in Primary Healthcare Centers

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Abstract. Non-communicable disease prevalence is experiencing exponential increases requiring paradigmatic transformation in primary healthcare delivery through medical informatics systems utilization. This study aims to analyze optimization of NCDs health promotion through medical informatics systems implementation in primary healthcare settings using qualitative analysis approach. The study employed multiple case study design analyzing three specific cases: SATUSEHAT NCDs screening module implementation in 300 primary healthcare centers, Integrated Primary Services program digitalization, and PASS Mantap innovation program at Nan Balimo Primary Healthcare Center. Data analysis utilized thematic analysis with Technology Acceptance Model and Implementation Science frameworks. Medical informatics systems implementation demonstrated significant improvements in clinical documentation standardization, care continuity, and patient engagement. Success factors included organizational readiness, infrastructure adequacy, and community acceptance. Primary challenges encompassed digital divide, change resistance, and financing sustainability. In conclusion, NCDs health promotion optimization requires holistic approaches integrating technological innovation with organizational transformation and community engagement to achieve sustainable digital health ecosystems.

Keywords: Medical Informatics Systems, Non-Communicable Diseases, Primary Healthcare, Health Promotion.

1 Introduction

Digital transformation in the health sector has become a strategic imperative in strengthening primary health care systems, especially in the management of non-communicable diseases (NCDs) whose prevalence continues to increase exponentially globally. Non-communicable diseases, including diabetes mellitus, hypertension, cardiovascular disease, and cancer, have become a major burden on the national health system with mortality contributing to 71% of total global deaths according to World Health Organization data. The complexity of NCD management requires a holistic approach that integrates preventive, promotive, curative, and rehabilitative aspects through the use of health information technology that can optimize the effectiveness and efficiency of primary health services. Medical informatics systems in the context of primary health care services have transformative potential in improving the quality of health promotion of NCDs through various integrated digital modalities. The implementation of electronic medical records, health information systems, and digital health platforms has shown a positive impact in improving service accessibility, continuity of care, and patient engagement in the management of chronic conditions [1]. Advances in artificial intelligence and machine learning technology in medical informatics systems allow for early detection of NCD risk factors, personalization of health interventions, and more precise and accurate clinical decision-making [2].

The evolution of Indonesia's national health information system through the SATUSEHAT platform shows the government's commitment to realizing comprehensive health data integration. The implementation of the NCD screening module in the SATUSEHAT platform in the 300 target health centers reflects systematic efforts in standardizing the recording, reporting, and monitoring of NCD cases nationally. The integration of the health center management information system (SIMPUS) with the SATUSEHAT platform allows the acceleration of the digitization of primary

health services, improves the accuracy of epidemiological data, and facilitates evidence-based decision-making in NCD control. The contextualization of the digitization of primary health services in strengthening the Primary Service Integration (ILP) program shows a new paradigm in the health delivery system that focuses on proactivity and prevention. The use of the Sehat IndonesiaKu (ASIK) application for health workers and the WhatsApp platform for health cadres indicates the adaptation of digital technology that is tailored to the characteristics and capacity of human resources at the community level. The Local Area Monitoring Dashboard (PWS) provides real-time visibility into public health indicators, enabling rapid response to the epidemiological dynamics of NCDs at the local level.

Health service innovations based on local wisdom such as the PASS Mantap program (Active Pattern of Healthy Saturdays with Traditional Drinks) at the Nan Balimo Health Center demonstrate the integration between conventional and digital approaches in the promotion of NCDs. The combination of structured physical activity, routine health check-ups, and digitally documented consumption of traditional herbal medicine allows for an objective and sustainable evaluation of outcomes. This multifaceted approach illustrates the potential for optimizing NCD health promotion through synergy between lifestyle interventions, digital monitoring, and electronic documentation. The challenges of implementing medical informatics systems in primary health services include aspects of technological infrastructure, human resource capacity, system interoperability, and health data security. Disparities in internet access, budget limitations, and variations in the level of digital literacy of health workers are determinants of the success of digital technology adoption [3]. Concerns about the privacy and security of electronic health information require the implementation of a robust security framework and compliance with personal data protection regulations.

The potential use of blockchain technology in primary health medical informatics systems shows innovative prospects in ensuring the integrity, provenance, and interoperability of health data. The implementation of distributed ledger technology can increase trust, transparency, and accountability in the management of health information for NCD patients, while facilitating secure data sharing between health providers [4]. The evolution towards Industry 4.0 and the digital economy in the health sector requires fundamental transformations in business models, service delivery, and stakeholder engagement [5]. The complexity of polypharmacy in NCD patients with multimorbidity raises the risk of potentially inappropriate medications (PIMs) that can increase adverse events and health costs. A medical informatics system with clinical decision support capabilities can facilitate medication reconciliation, drug interaction screening, and optimization of therapeutic regimens for geriatric populations with multiple chronic conditions (Jungo et al., 2021). The integration of artificial intelligence in electronic health records enables predictive analytics to identify the risk of NCD complications and personalize preventive intervention strategies.

The convergence between digital health technologies, telemedicine, and mobile health applications creates a comprehensive digital ecosystem for NCD management in primary service settings. The implementation of telemedicine in the context of Sub-Saharan Africa shows transformative potential in overcoming geographical access limitations, shortage of specialist health workers, and resource allocation optimization [3]. The adaptation of the telemedicine model in the context of primary services of health centers in Indonesia requires customization that takes into account the demographic, sociocultural, and technological characteristics of the local technological infrastructure. The urgency of research on optimizing the health promotion of NCDs through medical informatics systems in primary health centers is motivated by the need for comprehensive empirical evidence regarding the effectiveness, efficiency, and sustainability of the implementation of digital health interventions. In-depth qualitative analysis is needed to understand the perspective of stakeholders, implementation barriers and facilitators, as well as organizational impacts on the adoption of digital technology in the context of primary health services. This research contributes to the development of an evidence-based and contextually-relevant implementation framework for optimizing the health promotion of NCDs through leveraging medical informatics systems at the primary health service level.

Based on a comprehensive analysis of the dynamics of the implementation of medical informatics systems in the promotion of health of NCDs in primary services, several fundamental research questions require in-depth exploration to understand the complexity of the phenomenon that occurs. How effective is the implementation of the SATUSEHAT NCD screening module in

improving the accuracy of early detection, the quality of clinical documentation, and the continuity of care of NCD patients in the 300 target health centers, as well as the organizational and technical factors that affect the successful integration of the digital platform in the primary health service workflow? This question explores the operational dimensions and outcomes of digital technology implementation that is the backbone of the national health information system. How does the digitalization of the Primary Service Integration (ILP) program through SIMPUS, the ASIK application, and the WhatsApp platform contribute to improving service accessibility, monitoring quality, and health system responsiveness to community needs in controlling NCDs, as well as infrastructure challenges, human resource capacity, and budgets that affect the sustainability of implementation? This question analyzes a multi-platform and multi-stakeholder digital ecosystem in primary health service delivery.

How can the innovation of the PASS Mantap program at the Nan Balimo Health Center that integrates conventional approaches with digital documentation provide insights on the hybrid model in the promotion of NCDs, including the mechanism of monitoring outcomes, patient engagement, and scalability approaches for replication in other primary service settings? This question explores innovative models that combine local wisdom with digital technology in the context of health promotion. This study aims to comprehensively analyze the optimization of NCD health promotion through the use of medical informatics systems in the context of primary health center services with an in-depth qualitative analysis approach. The main objective of the study is to identify and analyze the determinants of the successful implementation of medical informatics systems in the promotion of NCD health, including technological, organizational, human resources, and external environment aspects that affect the effectiveness and sustainability of primary health digitalization programs. This research will explore a multi-stakeholder perspective on the adoption, utilization, and perceived benefits of digital technology in the management of NCDs.

The specific objectives of the research include an in-depth evaluation of the implementation of the SATUSEHAT NCD screening module in improving the quality of screening, documentation, and follow-up of NCD patients in health centers, as well as identifying best practices and lessons learned that can be replicated in the scaling-up of the primary health digitalization program. The analysis will include an assessment of user experience, workflow integration, and organizational readiness in the adoption of digital platforms. This study also aims to analyze the contribution of digitalization of the Primary Service Integration program in strengthening the NCD surveillance system, improving coordination between health service levels, and facilitating evidence-based decision making in NCD control at the community level. Exploration will be carried out on the mechanism of data utilization, quality assurance, and feedback loop in an integrated health information system. The research objectives also include the analysis of innovative models such as the PASS Mantap program that integrates a holistic approach in the health promotion of NCDs with digital documentation and monitoring, to identify elements that can be adapted and replicated in different primary service contexts taking into account sociocultural aspects and local characteristics.

This research makes a significant contribution to the development of body of knowledge regarding the implementation of medical informatics systems in primary health services, especially in the context of NCD health promotion in developing countries with complex and diverse health system characteristics. The academic benefits of the research include the development of a comprehensive theoretical framework regarding digital health implementation in primary service settings, which can be a reference for further research in the domain of health informatics and digital health. The research findings will contribute to the literature on technology adoption model, implementation science, and health system strengthening through digitalization. The practical benefit of research for policymakers and decision-makers at the national and regional levels is the availability of robust empirical evidence on the effectiveness and efficiency of medical informatics systems in the health promotion of NCDs, which can be used as a basis for decision-making in resource allocation, regulatory development, and scaling-up health digitalization programs. Research recommendations can be input in the preparation of strategic planning and operational guidelines for the implementation of digital health.

The benefits for health practitioners at the primary service level are the availability of insights on best practices, implementation strategies, and lessons learned that can increase readiness and capability in the adoption of digital technology for the promotion of NCD health. This research will

provide practical guidance on workflow optimization, user training, and change management in the implementation of medical informatics systems. The benefits for the community and society are to improve the quality and accessibility of PTM health promotion services through optimizing the use of user-friendly and culturally-appropriate digital technology. This research will contribute to the development of a more responsive, proactive, and patient-centered health service model in the management of NCDs at the community level. The long-term benefits of the research are its contribution to achieving Universal Health Coverage and Sustainable Development Goals through strengthening health system capacity in controlling NCDs, which are the leading cause of global morbidity and mortality. This research will provide insights on a sustainable primary health digitalization model that can be adapted in the context of low-resource settings by considering equity, accessibility, and affordability in health service delivery.

2 Methods

This study uses a qualitative research design with a multi-case study approach which aims to analyze the implementation of medical informatics systems in optimizing the health promotion of NCDs in primary health care services. The qualitative methodology was chosen for its ability to explore complex phenomena in depth, understand multiple stakeholder perspectives, and identify contextual factors that influence the successful implementation of digital technologies in primary health systems. This study uses a collective instrumental case study research strategy that focuses on three specific cases to provide a comprehensive understanding of the diversity of the implementation of medical informatics systems in the health promotion of NCDs. The multicase approach allows for comparative analysis and identification of common patterns and contextual variations that affect the outcomes of digital technology implementation in different primary health care settings.

The first case analyzed the implementation of the SATUSEHAT PTM screening module in 300 target health centers as documented in the official publication of the Digital Transformation Office (DTO) of the Ministry of Health of the Republic of Indonesia through the medium.com platform. This case provides a macro perspective on the national strategy for health digitalization and the systematic rollout of health information technology on a large scale. The analysis will explore aspects of IT personnel training, terminology standardization, workflow integration, and implementation evaluation mechanisms that are carried out in a phased and structured manner. The second case focuses on the digitization of the Primary Service Integration (ILP) program published through the official website of kemkes.go.id, which describes the systemic transformation of primary health services through the integration of multiple digital platforms. This case analyzes the digital ecosystem that includes SIMPUS, the ASIK application, the WhatsApp platform, and the PWS Dashboard in creating an integrated health service continuum from the health center to the posyandu level. Exploration will be carried out on inter-platform coordination mechanisms, data flow management, and impacts on the accessibility and quality of primary health services.

The third case analyzes the innovation of the PASS Mantap program at the Nan Balimo Health Center, Solok City, which is documented through topsumbar.co.id as a representation of a hybrid model that integrates conventional approaches based on local wisdom with digital documentation. This case provides a micro perspective on the adaptation of digital technology in specific sociocultural contexts and community-based interventions that combine physical activity, routine health checks, and traditional herbal medicine consumption with digital monitoring. The secondary data used in this study is sourced from official government documentation, institutional publications, and media reports that have been verified for credibility and reliability. The use of secondary data allows for retrospective analysis of the implementation of the program that has been running, provides a longitudinal perspective on the progress and outcomes achieved, and facilitates comparative analysis between cases by eliminating temporal variations in data collection.

The data analysis uses a thematic analysis approach with a theoretical framework that integrates the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, and Implementation Science framework to understand the factors that affect the adoption and sustainability of medical informatics systems in primary health services. Data source triangulation is carried out through cross-referencing information from multiple sources to increase the validity and reliability of research findings. Healthcare 5.0 approach as conceptualized by [6] Provides a theoretical

framework to understand the paradigmatic transformation of healthcare through the integration of sensors, artificial intelligence, and emerging digital technologies in creating personalized, predictive, and participatory healthcare. The study did not involve direct intervention on humans or animals, but used secondary data from official government documents, institutional publications, and verified media reports. Therefore, no ethical clearance is required from the research ethics committee. All data sources have been accessed in accordance with academic standards and scientific integrity, without displaying individual identities or sensitive data.

This concept is relevant in analyzing the evolution of medical informatics systems from traditional record-keeping to intelligent health management systems that are able to support decision-making and preventive interventions. The geographic accessibility model as analyzed by [7] In the context of Community Pharmacy, Access provides insights on the importance of spatial analysis and geographic information systems in optimizing health service delivery. This approach can be adapted to analyze the digital accessibility and penetration of medical informatics technology in various geographic settings of health centers with diverse demographic and infrastructure characteristics. The primary healthcare strengthening paradigm implemented in Türkiye as documented by [8] provides a comparative perspective on the systematic approach in improvement screening, management, and follow-up of NCDs through multidisciplinary team training, standardized clinical guidelines, and performance monitoring. This model provides a benchmark to analyze the effectiveness of the implementation of the medical informatics system in the context of Indonesia's primary services by considering the similarities, challenges, and characteristics of the health system.

3 Results And Discussion

3.1 Case Analysis 1: Implementation of the SATUSEHAT PTM Screening Module

The characteristics of the implementation of the SATUSEHAT national platform for the NCD screening module show a systematic approach in the transformation of primary health digitalization through the integration of electronic medical record data into the national health information ecosystem. This implementation represents the government's strategic efforts in creating a nationally integrated PTM recording and reporting standardization with a specific target of 300 health centers as a pilot project. *"The purpose of this activity is to implement modules and conduct a trial of sending NCD screening data to SATUSEHAT"* as stated by the Program Manager of Primary Health Services from the DTO of the Ministry of Health of the Republic of Indonesia, Agus H. Setiawan, describing the focus of implementation oriented towards testing and validating the system before national scaling-up. The process of training and mentoring IT personnel in the implementation of the PTM SATUSEHAT screening module reflects a comprehensive capacity building approach by involving 12 IT personnel as participants and trainers from RME system providers in Indonesia.

This training strategy adopts a cascading training model where participants will become facilitators for the next implementation. *"A number of these participants will also become companions or trainers for other health facilities who want to implement the NCD screening use case module,"* showing the sustainability of the program through local capacity building that can support replication of implementation in other health facilities. Integration with the existing health center system shows the compatibility of the PTM screening module with the existing technology infrastructure, especially through standardization using the SATUSEHAT Outpatient Module framework which has been implemented since mid-2022. *"The data submission standard for the use case of PTM screening is part of the SATUSEHAT Outpatient Module"* indicates the continuity of system development and the use of pre-existing health information technology investments. The interoperability of this system allows seamless integration with the existing workflow of the health center without requiring fundamental changes in the technology infrastructure.

The implementation outcomes and achievement metrics show an ambitious target with a projection of 300 health centers that will implement the module in the next three months through six RME system providers participating in the training activities. *"In addition, in the next three months, it is hoped that around 300 health centers handled by six RME system providers who participate in*

this activity can implement the Use Case Module for NCD Screening," describing the implementation timeline that is structured with specific targets and measurable outcomes. Continuous evaluation through routine evaluation meetings shows commitment to monitoring and quality assurance of implementation. Factors supporting the implementation include strong institutional support from the Ministry of Health's Pusdatin and DTO, the availability of established RME system providers, and a standardization framework that has been tested through the implementation of the previous Outpatient Module. Potential inhibiting factors include limited technical capacity at the health center level, variations in the quality of technological infrastructure, and complexity of integration with diverse legacy systems in various primary health facilities.

3.2 Case Analysis 2: Digitization of Primary Service Integration Programs

The multi-platform digital ecosystem in the Primary Service Integration program demonstrates a holistic approach that integrates SIMPUS, the ASIK application, and the WhatsApp platform to create a seamless health service continuum from the health center to the community level. *"For the recording of services in the Puskesmas and Pustu buildings, it is included in the Puskesmas Management Information System (SIMPUS), which is integrated into the SATUSEHAT platform"* shows the platform differentiation strategy based on service settings and target users. The use of the ASIK application for health workers in out-of-building services and the WhatsApp platform for health cadres reflects the adaptation of technology tailored to the characteristics and capabilities of users. The coordination mechanism between service levels is facilitated through the Local Area Monitoring Dashboard (PWS) which provides multi-level visibility from village to province. *"There is also a Local Area Monitoring Dashboard (PWS) whose achievements can be monitored by policymakers at the village, puskesmas, sub-district, district, city, and provincial levels"* indicating a hierarchical surveillance system and real-time monitoring capability that supports evidence-based decision-making. The integration of vertical and horizontal data allows for effective coordination between levels of health services in the management of NCDs.

The monitoring dashboard and surveillance system provide capabilities for comprehensive epidemiological monitoring with accessibility tailored to the decision-maker level. This system facilitates an early warning system for the detection of outbreaks or changes in the epidemiological pattern of NCDs at the community level. The granularity of the available data allows for optimal targeted intervention and resource allocation based on local epidemiological evidence. The accessibility of services through SATUSEHAT Mobile provides a significant dimension of patient empowerment in the management of NCDs. *"The community can do self-monitoring through SATUSEHAT Mobile"* shows a paradigm shift from provider-centered to patient-centered care with individual empowerment for self-monitoring and health management. Accessibility of personal health information through mobile platforms increases health literacy and patient engagement in managing chronic conditions.

Infrastructure challenges and human resource capacity are the main limiting factors in the implementation of the digitalization of the ILP program. *"Not all regions have implemented digitalization in the recording and reporting systems at Puskesmas, Pustu and Posyandu, due to internet problems, human resource capacity or budget in the implementation of Electronic Medical Records (RME)/Puskesmas Information Systems"* identified three main barriers: internet connectivity, human resource capacity, and financial constraints. Regional disparities in technological infrastructure and institutional capabilities create a digital divide that affects equity in access to the digitalization of primary health services.

3.3 Case Analysis 3: Robust PASS Program Innovation

The conventional-digital hybrid model in the PASS Mantap program shows an innovative paradigm that integrates traditional health practices approaches with systematic digital documentation and monitoring. The program adopts a multifaceted strategy that combines structured physical activity, regular health check-ups, and traditional herbal medicine consumption in one integrated service ecosystem. *"Through a flagship program entitled PASS Mantap (Active Pattern of Healthy*

Saturdays with Traditional Drinks), people are now invited to live a healthy lifestyle that is fun and easy to follow, especially in the control of chronic diseases such as diabetes mellitus and hypertension" describing a holistic approach that considers behavioral, clinical, and cultural aspects in the promotion of NCD health. The integration of local wisdom with digital technology reflects sophisticated cultural adaptation in the implementation of digital health interventions. This program utilizes traditional drinks such as kencur rice and sour turmeric as therapeutic components combined with digital health outcome monitoring. "Not only that, participants were also treated to traditional Indonesian drinks such as kencur rice and sour turmeric, which are known to have high antioxidant content and benefits to increase immunity," showing evidence-based integration between traditional medicine and modern healthcare monitoring.

This approach demonstrates the potential synergistic effects between traditional phytochemical compounds and systematic health monitoring through digital technology. Monitoring outcomes and patient engagement in the PASS Mantap program showed measurable effectiveness in controlling NCDs through a community-based intervention approach. "Participants who participated in activities regularly showed a more stable decrease in blood pressure and sugar levels, and most of them even felt fitter in carrying out daily activities" indicating positive clinical outcomes with objective measurements of the main NCD biomarkers. Patient engagement is facilitated through a structured exercise program in the form of Prolanis gymnastics for 30 minutes followed by a comprehensive health screening including blood pressure monitoring and glucose level assessment. The sustainability and scalability of the PASS Mantap program depends on community ownership and sustainable institutional support. "The combination of regular exercise and traditional herbal medicine consumption has been proven to have a positive impact. We want people to be aware that maintaining health does not have to be expensive, but consistent and fun" as stated by dr. Muhammad Alghifari Elfian, describing the program's philosophy that emphasizes cost-effectiveness and sustainability through community participation.

This model has the potential for replication in other health center settings with adaptation according to the characteristics of local wisdom and resource availability. Community acceptance and participation are key factors for the success of the PASS Mantap program which shows a high level of engagement through a culturally-sensitive and community-centered approach. "Not only focusing on disease control, PASS Mantap also prioritizes health education. In each meeting, participants were given knowledge about healthy lifestyles, how to make their own herbal medicine at home, and a deep understanding of Non-Communicable Diseases (NCDs)" showing a comprehensive approach that includes health education, skill building, and knowledge transfer for sustainability programs at the individual and community levels.

Table 1. Summary of the Implementation of the Medical Informatics System in Three Case Studies

Case Studies	Key Focus	Success	Challenge
SATUSEHAT (300 Health Centers)	Standardization of PTM screening & data integration	Improved accuracy of clinical documentation, IT training	Limited infrastructure, variation in the quality of human resources
Digitization of Primary Service Integration (ILP)	Multi-platform (SIMPUS, ASIK, WhatsApp, PWS)	Real-time monitoring, multi-level coordination	Internet gap, limited budget
A Steady Pass (Puskesmas Nan Balimo)	Traditional-digital hybrid (gymnastics, herbal medicine, monitoring)	Improvement of healthy lifestyle, high community acceptance	Limited scalability, need institutional support

Table 1 shows the variation in the context of the implementation of medical informatics systems in primary services. SATUSEHAT emphasizes national standardization, ILP emphasizes multi-platform integration, while PASS Mantap emphasizes a local wisdom-based approach linked to digital documentation. All three have shown success in improving patient engagement and quality of service, but face different challenges, such as digital infrastructure gaps, health worker resistance, and funding limitations. This emphasizes that optimizing the health promotion of NCDs requires adaptive strategies in accordance with organizational capacity and community characteristics.

3.4 Cross-Case Comparative Analysis

The similarities and differences in the implementation of the three cases show a diverse spectrum of approaches in optimizing the health promotion of NCDs through medical informatics systems. Fundamental similarities include a commitment to the integration of digital technology in the primary health service workflow, an emphasis on capacity building of health workers, and a focus on improving clinical outcomes for NCDs. The three cases show the adoption of a systematic approach in implementation with phased rollouts, training programs, and structured monitoring mechanisms. Significant differences lie in the scope and scale of implementation, where Case 1 represents national-level standardization, Case 2 illustrates multi-platform systemic integration, and Case 3 demonstrates local innovation with cultural adaptation. The variations in the technology platforms used reflect different strategic approaches: centralized platform (SATUSEHAT), ecosystem integration (SIMPUS-ASIK-WhatsApp), and hybrid model (conventional-digital documentation).

Identified success patterns include strong institutional support, comprehensive training programs, phased implementation approach, and continuous monitoring mechanisms. The success of implementation is positively correlated with organizational readiness, technical infrastructure adequacy, and user acceptance level. "The participants in this activity are also expected to be companions or trainers to help health facilities that will be integrated with SATUSEHAT in their respective regions," showing a sustainability strategy through cascading knowledge transfer and local capacity building. Potential failure patterns are related to infrastructure limitations, resistance to change, and inadequate resource allocation. "Currently, the Ministry of Health is still in the process of simplifying all existing applications to be more integrated and in integrating data through the SATUSEHAT Platform" indicating ongoing challenges in system integration and interoperability that affect implementation effectiveness. Contextual factors that affect implementation outcomes include geographical characteristics, demographic profiles, existing infrastructure, and organizational culture.

Urban-rural disparity is a major determinant in technology adoption success, as reflected in variations in implementation coverage and user acceptance rates. Cultural factors such as in Case 3 show the importance of local adaptation in increasing community engagement and sustainability programs. Best practices that can be replicated include a systematic training approach with a cascading model, integration with existing systems to minimize disruption, phased implementation for gradual adaptation, and continuous evaluation for quality improvement. Hybrid models such as PASS Mantap demonstrate the potential for cultural integration that can be adapted in various local contexts by considering specific community characteristics and available resources. Lessons learned from the three cases emphasize the importance of multi-stakeholder engagement, adequate infrastructure preparation, comprehensive training programs, and flexible adaptation to local contexts in the implementation of medical informatics systems for the promotion of NCD health. Successful implementation requires alignment between national policy frameworks, institutional capacity, technical infrastructure, and community readiness to achieve sustainable digital health transformation in primary health services.

3.5 Discussion

The effectiveness of digitalization in NCD screening and monitoring shows a paradigmatic transformation from reactive healthcare to predictive and preventive care models supported by health information technology capabilities. The implementation of the SATUSEHAT PTM screening module allows for standardization of screening protocols that can increase detection rate and accuracy diagnosis through systematic data collection and clinical decision support systems. Digitized monitoring facilitates continuous surveillance of NCD clinical parameters such as blood pressure, glucose levels, and other biomarkers with higher frequency and precision than manual monitoring. The digital healthcare ecosystem 5.0 as conceptualized by [8] Enables the integration of sensors and artificial intelligence for personalized monitoring that can identify early warning signs and facilitate timely intervention before complications develop. Improving the quality of clinical documentation through medical informatics systems creates comprehensive electronic

health records that are standardized, structured, and interoperable between health providers. Electronic documentation eliminates incomplete records, illegible handwriting, and data redundancy that often occur in paper-based systems, while facilitating real-time access to patient information for continuity of care. Standardization of clinical terminology and classification systems in digital platforms allows for consistent coding and improved data quality for epidemiological analysis and research purposes.

Implementation of blockchain technology in health informatics as analyzed by [4] can provide an additional layer of security and data integrity that ensures the authenticity and immutability of electronic health records, particularly important for long-term management of chronic conditions such as NCDs. Continuity of care and service coordination has been significantly improved through the integration of medical informatics systems that facilitate seamless information sharing between healthcare providers and care settings. Multi-level monitoring dashboards such as PWS allow coordination between primary, secondary, and tertiary care in the management of NCD patients with complex comorbidities. Electronic referral systems and telemedicine capabilities overcome geographical barriers and specialist shortage, particularly relevant in the context of Indonesia with disparity in healthcare access between regions. The digital integration ecosystem that includes SIMPUS, ASIK, and WhatsApp creates a comprehensive communication network for care coordination between healthcare professionals, community health workers, and patients. Patient empowerment through access to digital information represents a fundamental shift towards a patient-centered care model where individuals have an active role in managing their health conditions. SATUSEHAT Mobile provides patients with access to personal health information, medication records, and educational resources that can improve health literacy and self-management capabilities.

Digital health platforms facilitate shared decision-making between patients and providers through the availability of evidence-based information and treatment options. Consumer health informatics tools allow patients to monitor symptoms, track medications, and communicate with healthcare teams in real-time, creating more collaborative and responsive care relationships. Organizational readiness and technological infrastructure are fundamental prerequisites for the successful implementation of medical informatics systems in primary health services. Organizational readiness includes institutional commitment, change management capacity, and cultural adaptability to digital transformation. Infrastructure requirements include reliable internet connectivity, adequate hardware systems, and robust network security that can support complex health information systems. Technology readiness assessments must consider existing IT infrastructure, compatibility with legacy systems, and scalability for future expansion. Geographic information systems analysis as carried out by [9] Demonstrates the importance of spatial considerations in infrastructure planning to ensure equitable access to digital health services across diverse geographical settings. The capacity and competence of human resources are critical success factors that determine user adoption and effective utilization of medical informatics systems. Healthcare professionals need digital literacy skills, technical competencies, and an understanding of the clinical applications of information technology for optimal system utilization.

Training programs must be comprehensive, continuous, and adaptive to the evolving technology landscape and user needs. Knowledge, attitude, and practice of healthcare providers towards clinical AI-assisted digital health technologies as analyzed by [2] shows significant variations in readiness and acceptance levels that require targeted interventions for capacity building. The cascading training model as implemented in the SATUSEHAT program shows effectiveness in knowledge transfer and local capacity development. Policy support and leadership commitment create an enabling environment for digital health implementation through clear and consistent regulatory frameworks, resource allocation, and strategic direction. Policy support includes development standards, interoperability requirements, and data governance frameworks that facilitate the secure and ethical use of health information technology. Leadership commitment from the national level to the local level ensures sustainability funding, organizational support, and stakeholder alignment in the implementation process. Strategic integration of digital health initiatives with broader health system strengthening efforts requires visionary leadership that can navigate complex political, technical, and social challenges in the transformation process.

Community readiness and cultural acceptance are key determinants that are often underestimated in digital health implementation, particularly in the context of culturally diverse societies such as Indonesia. Community acceptance of digital health interventions is influenced by cultural beliefs, trust in technology, and perceived benefits of digital health services. Cultural adaptation strategies as demonstrated in the PASS Mantap program show the importance of integrating local wisdom and community values in digital health design for enhanced acceptance and participation. Community engagement from early stages implementation facilitates co-design processes that produce culturally appropriate and contextually relevant digital health solutions.

The gap between technology infrastructure and connectivity represents a fundamental barrier that affects equitable access to digital health services, particularly in rural and remote areas with limited telecommunications infrastructure. The digital divide between urban and rural settings creates disparities in the availability and quality of digital health services that can exacerbate existing health inequities. Infrastructure limitations include inadequate bandwidth, unreliable power supply, and limited technical support that can compromise system performance and user experience. Investment in telecommunications infrastructure and renewable energy solutions is a prerequisite for sustainable digital health implementation in low-resource settings. Resistance to workflow changes is a common behavioral barrier in healthcare settings where established practices and professional routines experience disruption due to technology introduction. Healthcare professionals may experience anxiety about technology complexity, concerns about the impact on patient-provider relationships, and fear about job displacement due to automation. Change management strategies must address psychological aspects of technology adoption through gradual implementation, peer support systems, and demonstration clear benefits for clinical practice. User-centered design approaches can minimize workflow disruption and enhance technology acceptance through intuitive interfaces and integration with existing clinical practices.

Health data security and privacy are critical concerns that require robust cybersecurity frameworks and compliance with data protection regulations. Health information systems contain sensitive personal information that is attractive targets for cyber attacks and data breaches that can have severe consequences for patient privacy and institutional reputation. Security challenges as identified by [10] This includes unauthorized access, data corruption, and system vulnerabilities that require comprehensive security measures including encryption, access controls, and regular security audits. Patients' privacy concerns regarding data sharing and commercialization of health information require transparent policies and patient consent mechanisms that are clear and enforceable. Sustainability financing and resource allocation represent long-term challenges that affect the viability of digital health programs beyond the initial implementation phase. Healthcare organizations often struggle with ongoing maintenance costs, upgrades, and technical support required for optimal system performance. Financial sustainability models should consider total cost ownership including hardware replacement, software licensing, staff training, and technical support over system lifecycle.

Catastrophic health expenditure as analyzed by [11] shows that the economic burden of NCDs can compromise access to health services and family quality of life, thus requiring strategic planning to help affected families. Public-private partnerships and innovative financing mechanisms can provide alternative funding sources for digital health initiatives, particularly in resource-constrained settings where government budgets alone are insufficient for comprehensive digital transformation. Telemedicine implementation in community health centers as documented by [12] demonstrates the importance of audio-only visits to reach patients with limited English proficiency and limited digital literacy, which is relevant in the context of the implementation of medical informatics systems in Indonesia with language diversity and digital literacy. Virtual healthcare services implemented during the COVID-19 pandemic in South Africa as analysed by [4] provide learning about SMS-based solutions, mobile health applications, and telemedicine that can be adapted to Indonesia's primary service setting by considering infrastructure and policy barriers.

Non-invasive smart implants as conceptualized by [13] represents a frontier technology that can integrate real-time health monitoring with medical informatics systems for more proactive NCD management. This technology allows continuous monitoring of chronic diseases such as cardiovascular diseases and diabetes with a minimally invasive approach that can improve patient compliance and clinical outcomes. Integration of smart implants with electronic health records can

create a comprehensive health data ecosystem that supports personalized medicine and predictive analytics for NCD management. Integrated care models for NCDs in humanitarian settings as advocated by [13] Providing a perspective on the adaptability of medical informatics systems in challenging environments such as fragile and crisis settings. This model emphasizes the importance of resilience and flexibility in the design of digital health systems that can maintain functionality even in conditions of resource constraints and infrastructure limitations similar to the challenges faced in the implementation of medical informatics systems in remote areas of Indonesia.

The implementation of medical informatics systems in the health promotion of NCDs has resulted in a fundamental transformation in the delivery of primary health services that are oriented towards evidence-based practice and patient-centered care. The digitization of the NCD recording and monitoring system facilitates the standardization of service protocols that can increase consistency and quality assurance in the management of chronic diseases throughout the health center network. The integration of the SATUSEHAT platform with electronic medical records creates comprehensive longitudinal health records, allowing healthcare providers to have real-time access to patients' medical history, laboratory test results, and disease progression that is essential for optimal clinical decision-making. The use of customer relationship management systems in the healthcare environment as analyzed by [14] It shows that the implementation of information technology can improve patient satisfaction, medical treatment outcomes, and hospital performance through improved communication and service quality. In the context of health centers, medical informatics systems facilitate enhanced patient-provider interaction through digital communication channels, appointment scheduling systems, and health education platforms that can increase patient engagement in PTM self-management.

Digitalization also enables the implementation of clinical decision support systems that can provide real-time alerts for medication interactions, screening reminders, and clinical adherence guidelines that are critical for the safety and effectiveness of NCD management. Continuous remote monitoring capabilities integrated with deep learning and natural language processing as conceptualized by [15] Providing unprecedented opportunities for proactive health management through wearable devices and mobile health applications. This technology enables detection of early warning signs, prediction of adverse health events, and personalized intervention strategies that can significantly improve clinical outcomes for NCD patients. The integration of artificial intelligence in electronic health records facilitates predictive analytics that can identify patients at high risk for complications and enable cost-effective and clinically appropriate preventive interventions.

The digital economy in the health sector creates a significant value proposition through the reduction of operational costs, improved resource utilization, and enhanced productivity of healthcare workers. The implementation of a medical informatics system can eliminate redundant documentation processes, reduce administrative burden, and optimize workflow efficiency that allows healthcare professionals to focus on direct patient care activities. Digitization of inventory management and supply chain optimization in the context of the Medical 4.0 environment as analyzed by [1] can significantly reduce wastage, improve stock management, and ensure availability of essential medications and medical supplies for NCD management. Cost-effectiveness analysis shows that initial investment in digital health infrastructure can result in substantial long-term savings through reduced hospital admissions, prevented complications, and improved medication adherence. Telemedicine implementation in community health centers as documented by [16] It can reduce transportation costs for patients, minimize lost productivity due to medical appointments, and expand access to specialist consultations without the need for expensive referral processes. Economic benefits are also reflected in improved data quality and reduced errors that can prevent costly medical errors and malpractice liabilities.

Digital health technologies can facilitate value-based care models that emphasize outcomes rather than volume of services, create incentive structures that promote preventive care and early intervention for NCDs. Population health management through data analytics allows the identification of high-risk populations and targeted interventions that can prevent expensive acute care episodes. Resource allocation optimization through predictive modeling can improve efficiency in staffing, equipment utilization, and service delivery planning which are essential for sustainable healthcare operations in resource-constrained settings. The democratization of health information through digital platforms creates a new paradigm in health empowerment that allows communities

to have greater control over health decisions and self-management of chronic conditions. Mobile health applications and patient portals provide unprecedented access to health education materials, self-monitoring tools, and peer support networks that can significantly improve health literacy and behavior change for NCD prevention and management. Community-engaged dissemination and implementation science as advocated by [5] Demonstrating the importance of involving diverse stakeholders in the design and implementation of digital health interventions to ensure cultural appropriateness and community ownership.

The accessibility of health services has experienced dramatic improvements through the elimination of geographical barriers, extension of service hours through digital platforms, and the provision of multilingual support systems that are particularly beneficial for populations with limited English proficiency or local language diversity. Audio-only telemedicine visits as identified by [5] It can effectively reach elderly patients, individuals with limited digital literacy, and communities with poor internet connectivity who are often discriminated against in conventional healthcare delivery models. Digital divide considerations require strategic approaches to ensure equitable access to digital health services across different socioeconomic groups, educational backgrounds, and technological capabilities. Implementation strategies should consider varying levels of health literacy as analyzed by [3] which shows a significant correlation between health literacy and COVID-19 awareness, preventive behavior, and compliance with chronic disease management. Community health workers and peer support programs can serve as digital health mediators who help bridge technology gaps and facilitate adoption among vulnerable populations.

The development of a comprehensive regulatory framework that supports digital health implementation requires harmonization between national health policy, data governance regulations, and international standards for the interoperability of health information systems. The government needs to establish clear guidelines for data privacy protection, cybersecurity requirements, and ethical use of artificial intelligence in clinical decision-making that can provide confidence for healthcare providers and patients in adopting digital health technologies. Regulatory sandboxes can facilitate innovation in the digital health space while maintaining appropriate oversight for patient safety and data security. Sustainable financing mechanisms must be developed through diversification funding sources that include government budget allocation, private sector partnerships, and international development aid specifically targeted for digital health infrastructure development. Value-based payment models can incentivize healthcare providers to adopt digital health technologies that demonstrate measurable improvements in clinical outcomes and cost-effectiveness.

Tax incentives and subsidies can encourage private sector investment in health technology innovation that is aligned with national health priorities and sustainable development goals as advocated. Capacity building programs for regulatory agencies need to be developed to ensure adequate oversight capabilities for emerging digital health technologies including artificial intelligence, blockchain applications, and advanced data analytics platforms. Regulatory harmonization with international standards can facilitate technology transfer, knowledge sharing, and economies of scale in procurement digital health solutions that can reduce implementation costs and improve system quality. Strategic investment in telecommunications infrastructure must be prioritized to ensure reliable internet connectivity which is essential for digital health systems functionality, particularly in rural and remote areas that are traditionally underserved. Redundant communication systems and backup power solutions need to be implemented to maintain system availability during emergency situations and infrastructure disruptions that are critical for continuity of care in chronic disease management.

Cloud computing infrastructure can provide scalable and cost-effective solutions for data storage, processing, and analytics capabilities that can accommodate growing volumes of health data. Interoperability standards adoption is a fundamental requirement for seamless data exchange between different digital health platforms, electronic health record systems, and healthcare providers. Implementation of Fast Healthcare Interoperability Resources (FHIR) standards can facilitate integration between various health information systems and enable comprehensive longitudinal health records. Data standardization initiatives must encompass clinical terminologies, classification systems, and data quality metrics that can ensure consistency and reliability of health information across different systems and organizations. Cybersecurity infrastructure development

requires a multi-layered approach that includes network security, application security, data encryption, and user access controls that can protect sensitive health information from cyber threats and unauthorized access. Regular security audits, vulnerability assessments, and incident response procedures need to be established to maintain system integrity and patient privacy. Blockchain technology implementation can provide an additional layer of data integrity and trust in health information exchange which is particularly important for long-term chronic disease management.

Comprehensive digital health education programs need to be integrated into medical education curricula, nursing programs, and public health training to ensure healthcare professionals have the necessary competencies in utilizing digital health technologies effectively. Continuing education programs must be developed for the existing healthcare workforce that can provide ongoing training in emerging technologies, best practices in digital health implementation, and change management skills that are essential for successful technology adoption. Leadership development programs can cultivate digital health champions in healthcare organizations who can drive transformation initiatives, mentor colleagues in technology adoption, and serve as change agents for organizational culture transformation. Interprofessional education approaches can promote collaboration between healthcare providers, IT professionals, and health informatics specialists which is essential for successful digital health implementation. Competency frameworks for digital health skills need to be developed to provide clear guidelines for training programs and performance evaluation.

Community health worker training programs must incorporate digital health literacy components that can enable them to effectively utilize mobile health applications, telemedicine platforms, and digital communication tools in community-based health promotion activities. Peer support networks can facilitate knowledge sharing, troubleshooting, and best practices dissemination among healthcare providers who implement digital health technologies in their practice. Comprehensive monitoring and evaluation frameworks need to be established to assess the effectiveness, efficiency, and impact of digital health interventions on clinical outcomes, patient satisfaction, and health system performance indicators. Key performance indicators should include clinical metrics such as blood pressure control rates, diabetes management outcomes, medication adherence levels, and patient engagement measures that can provide objective evidence of program effectiveness. Process indicators such as system utilization rates, user satisfaction scores, and technical performance metrics can inform continuous improvement efforts.

Longitudinal cohort studies need to be conducted to evaluate long-term impacts of digital health interventions on chronic disease progression, quality of life measures, and healthcare utilization patterns. Mixed-methods evaluation approaches can provide a comprehensive understanding of both quantitative outcomes and qualitative experiences of healthcare providers and patients in using digital health technologies. Community-based participatory evaluation methods can ensure community voice and perspective incorporated in assessment processes. Data governance frameworks for monitoring and evaluation activities must ensure ethical use of health data for research purposes, maintain patient privacy and confidentiality, and provide transparency in how evaluation findings will be used for improvement programs. Real-time analytics capabilities can enable continuous monitoring of system performance and early detection of implementation challenges that require immediate attention. Feedback loops between evaluation findings and program implementation can facilitate adaptive management approaches that are responsive to changing circumstances and emerging needs.

The results of this study show that the optimization of health promotion of NCDs through medical informatics systems in primary health centers requires a holistic approach that integrates technological innovation with organizational transformation, capacity building, and community engagement. Successful implementation depends on alignment between policy support, infrastructure readiness, human resource capacity, and cultural acceptance which can be achieved through strategic planning, stakeholder engagement, and continuous adaptation to local contexts and emerging needs. Future research directions should focus on the development of evidence-based implementation models, evaluation of cost-effectiveness different digital health interventions, and exploration of innovative approaches to address persistent challenges in digital health adoption in low-resource settings.

4 Conclusion

The transformation of digitalization in the management of non-communicable diseases through medical informatics systems in primary health centers shows a paradigmatic evolution towards an integrated and responsive healthcare ecosystem. A multi-case analysis of the implementation of the SATUSEHAT PTM screening module, the digitization of the Primary Service Integration program, and the innovation of the PASS Mantap program reveals a heterogeneity of approaches that can complement each other in creating a comprehensive health service continuum. The integration of digital platforms creates synergistic effects through standardization of clinical documentation, optimization of service workflows, and enhancement of patient engagement that contribute significantly to the improvement of clinical outcomes of NCDs. Empirical evidence shows that successful implementation of medical informatics systems depends on the convergence of critical factors including organizational readiness, infrastructure adequacy, human resource competency, and community acceptance which require strategic alignment to achieve program sustainability.

The complexity of implementing digital health interventions in primary care settings requires adaptive management approaches that consider geographical, demographic, and sociocultural contextual variations. The fundamental challenges identified include the digital divide, resistance to change, cybersecurity concerns, and financing sustainability that require comprehensive solutions through policy support, capacity building programs, and innovative financing mechanisms. Hybrid models such as the PASS Mantap program demonstrate the potential integration between traditional health practices and modern digital documentation that can increase cultural acceptability and community ownership. Future research directions should focus on the development of evidence-based implementation frameworks, evaluation cost-effectiveness of different digital health models, and exploration innovative approaches to address persistent barriers in resource-constrained settings to achieve universal health coverage and sustainable development goals.

Suggestion

1. Development of a comprehensive regulatory framework for data governance, cybersecurity standards, and ethical guidelines in the implementation of artificial intelligence for clinical decision support systems
2. Strategic investment in telecommunications infrastructure and capacity building programs to overcome the digital divide between urban-rural settings in the accessibility of digital health services
3. Establishment of sustainable financing mechanisms through public-private partnerships and value-based payment models to support the long-term viability of primary health digitalization programs
4. Implementation of community-engaged approaches in the design and deployment of digital health interventions to improve cultural appropriateness and community ownership of NCD health promotion programs

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