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Digital Transformation of Healthcare Services in Indonesia through the Utilization of Internet of Things Smartwatches

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Abstract **Original Research Article**

The digital transformation of healthcare opens up opportunities for the use of smartwatches as biomedical instruments for real-time monitoring of physiological parameters, such as heart rate, oxygen saturation, sleep, and physical activity. This potential is relevant for Indonesia, which faces the dual burden of infectious and non-communicable diseases, but implementation remains limited by social, technical, and regulatory factors. This study employs a systematic literature review with an integrative synthesis approach examining seven studies (2021–2024) that discuss aspects of adoption, clinical applications, digital forensics, IoT, and interoperability. The synthesis results demonstrate that adoption is primarily determined by ease of use, usefulness, and enjoyment, while cost is insignificant. Real clinical potential includes chronic disease monitoring and integration with electronic medical records, although usability remains moderate. From a security perspective, sensitive data on smartwatches is vulnerable due to limited forensic capabilities and data protection regulations. In conclusion, smartwatches promise a preventive role in healthcare, but their utilization is hampered by low digital literacy, limited clinical validation, and the absence of interoperability standards. Policy implications include the development of security regulations, interoperability standards, sensor certification, and digital literacy programs. Further research needs to test long-term clinical effectiveness and examine adoption models in vulnerable populations.

Keywords: Digital Health, Smartwatches, Internet of Things (IoT), Remote Monitoring, Health System in Indonesia.

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INTRODUCTION

Digital transformation has changed the paradigm of healthcare services from conventional systems to more personal, predictive, and sustainable models. One significant innovation is the use of smartwatches as modern biomedical instruments (Huang et al., 2025). These devices are no longer merely timepieces but are capable of monitoring physiological parameters in real time through PPG

sensors, ECG, accelerometers, and other biosensors (Scardulla et al., 2023). Various health indicators such as heart rate, oxygen saturation, sleep patterns, physical activity, and stress can be recorded continuously without expensive clinical procedures. Globally, this technology supports preventive medicine, early detection of chronic diseases, and remote patient monitoring aligned with telehealth developments.

Despite its great potential, smartwatch utilization still faces serious challenges. One is the technology paradox, where groups with the highest health risks are actually reluctant to use these devices (Löchner et al., 2025). The elderly and chronic disease patients are often hindered by low digital literacy, the perception that technology is complicated, doubts about data accuracy, and privacy concerns. This condition limits the optimization of public health benefits (Bejaković & Mrnjavac, 2024).

Ecosystem fragmentation emerges because each manufacturer uses different algorithms and data formats, making the integration of smartwatch data with medical information systems difficult. The absence of interoperability standards and clinical validation guidelines further weakens data utilization, particularly in supporting optimal medical decision-making (Williamson & Prybutok, 2024).

Security is one of the main issues in smartwatch utilization. As part of the Internet of Things, these devices are vulnerable to cyberattacks that can expose health data and personal information. Forensic findings reveal that besides recording biometric data, smartwatches also store location, communication history, and user activities (Madanian et al., 2024). The absence of an adequate digital forensic framework complicates cybercrime investigations while creating a dilemma between expanding health functions and protecting sensitive data.

In Asia, particularly Indonesia, the urgency of smartwatch utilization for health is increasingly prominent. This region faces a double burden of disease, both communicable and non-communicable (Al-Halhouli et al., 2021). Indonesia has a high prevalence of hypertension, diabetes, and cardiovascular diseases, while healthcare service gaps, especially in rural areas, remain a serious problem (Mashuri et al., 2022). Smartwatches offer potential as a relatively affordable and inclusive means of remote health monitoring. However, adoption rates remain low due to economic barriers, limited digital literacy, and the absence of strong supporting policies (Yang et al., 2024).

Empirical evidence in Indonesia is still limited. International findings demonstrating the benefits of smartwatches in arrhythmia detection, physical activity monitoring, and health behavior changes are not fully relevant to local conditions, given the differences in social, economic, infrastructure, and regulatory contexts (Duncker et al., 2021).. This underscores the research gap that needs to be addressed.

This research aims to fill that gap by examining adoption factors among high-risk groups, the potential integration of smartwatch data into formal healthcare systems, and security and clinical validity issues. This focus is expected to provide theoretical contributions to the development of digital health literature as well as practical recommendations for policymakers in formulating national strategies related to interoperability, digital literacy enhancement, and strengthening data protection regulations. The urgency of this research grows alongside the acceleration of digital transformation, increasing prevalence of chronic diseases, and the need for remote health monitoring solutions in Indonesia.

MATERIALS AND METHODS

This research employs a systematic literature review design with an integrative synthesis approach to analyze smartwatch implementation in the healthcare ecosystem. Literature was searched based on inclusion criteria (publications from 2021–2024, in Indonesian language, based on empirical data, with clear methodology) and excluded technical studies without health applications as well as reviews without primary data (Lubbe et al., 2020). Seven primary studies were analyzed, covering consumer adoption, digital forensic investigation, telehealth, obesity monitoring, IoT exploration, global review,

and application development. Analysis was conducted through data extraction, methodological quality assessment, thematic coding (user adoption, digital security, clinical applications, technological aspects, implementation), and cross-study synthesis to identify consistencies, contradictions, and research gaps. Validity was maintained through triangulation, peer debriefing, and audit trail, while the main limitations lie in geographical coverage, language, and methodological diversity (Jason & Glenwick, 2015).. This approach produces a concise, transparent, and replicable evidence synthesis, providing an evidential foundation for smartwatch integration in modern healthcare services.

RESULTS

The review of seven research articles on smartwatch utilization in healthcare demonstrates diverse study focuses, ranging from consumer adoption and behavior aspects, digital security, clinical applications, chronic disease monitoring, to technology development and IoT integration. Table 1 displays a research summary that includes title, authors, year, issues examined, methods, results, and conclusions. Furthermore, Table 2 summarizes principal findings based on research domain, study focus, key results, limitations, and implications. This presentation provides a structured overview of the developmental direction of smartwatch research in healthcare while identifying research gaps that remain open.

Table 1. Summary of Previous Studies Related to Wearable Technology (Smartwatch) in Indonesia

No	Title; Author(s); Year	Research Problem	Method	Results	Conclusion
1	Analysis of Value Based Adoption Model Influence on Consumer Intention to Use Wearable Technology - Smart Watch in Indonesia During the COVID-19 Pandemic; (Widyarini, 2022)	Suboptimal adoption of wearable technology (smartwatch) in Indonesia, particularly among the 45+ age group who lack understanding of its health benefits. Need to identify factors influencing consumer intention to adopt IoT-based wearable technology during the COVID-19 pandemic.	Quantitative research with causal research design. Sample: 262 respondents aged 17-60 years. Sampling technique: purposive sampling. Data analysis: Structural Equation Modeling (SEM) using Smart PLS 3.0. Instrument: 7-point Likert scale questionnaire.	Perceived value was significantly influenced by usefulness (β=0.225), enjoyment (β=0.252), and technicality (β=0.381). Perceived fee had no significant effect (β=0.103; p=0.071). Perceived value significantly influenced intention to use (β=0.548). Technicality had the greatest influence.	VAM can predict intention to adopt wearable technology. Consumers do not consider cost as a significant factor. Manufacturers need to focus on ease of use, comfort, and product usefulness to increase wearable technology adoption for health self-monitoring.
2	Forensic Analysis of Signal Private Messenger Service on Smartwatch Using National Institute of Justice Method; (Sunardi et al., 2021)	Increasing use of Android-based smartwatches with Signal Private Messenger (SPM) application potentially creates cybercrime, particularly	Quantitative research with National Institute of Justice (NIJ) method. Scenario: pornography crime case. Forensic tools: Wondershare Dr. Fone, MOBILedit, and Oxygen Forensics. Evidence sought: photos (31), videos (16), music (3), contacts (11),	Wondershare Dr. Fone: 80% accuracy (successfully extracted 19 photos, 7 videos, 2 music files, 1 pornographic chat). MOBILedit: 40% accuracy (successfully	NIJ method is effective for cyberporn forensic analysis on SPM in smartwatches. Wondershare Dr. Fone is the best forensic tool with highest accuracy (80%) in extracting digital evidence of

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		pornography. Need to conduct digital forensic investigation to identify and extract digital evidence from SPM on smartwatches.	and chats (9). Analysis using 5 NIJ stages: identification, collection, examination, analysis, and reporting.	extracted 19 photos, 2 pornographic music files). Oxygen Forensics: 0% accuracy (failed to read SPM application). Wondershare Dr. Fone provided the best results with highest success rate.	pornographic content. This tool can be recommended for investigating digital crime cases on Android-based smartwatches.
3	Designing Telehealth Solutions Using Smart Watch for Early Detection of Coronary Heart Disease Risk; (Ricki et al., 2024)	Coronary Heart Disease is the leading cause of death from non-communicable diseases in Indonesia. Need for early detection and prevention solutions through technology. Korpagama UGM Clinic has 750 patients per month with various diseases including coronary heart disease, but lacks a continuous monitoring system.	Qualitative research with action research design. Design of "Gama Medik" mobile application connected to smartwatch using PPG (Photoplethysmography) sensor for heart rate monitoring. Evaluation using System Usability Scale (SUS) method with 10 respondents. Integration with Google Fit and Korpagama UGM Clinic SIM.	Gama Medik application successfully designed with health monitoring features and early detection of coronary heart disease risk. Average SUS score: 62 ("Sufficient" category). Application equipped with interoperability that can be connected to Clinic SIM. Patients can monitor health condition through continuous care. Healthcare workers can monitor patients more easily.	Features in Gama Medik application function well and can help users monitor their health. Additional early detection feature for heart disease adds advantages to the information system. Smartwatch is effective for continuous care and facilitates healthcare workers in monitoring patient conditions. Telehealth solution is well received by users.
4	Physical Activity Analysis in Obese Individuals Using Smartwatch; (Sobarna et al., 2021)	Increasing obesity due to lifestyle with low physical activity. Obesity becomes an early signal of non-communicable diseases such as diabetes and cholesterol. Need to analyze physical activity of obese individuals to understand activity patterns and their	Single Subject Research (SSR) experimental study. Subject: 1 Gunadarma University student with weight 110kg, height 171cm, BMI 37.6 (obese). Monitoring for 7 days using smartwatch. Instruments: active lifestyle rubric and smartwatch. Parameters: steps, heart rate, calories in and out.	Average steps: 1,704/day (very low category, normal 7,000-13,000). Average heart rate: 67bpm (normal and low). Average calories burned: 44 calories (low category). Subject's daily caloric need: 2,296.7 calories. Excess calories occurred on 5 out of 7 observation days due	Physical activity of obese subject is classified as very low/light. Active lifestyle of obese individual is very lacking based on smartwatch monitoring. Imbalance between caloric intake and physical activity causes caloric excess potentially increasing body weight. Smartwatch is effective for monitoring physical

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		relationship with obesity conditions.		to low physical activity.	activity and helping manage obesity.
5	Exploration of IoT-based Android Smartwatch Role in Healthcare; (Utomo, 2024)	Potential of IoT-based smartwatch in healthcare has not been deeply explored. Challenges include data validity and accuracy, integration with healthcare systems, and data privacy and security. Need to explore smartwatch role in improving public health management through real-time monitoring.	Qualitative research with descriptive analysis method. Case study using Samsung Galaxy Watch 4 and Samsung Health application. Focus on monitoring physical activity, heart rate, sleep, and stress management. Data analysis using digital signal processing and machine learning algorithms. Measured parameters: heart rate (60-100 bpm normal), oxygen saturation (95-100% normal).	Samsung Galaxy Watch 4 is equipped with 10 health sensors including heart rate, SpO2, ECG, BIA (body composition), blood pressure, accelerometer, gyroscope, ambient light, and GPS. Samsung Health application provides comprehensive monitoring: physical activity, sleep patterns, nutrition, heart and mental health, body weight. Data is stored periodically and continuously updated in real-time through IoT connection.	IoT-based Android smartwatch facilitates user monitoring of body condition routinely and periodically. Sensors have good accuracy for recording real-time health data. Device provides monitoring convenience that is continuously updated based on changes in user condition. IoT integration enables health data to be analyzed for personal and accurate recommendations.
6	An Examination of the Implementation of Internet of Things in Healthcare Utilising Smartwatches; (Boshrabadi et al., 2024)	IoT-based smartwatch has not received optimal attention in healthcare sector despite having great potential. Challenges include patient compliance, technical issues, and privacy concerns. Need for comprehensive study on IoT smartwatch implementation in various healthcare fields to identify effective areas and adoption barriers.	Systematic literature review. Database: PubMed, ScienceDirect, IEEE (2010-2022). From 227 initial papers, 43 papers reviewed after screening. Inclusion criteria: peer-reviewed journals, focus on IoT health applications using smartwatch, English language, empirical data. Keywords: wearables, IoT, smartwatch, smart bracelet, healthcare, disease.	Smartwatch is used in 5 healthcare fields: (1) Health improvement (physical monitoring, eating behavior, sleep, medication compliance for elderly); (2) Disease prevention & diagnosis (physiological parameters, Parkinson's detection, atrial fibrillation, cancer); (3) Rehabilitation & speech therapy (stroke, Parkinson's); (4) Palliative care (diabetes, cancer pain management); (5) PPG technology for	IoT-based smartwatch has wide applications in healthcare but is not optimally utilized. Effective for continuous monitoring, early disease detection, and remote healthcare especially for elderly and chronic diseases. Solutions needed to overcome barriers: patient compliance, technical issues, and privacy. By addressing these challenges, smartwatch integration can improve healthcare quality and efficiency.

No	Title; Author(s); Year	Research Problem	Method	Results	Conclusion
				heart rate monitoring and arrhythmia detection. Barriers: patient compliance, magnetic interference with implants, skin problems, data synchronization, privacy.	
7	Health Monitoring Application Utilizing Android-Based Smartwatch; (Reza & Suryana, 2022)	Importance of vital health monitoring (heart rate and oxygen saturation) especially during COVID-19 pandemic. Coronary heart disease is the leading cause of death in Indonesia. Need for application that can help people monitor health and predict heart disease risk using smartwatch.	Waterfall method for application development. Literature study from books, journals, health websites (Halodoc, Alodokter, WHO). Technology: Google Fit API to retrieve heart rate and SpO2 data, Heart Disease Prediction API for heart disease prediction, Firebase Cloud Messaging. Platform: Flutter for Android. Testing: Blackbox testing.	Application successfully integrated Google Fit API for monitoring heart rate (normal 60-100 bpm) and oxygen saturation (normal 95-100%). Heart disease prediction feature using Heart Disease Prediction API with JSON response. All functionalities (login, register, heart rate detection, SpO2 detection, heart disease prediction, edit profile, logout) passed blackbox testing. Application provides treatment information for abnormal conditions and happy hypoxia management.	All application features function well and can help users monitor health. Heart disease prediction feature adds application functionality. Further development can add other health monitoring features and improve UI/UX appearance to be more attractive especially for younger generation while still considering user experience.

Table 2. Summary of Research Findings of Smartwatches in Health

Research Domain	Main Focus	Key Findings	Limitations	Implications
Adoption & Consumer Behavior (VAM, TAM)	Intention to use, perceived value	Ease of use (β=0.381, p<0.001) → strongest factor; enjoyment & usefulness significant; price not significant	Bias toward young & tech-savvy respondents	Interface design & user experience more important than financial factors
Digital Security & Forensics	Data extraction, forensic tool evaluation	Wondershare 80% accuracy, MOBILedit 40%, Oxygen 0%; encrypted applications (Signal) difficult to access	No standardized forensic protocols for wearables	Urgent need for security protocols & smartwatch-specific forensic standards

Research Domain	Main Focus	Key Findings	Limitations	Implications
Clinical Applications & Telehealth	CVD risk detection, real-time monitoring	Successful integration with EMR; low usability (SUS=62/100)	Requires training & more user-friendly interface	High potential for remote patient monitoring with infrastructure support
Chronic Disease Monitoring (Obesity)	Physical activity & energy	Average 1,704 steps/day vs target 7,000–13,000; energy surplus >2,300 calories	Single-subject study, not representative	Smartwatch effective as monitoring tool, not as standalone behavior change agent
Technology & IoT Infrastructure	Sensor validation, data pipeline	HR accuracy 95%, SpO2 93%, sleep tracking 81%; interoperability & battery → constraints	Accuracy varies across metrics; battery issues	Requires sensor standardization & low-power architecture
Application Development & API	Google Fit integration, AI, Firebase	100% functional success; AI-based decision support features	Clinical validation not yet extensive	Application capable of serving as clinical decision support tool
Global Review (43 studies)	Usage domains, common issues	32% health improvement, 28% diagnosis, 18% rehabilitation, 12% palliative, 10% speech; privacy (55%) & EHR integration (40%) main issues	Methodological variation, short-term studies	Wide potential, but requires regulation & cross-population validation

DISCUSSION

The synthesis of smartwatch research in healthcare reveals three main findings. First, determinant factors of adoption are more influenced by perceived value in ease of use aspects (β=0.381), followed by enjoyment and usefulness, while cost does not emerge as a significant barrier. Second, security and forensic aspects expose serious vulnerabilities, marked by disparities in forensic tool performance (Wondershare 80% vs Oxygen 0%) and resistance of encrypted applications that demonstrate weak digital investigation capabilities in the wearable ecosystem. Third, the clinical prospects of smartwatches are evident, proven through HR, SpO_2 monitoring, and integration with EMR, but practical effectiveness remains constrained by moderate usability (SUS=62) and limited behavior change effects without structured intervention (example: obesity study averaged only 1,704 steps/day). Technical validation demonstrates high accuracy in some metrics (HR ~95%, SpO_2 ~93%) but variability persists in other metrics (sleep, step counting), which reduces overall reliability. Theoretically, these findings are consistent with the Value-Based Adoption Model (VAM) and Technology Acceptance Model (TAM), which confirm that perceived usefulness and perceived ease of use become primary mediators of adoption intention, while enjoyment reinforces usage retention (Rauniar et al., 2014). The phenomenon of low adoption among vulnerable groups can be explained through Diffusion of Innovations theory, which states that the more complex a technology is, the more difficult its dissemination among populations with low digital literacy (Rauner & Stummer, 2025). The socio-technical perspective confirms that implementation success depends not only on technological performance but also on the integration of interface design, health information infrastructure, regulations, and clinical practices in the field (Ștefan et al., 2024). The relevance of smartwatches in Indonesia becomes increasingly clear due to the double burden of communicable and non-communicable diseases, including high prevalence of hypertension, diabetes, and cardiovascular conditions. At the same time, healthcare service disparities, particularly in remote areas, amplify the urgency of utilizing remote monitoring technology (Löchner et al., 2025). However, challenges arise from low digital literacy among elderly groups, limited digital infrastructure,

and the absence of national regulations regarding interoperability and health data security. In other words, although technological opportunities are substantial, implementation remains dependent on social, economic, and policy contexts. This synthesis is constructed on several important assumptions.

1. Results from primary studies conducted between 2021–2024 are assumed to remain relevant to current implementation conditions, although technology and policies can change rapidly.
2. The accuracy of tested sensors (for instance, Galaxy Watch 4) is assumed to be representative of the consumer-grade category, although inter-model variation may limit generalization.
3. Research involving young and technologically literate participants is assumed to provide indication of adoption trends, although it does not fully reflect vulnerable populations.
4. Interpretation of clinical effectiveness assumes the presence of basic infrastructure support (API, cloud, digital health systems), which in reality is not yet evenly distributed in Indonesia.

The policy implications of these findings are evident. The government needs to establish interoperability standards between wearables and national systems such as SatuSehat, accompanied by stricter health data protection regulations. A national certification mechanism is required to ensure sensor accuracy, device security, and digital forensic capability before entry into the healthcare market. Device subsidies or integration with JKN programs can expand access, while digital literacy programs specifically for the elderly and chronic disease patients must be developed. Smartwatches should also be positioned within clinical workflows, for example early warning systems, post-hospitalization monitoring, or teleconsultation, so that collected data can be directly translated into medical actions.

The priority research agenda moving forward encompasses four aspects:

1. Longitudinal clinical trials on vulnerable populations to assess long-term effectiveness on chronic disease outcomes.
2. Sensor validation in the Indonesian context considering ethnic variation, climate, and activity patterns.
3. Forensic and data security research to develop digital investigation methods and secure cloud architecture.
4. Behavior change intervention studies based on notification design, gamification, or digital coaching, accompanied by cost-effectiveness evaluation if integrated with public financing systems such as JKN.

Thus, smartwatches in healthcare are no longer merely viewed as lifestyle devices but as part of modern health strategy. However, the success of this transformation depends heavily on synergy between scientific evidence, public policy, inclusive technology design, and robust data governance.

CONCLUSION

Smartwatches have evolved into biomedical instruments with substantial potential in supporting early detection, continuous monitoring, and preventive health strategies. However, their utilization still faces a paradox: high-risk groups actually have the lowest adoption rates due to limited digital literacy, perceived complexity, and privacy concerns. Other challenges emerge from digital ecosystem fragmentation, low interoperability standards, limited clinical validation, and vulnerability to cybersecurity threats. This condition creates a tangible gap between the potential benefits of technology and practical implementation, particularly in developing countries such as Indonesia that face a double burden of disease and limited healthcare service access.

RECOMMENDATIONS

Future research and policy need to emphasize three main aspects:

1. Strengthening digital literacy and technology inclusion for the elderly and chronic disease

patients to ensure more equitable smartwatch utilization.

2. Formulation of interoperability standards and clinical validation so that generated data can be effectively integrated into healthcare service systems.
3. Development of security regulations and digital health data governance to ensure privacy while enhancing public trust.

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