Proceedings of the International Conference on Public Health, Vol. 10, Issue 1, 2025, pp.62-73

ISSN 2424-6735 online
DOI: https://doi.org/10.17501/24246735.2025.10105

DIGITAL TECHNOLOGY INNOVATION IN SUPPORTING EARLY DETECTION OF CERVICAL CANCER: A SYSTEMATIC REVIEW OF SMARTPHONE APPLICATIONS, DIGITAL EDUCATION, AND TELEMEDICINE TRAINING

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Abstract: Cervical cancer is one of the leading causes of death among women worldwide, particularly in developing countries. Low health literacy, a shortage of trained healthcare professionals, and limited access to modern medical facilities are significant barriers to early detection. Technological innovations, including smartphone-based applications, digital education via social media, and telemedicine-based training, offer promising solutions to enhance access to and quality of healthcare services. This study is a systematic review conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Data were retrieved from multiple electronic databases, including PubMed, ScienceDirect, and the Cochrane Library. Studies meeting the inclusion criteria were analyzed to assess the effectiveness of digital technologies in supporting early cervical cancer detection. Data extraction and risk assessment were performed independently by two researchers. Eight selected studies demonstrated the effectiveness of technology-based interventions in improving health literacy, diagnostic accuracy, and healthcare worker competence. Digital education delivered via platforms such as WhatsApp and Facebook has been shown to enhance knowledge and attitudes among women of reproductive age regarding early cervical cancer detection. Smartphone-based applications utilizing artificial intelligence (AI) achieved an accuracy rate of up to 93.8%, while telemedicine-based mentorship programs improved screening quality, with the Kappa coefficient increasing from 0.64 to 0.79. Technological innovations involving smartphone applications, digital education, and telemedicine mentorship have significant potential to overcome barriers to early cervical cancer detection. These strategies could be integrated into national healthcare programs to expand screening coverage and improve effectiveness, particularly in resource-limited settings.

Keywords: cervical cancer, smartphone applications, digital education, telemedicine, early detection.

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1. Introduction

Cervical cancer is a female reproductive health problem that needs to be treated, especially in developing countries such as Indonesia. According to the Global Cancer Observatory (GLOBOCAN), the incidence of cervical cancer ranks second as the most common cancer that affects women with a high mortality rate (Harsono et al., 2022). One of the factors causing the high mortality rate due to cervical cancer is late detection, resulting in more than 70% of cases being found in advanced stages. This condition is exacerbated by the low level of health literacy in women of childbearing age, especially related to the importance of early detection, one of which is Visual Inspection with Acetic Acid (IVA) (Rambe et al., 2023).

Other conditions such as limited health infrastructure, lack of trained medical personnel, and lack of access to modern diagnostic facilities are the main challenges in the implementation of early detection programs in various regions, especially remote areas (Asgary et al., 2020). Because of this, digital-based technological innovation is one of the potential solutions to overcome this condition. Technologies such as smartphone-based applications and artificial intelligence (AI) can provide faster, more accurate, and accessible diagnostic support to previously hard-to-reach communities (Harsono et al., 2022).

In addition, digital-based health education through platforms such as WhatsApp and Facebook has shown effectiveness in increasing women's health literacy, attitudes, and participation in cervical cancer early detection programs. The program allows for the interactive, cost-effective, and relevant delivery of health information for a variety of cultural backgrounds (Imelda et al., 2022). This approach not only reaches out to individuals, but also strengthens the role of communities in supporting cervical cancer prevention efforts.

Along with the development of technology, telemedicine-based training and mentorship are also an important strategy in improving the competence of health workers. With remote mentorship, medical personnel can obtain ongoing guidance to ensure the quality of diagnosis and early detection case management. This program has been shown to improve diagnostic accuracy as well as reduce the rate of overdiagnosis in early detection of cervical cancer (Asgary et al., 2020). This approach provides a great opportunity to address the problem of limited human resources and geographical location.

Against this background, this research aims to explore the potential of digital-based technological innovations and health education, as well as telemedicine-based training in improving the effectiveness of early detection of cervical cancer. It is hoped that the results of this study can be a strategic recommendation to support cervical cancer prevention efforts in a more comprehensive and inclusive manner.

2. Materials and Methods

2.1 Study Design

This study is a systematic review that follows the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which aims to analyze various technology-based innovation approaches, including digital education, artificial intelligence (AI)-based smartphone applications, and telemedicine-based training and mentorship, in supporting early detection of cervical cancer.

2.2 Data Sources and Search Strategies

Literature searches are conducted through major electronic databases, such as PubMed, ScienceDirect, the Cochrane Library, and Google Scholar, which contain reputable scientific journals and reliable literature. Key keywords used included a combination of terms such as "cervical cancer screening" AND "smartphone-based application", "digital education" AND "cervical cancer prevention", "telemedicine mentorship" AND "healthcare worker training", "visual inspection with acetic acid (VIA)" AND "artificial intelligence", and "risk communication" AND "knowledge improvement in cervical cancer." Articles included in this review must meet the following inculcation criteria: Original research articles, published in 2021 - 2024, written in English or Indonesian, quantitative studies *(cross-sectional, cohort, case-control),* evaluation of intervention programs *(randomized controlled trials or non-randomized trials),* and literature reviews published in *peer-reviewed scientific journals.*, involving women of childbearing age, health workers, or related populations involved in digital and smartphone-based cervical cancer early detection programs.

2.3 Article Screening and Selection

In the first stage, the initial search is filtered by title and abstract to evaluate its relevance to the research topic. The second stage of full-text evaluation. This evaluation is conducted to ensure that the article meets all inclusion criteria, such as appropriate target populations, technology-based or education-based interventions, and measurable outcomes and relevant study designs. The next stage is discussion, if there are differences, two researchers are carried out to reach an agreement. If differences persist, a third researcher is involved to provide a final decision.

2.4 Data Extraction and Synthesis

The first step is the identification of the study, where basic information such as the author's name, year of publication, research location, and research objectives are recorded. This data not only provides geographical and temporal context, but also helps in the organization and classification of relevant articles. Furthermore, the research design used in each article is analyzed. Design types such as randomized controlled trials (RCTs), cohort studies, cross-sectional studies, or systematic reviews are identified to understand the methodological approaches used in data collection and analysis. Population and intervention are the elements that are then extracted. The information collected included the characteristics of participants, such as women of childbearing age or health workers, as well as detailed explanations of the interventions carried out, such as the use of smartphone-based applications, digital education via WhatsApp or Facebook, and telemedicine-based mentorship

2.5 Study Quality Assessment

The assessment was conducted using recognised tools, namely the Newcastle-Ottawa Scale (NOS) for observational studies, and the Cochrane Risk of Bias Tool for interventional studies. NOS is used to evaluate the quality of studies based on three main aspects: participant selection, validity of results, and quality of study design. The Cochrane Risk of Bias Tool is used to evaluate potential bias at different

stages of research. Assessments were carried out in several main domains, such as randomization, allocation concealment, blindness of participants and researchers, and outcome data completeness.

3. Results and Discussion

3.1 Results

3.1.1 Quality Assessment

All the articles analyzed had good and very good ratings, so that 8 articles were included in the study

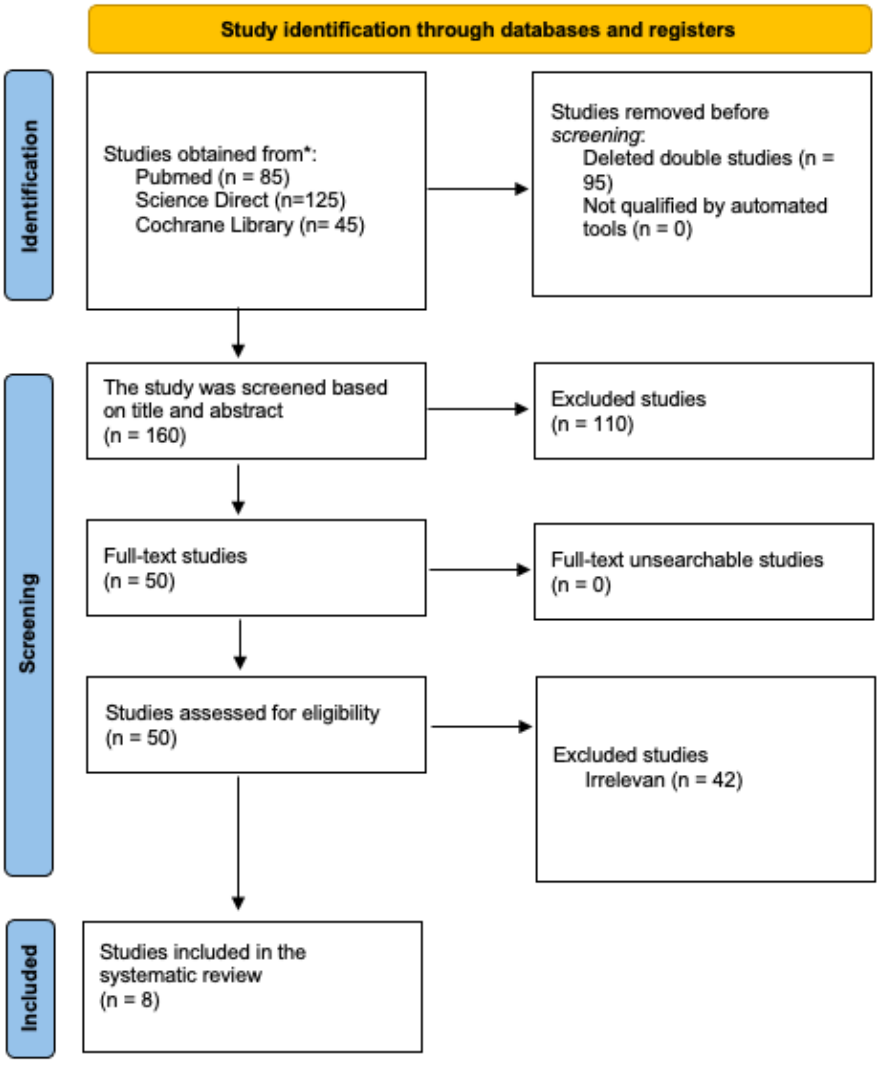

Figure 1: PRISMA Flow Chart

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No	Research Name and Year	Research Title	Research Design	Data Sources and Data Collection Methods	Number of Samples or Informants	Key Findings
1	Asgary et al., (2019)	Acceptability and Implementation Challenges of Smartphone-Based Training of Community Health Nurses for Visual Inspection with Acetic Acid in Ghana: mHealth and Cervical Cancer Screening	Qualitative descriptive studies	Data from semi-structured interviews with nurses and patients in Ghana; Evaluation of smartphone-based VIA training	15 nurses, 21 patients	Smartphone-based training improves VIA diagnostic and management competencies. Education through cervical imaging is effective in overcoming patient misconceptions and boosting trust.
2	Asgary et al., (2020)	Evaluating smartphone strategies for reliability, reproducibility, and quality of VIA for cervical cancer screening in Eswatini	Cohort study with smartphone-based mentorship evaluation	Women aged 25-49 years in Eswatini; Cervical images taken for analysis	4,247 women	Smartphone-based mentorship strategies improve VIA's diagnostic competence and screening quality. VIA's positivity rate decreased significantly after the mentorship program, with Kappa increasing from 0.64 to 0.79. Mentorship allows for telemedicine-based training to improve accuracy, reduce overdiagnosis, and increase the effectiveness of screening programs.
3	Imelda et al., (2022)	The Influence of WhatsApp Education Information Communication on Knowledge and Attitude of	Quasi-experiment with pre-test and post-test designs	50 women of childbearing age in Medan, using WhatsApp-based	50 respond	Educational via WhatsApp for 14 days showed a significant increase in knowledge ($p = 0.001$) and attitude ($p = 0.001$) towards early detection of cervical cancer using IVA.

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No	Research Name and Year	Research Title	Research Design	Data Sources and Data Collection Methods	Number of Samples or Informants	Key Findings
		Early Cervical Cancer Detection		questionnaires for education		
4	Rambe et al., (2023)	Effect of Health Education Using WhatsApp Group on Knowledge About Visual Inspection Acetate Test	Quasi-experiment with pre-test and post-test designs	Women of childbearing age at the Simpang Kiri Health Center; Data collected through questionnaires	98 women (49 cases, 49 controls)	WhatsApp-based health education significantly increased knowledge about IVA ($p = 0.011$).
5	Harsono et al., (2022)	Cervical pre-cancerous lesion detection: development of smartphone-based VIA application using artificial intelligence	Quasi-experiment with AI model evaluation	Women aged 30–50 years who were examined at Hasan Sadikin Hospital used cervical images before and after the VIA test	199 women (134 training data, 65 test data)	The smartphone-based AI model has a sensitivity of 80%, a specificity of 96.4%, and an accuracy of 93.8%, and can support early detection of cervical cancer in areas with limited resources.
6	Aprina et al., (2024)	Enhancing early cervical cancer detection through the mobile-based DEDIKASI application	Quasi-experiment with post-test only design	Women of childbearing age in Lampung Province; Data collected through questionnaires	388 women	The mobile-based DEDIKASI application is more effective than the EWS Cervical Ca. application in assessing the risk of cervical cancer, with an ISO score of 92%
7	Maria et al., (2024)	Effects of Intervention in WhatsApp and Facebook Groups to Improve Women's Literacy on Breast and Cervical Cancer Prevention	Quasi-experimentation with pre/post-	25 women (12 in WhatsApp groups, 13 in Facebook groups); AHL-C questionnaire used for	25 women	WhatsApp and Facebook-based interventions improved reading literacy scores and familiarity, but there was no significant improvement in comprehension or dialogue. Math scores

No	Research Name and Year	Research Title	Research Design	Data Sources and Data Collection Methods	Number of Samples or Informants	Key Findings
			intervention design	health literacy measurement		actually decreased in some items after the intervention.
8	Mohebi et al., (2018)	Development of Mobile Application for Cervical Cancer Screening in Women: Protocol of a Multi-Phase Study	Multi-phase research (literature review, cross-sectional studies, application development, and prototype evaluation)	Literature from databases such as PubMed, Scopus, and surveys in women's clinics; Data collected through questionnaires	246 women for cross-sectional studies; 5-20 members for expert panel	This study aims to identify inhibitory and supporting factors in cervical cancer screening, develop applications based on sociocultural needs, and evaluate application prototypes. m-health technology shows significant potential in increasing cervical cancer screening participation.

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3.1.2 Study Characteristics

Searches were conducted according to keywords and a total of 255 studies were identified, of which 8 studies were eligible to be included in the analysis. 1 study with *descriptive design,* 1 cohort study, 2 pre- and post-test quasi-experimental studies, and 2 *post-test studies only, 1 quasi-experiment with evaluation, 1 multi-phase study.* The results of the analysis are summarized in table.1 which is divided into 3 digital-based education themes, namely Digital-Based Education to Improve Health Literacy, Technological Innovation for Early Detection of Cervical Cancer and training and mentorship to improve diagnostic competence

3.2 Discussion

3.2.1 Digital-Based Education to Improve Health Literacy

Digital-based education has proven to be an innovative approach in improving health literacy, especially related to early detection of cervical cancer. Digital platforms like WhatsApp and Facebook offer conveniences such as cost-effective and accessible to reach underserved communities. Research by Imelda et al. (2022) showed that 14 days of education through WhatsApp, the results significantly improved the knowledge and attitudes of women of childbearing age towards early detection of cervical cancer using the Visual Inspection with Acetic Acid (IVA) method. The results of this study recorded a significant increase with a value of $p = 0.001$, which shows that the effectiveness of WhatsApp as a medium in conveying relevant health information and making positive behavior changes.

In addition to WhatsApp, the Facebook platform is also an effective educational medium. A study by Maria et al. (2024) evaluated the impact of WhatsApp and Facebook-based educational interventions on health literacy in women. In this study, educational materials that included readings, videos, and graphics were delivered to 25 participants who were divided into two groups. The results showed that both platforms managed to improve reading literacy and familiarity scores. However, challenges remain as no significant improvement in participants' deep understanding or dialogue skills was found. This suggests that although participants were more familiar with medical terms after the intervention, an in-depth understanding of their meaning and context was still limited. The advantage of social media as an educational tool lies in its ability to convey information visually and interactively. For example, the use of cervical images in the explanation of IVA procedures not only helps to overcome misconceptions, but also increases participants' confidence in screening. WhatsApp, with its fast communication feature, allows for direct interaction between participants and education providers, while Facebook provides a wider space for discussion and opinion. Nonetheless, studies show that participant engagement on Facebook tends to be lower than on WhatsApp, highlighting the importance of choosing a platform that matches user preferences.

However, the existence of digital education still has weaknesses. The research of Maria et al. (2024) found that although participants showed improved reading literacy and familiarity scores, deep understanding remained a difficult aspect to improve. This demonstrates the need to develop educational materials that are more interactive, culturally relevant, and designed to encourage better conceptual understanding. For example, adding live discussion elements, AI-based automated responses, or materials tailored to the participants' backgrounds can increase the effectiveness of the program.

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Overall, digital-based education strategies offer great potential to support early detection of cervical cancer in hard-to-reach communities with traditional approaches. By integrating interactive and inclusive program design, platforms like WhatsApp and Facebook have a critical role to play in improving health literacy and encouraging positive behavior change. This research is a strong foundation for the further development of technology-based public health programs that are accessible to people from all walks of life. According to R, Plackett (2020) mentions that social media (including Facebook) is effective for spreading messages, increasing awareness and recruitment (e.g. for vaccinations or screening programs), but evidence that campaigns or ads on Facebook independently increase screening behavior (not just awareness) is more of the best effect seen when Facebook is used as a *gateway* for registration, activity scheduling and combined with live reminders.

3.2.2 Technological Innovation for Early Detection of Cervical Cancer

Technological advances have brought significant changes in supporting early detection of cervical cancer, which has been a major focus in recent research. A study by Harsono et al. (2022) shows the application of artificial intelligence (AI) in smartphone-based applications for the detection of cervical precancerous lesions using Visual Inspection with Acetic Acid (VIA). This technology allows automatic analysis of cervical images with a sensitivity of up to 80%, specificity of 96.4%, and an overall accuracy of up to 93.8%. This makes AI-based applications a highly reliable solution, especially in resource-constrained areas, where access to trained medical personnel and advanced diagnostic facilities is minimal and limited.

Further research by Aprina et al. (2024) reveals the potential of the mobile-based DEDIKASI application in supporting early detection of cervical cancer. Not only does the app offer more effective risk evaluation than other platforms, but it also has an ISO 25010 score of 92%, confirming its superiority in terms of reliability and functionality. The platform is designed to assist healthcare professionals and individual users in assessing cervical cancer risk in an easy-to-use and intuitive way. Through the integration of responsive data and features, the app helps improve the user experience and fast and precise diagnosis.

Both studies highlight how modern technology can address the challenges faced in early detection of cervical cancer, especially in remote areas or developing countries. Technologies such as AI and mobile apps enable faster, more accurate, and accessible diagnostics to communities that were previously difficult to reach. By reducing reliance on expensive healthcare facilities and limited human resources, these technological innovations can become a key choice in the global effort to reduce cervical cancer mortality.

Not just a diagnostic tool, this innovation also helps the decision-making process based on data and educational media in public health. By introducing user-friendly technologies, such as the DEDICATION app and AI-based VIA, women in remote communities can be more empowered to understand and understand so that they can monitor their health conditions. This discovery opens up great opportunities for the further development of health technologies that can be integrated into national and global programs, in order to achieve a wider scope in efforts to prevent and treat cervical cancer incidence.

3.2.3 Training and Mentorship for Diagnostic Competency Improvement

Technology-based training and remote mentorship have proven to be a highly effective approach in improving the diagnostic competence of healthcare workers, especially in resource-constrained areas. A study by Asgary et al. (2019) shows that smartphone-based Visual Inspection with Acetic Acid (VIA) training is able to have a significant positive impact on health workers. Through this training, cervical imagery is used as an educational tool that not only increases patient confidence in screening procedures, but also overcomes the common misconceptions about early detection of cervical cancer. This shows that smartphone-based technology can be the right and effective solution to reach healthcare workers in remote locations.

Furthermore, research by Asgary et al. (2020) underscores the importance of telemedicine-based mentorship in improving the quality of VIA screening. This mentorship program is designed to provide regular guidance to healthcare workers, providing providers with the opportunity to receive direct support from experts despite being in remote locations. The results showed that the program significantly improved diagnostic accuracy, reduced overdiagnosis, and improved diagnostic quality measured through a Kappa increase from 0.64 to 0.79. These improvements demonstrate the ability of remote mentorship to address technical challenges and improve the standard of cervical cancer screening practices.

This technology-based training approach is particularly relevant in addressing challenges commonly faced in developing countries, such as lack of access to formal training and a lack of trained and competent human resources. By leveraging technologies such as smartphones and telemedicine, healthcare workers can be trained more efficiently, without having to leave the communities they serve. This not only speeds up the knowledge transfer flow but also ensures that they have adequate competencies to provide quality diagnostic services.

Overall, this technology-based training and mentorship is a form of technological advancement in empowering health workers in remote areas. In addition to improving diagnostic competence, strategies are to integrate evidence-based approaches into daily healthcare practice. By adopting technologies like these, health systems can effectively expand the coverage of quality services, ultimately impacting the reduction of cervical cancer deaths worldwide.

According to D, Sclieman, (2022) shows that mHealth interventions including SMS, phone calls, and instant messaging apps can improve knowledge even in some situations of increased screening coverage integrated with physical service models (such as mobile buses, message reminders). Social media like Facebook is effective for awareness and recruitment but is less consistent as a single medium to change behavior without any real action. On the other hand, artificial intelligence-based applications that analyze cervical images show prospective diagnostic performance and have the potential to improve the quality of screening on the service side, but evidence that AI applications themselves improve coverage in populations is still limited. X (2024). Therefore, field research in the form of comparative trials such as factorial cluster-RCT or hybrid implementation-effectiveness trials that test demand-side (WhatsApp, Facebook and supply-side AI enabled VIA, mobile services) is simultaneously needed to determine the most effective and cost-effective combination of technologies (V, Cardona. (2024).

4. Conclusion

Smartphone-based technologies and digital applications, such as the use of artificial intelligence (AI) and mobile platforms, have proven to be effective in supporting early detection of cervical cancer. The app demonstrates a high level of accuracy and is able to improve efficiency and accessibility in areas with limited resources.

Digital-based education through platforms such as WhatsApp and Facebook has succeeded in increasing health literacy, especially in terms of knowledge and familiarity about cervical cancer prevention. Nonetheless, challenges remain in improving deep understanding and dialogue capabilities.

Technology-based training and mentorship, including telemedicine, can significantly improve the diagnostic competence of health workers, reduce overdiagnosis, and improve the accuracy and quality of VIA screening. This strategy is particularly relevant to be implemented in communities with limited human resources and facilities.

Acknowledgments

The author would like to express his gratitude to the Ministry of Health of the Republic of Indonesia for the financing support in the development of the preparation of this article.

Conflict of Interest

The author declares that there is no conflict of interest regarding the writing, or publication of this article.

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