Rwanda Medical Journal RMJ

ORIGINAL ARTICLE Open Access

Evaluating the Outcomes of Digital Health Solutions for Human Papilloma Virus Vaccination and Cervical Cancer Services in Rwanda: A Mixed-Method Study

Authors: Hassan Sibomana[1]; Joyeuse Ukwishaka[1,2]; Hassan Mtenga[3]; Oswald Luoga[3]; Diana Acosta[4]; Marcie Fisher-Borne[4]; Grace Juan Soma[5]; Marcel Bahizi[6,7,8]; Francois Uwinkindi[1]; Marc Hagenimana[1]; Irene Mukanyandwi[1]; Innocent Mbele[3]; Maya Rivera Hildebrand[3,*]

Affiliations: *[1]Rwanda Biomedical Center/ Maternal Child and Community Health Division, Kigali, Rwanda; [2]Jhpiego, Kigali, Rwanda; [3]PATH, Washington, USA; [4]Merck & Co., Inc., Rahway, NJ, USA; [5]International Center for Child Health and Development (ICHAD), Brown School, Washington University in St. Louis, Missouri, USA; [6]Rwanda Food and Drug Authority, Kigali, Rwanda; [7]University of Rwanda, Kigali, Rwanda; [8]Kigali Independent University, Kigali, Rwanda*

ABSTRACT

INTRODUCTION: Cervical cancer remains a significant global health challenge, particularly in low-and middle-income countries, where access to prevention and screening is often limited. The World Health Organization has called for joint efforts to eradicate cervical cancer, pointing to HPV vaccination, screening, and treatment of cervical cancer. This study assessed the effect of the deployment of digital health solutions on HPV vaccination, cervical cancer screening, and treatment in Rwanda.

METHODS: A mixed-method approach integrating a descriptive cross-sectional analysis of secondary data with qualitative interviews was used. Microsoft Excel and STATA/SE software version 17.0 were used for data cleaning and analysis. Face-to-face interviews with key informants were conducted. Thematic analysis was performed for qualitative data analysis.

RESULTS: From 2020 to 2022, the percentage of girls aged 11 to 15 who completed the HPV vaccine series rose from 75 to 80%, an improvement that coincided with the introduction of the e-tracker for HPV vaccination records in 2022. The rate of women undergoing cervical cancer screening rose from 1 to 16% during the five-year period from 2018 to 2023. A notable surge occurred in 2020, following the adoption of the Open Medical Record System (OpenMRS) in cervical cancer service delivery. Interviews with key informants highlighted the pivotal role of digital health tools in enhancing HPV vaccination and cervical cancer screening coverage.

CONCLUSION: This study highlights the beneficial effects of digital health solutions on HPV vaccination and cervical cancer services in Rwanda. The results set a compelling example and provide insightful guidance for other healthcare systems in the region.

Keywords: HPV, HPV vaccination, Cervical Cancer, Digital Health Solution, Digital Health Intervention, Rwanda

***Corresponding author:** Maya Rivera Hildebrand, E-mail: mrivera@path.org; **Potential Conflicts of Interest (CoI):** Some of the authors are affiliated with the RBC, which serves as an implementing agency of the Ministry of Health. Others are associated with PATH, an organization that collaborates with the Ministry of Health in advancing the agenda for cervical cancer elimination. Their work is independent of their professional affiliations and does not rely on their roles within their respective organizations; **Funding:** PATH fully funded this study through Merck Sharp & Dohme LLC, a Merck & Co., Inc. subsidiary, Rahway, NJ, USA, known as MSD outside of the United States and Canada; **Academic Integrity.** All authors confirm that they have made substantial academic contributions to this manuscript as defined by the ICMJE; **Ethics of human subject participation:** The study was approved by the local Institutional Review Board. Informed consent was sought and gained where applicable; **Originality:** All authors: this manuscript is original has not been published elsewhere; **Review:** This manuscript was peer-reviewed by three reviewers in a double-blind review process; **Type-editor:** Peter (USA).

Received: 15th July 2024; **Initial decision given:** 11th October 2024; **Revised manuscript received:** 14th October 2024; **Accepted:** 12th January 2025.

 Publisher: Rwanda Biomedical Centre (RBC)/Rwanda Health Communication Center, P. O. Box 4586, Kigali. ISSN: 2079-097X (print); 2410-8626 (online)

Citation for this article: Hassan Sibomana; Joyeuse Ukwishaka; Hassan Mtenga, et al. Evaluating the Outcomes of Digital Health Solutions for Human Papilloma Virus Vaccination and Cervical Cancer Services in Rwanda: A Mixed-Method Study. Rwanda Medical Journal, Vol. 82, no. 1, p. 48-59, 2025. https://dx.doi.org/10.4314/rmj.v82i1.6

INTRODUCTION

Cervical cancer remains a pressing global health issue, especially in low-and middle-income countries (LMICs) like Rwanda, where access to prevention and screening is limited [1–3]. Cervical cancer ranks as the fourth most common cancer in women worldwide, with around 604,000 new cases and 34,200 deaths reported in 2020. Alarmingly, 90 percent of these cases occurred in LMICs [1,4]. Human papillomavirus (HPV) is the primary cause of cervical cancer [1].

Comprehensive cervical cancer control strategies, including vaccination, screening, and treatment, align with the World Health Organization (WHO) call for global collaboration in 2018 to combat cervical cancer effectively [1,5]. However, the effective rollout and acceptance of these measures face notable challenges, including limited public awareness, healthcare access issues, and adherence to vaccination and screening protocols [6–8].

Digital Health Solutions have emerged as effective tools to address challenges, enhancing accessibility and effectiveness through various technologies such as mobile apps and online platforms. They facilitate information dissemination, appointment reminders, and personalized notifications, ensuring continuity of care [9–11].

Such solutions, like reminder systems and electronic registries, have demonstrated efficacy in improving HPV vaccination coverage, delivery, and adherence [9,12–15]. They have been instrumental in strengthening cervical cancer screening programs and contributing to improved patient participation and coverage [16–19]. Research exploring the impact of digital health solutions on patient outcomes has demonstrated positive results in treatment effectiveness and survival rates [20,21]. These solutions enable real-time data capture and enhance data quality and exchange [22]. When integrated into national healthcare systems, particularly those operated by governments, they substantially improve data management and monitoring, data accessibility, reduce redundancy in data collection and storage, and ensure continuity of care across different healthcare services [19,23].

Rwanda established a national cancer registry in 1991, which was interrupted in 1994 but resumed in 2010 [24]. In 2019, Rwanda implemented the Expanded Program on Immunization (EPI) tracker module on the DHIS2 platform (e-tracker) with an electronic registry to monitor all childhood vaccinations [25–27]. The e-tracker system began recording HPV vaccine data in 2022. Since 2020, 28 district hospitals and two referral hospitals that provide cervical cancer screening services in Rwanda have adopted the mUzima application for cervical cancer screening services. This mobile application features both online and offline functionality and is integrated with the Open Medical Record System (OpenMRS), a web application enabling various facilities to access the same data [28]. The OpenMRS system is used in health facilities for cervical cancer screening in district hospitals and some health centers, as well as in Butaro Hospital, which is the national referral hospital for cancer patients.

Strong digital systems in HPV vaccination and cervical cancer services can help to attain the 90–70–90 vaccination, screening, and treatment targets outlined in the WHO cervical cancer elimination strategy (5). Therefore, there is a need to evaluate the outcomes of these interventions on healthcare service delivery and their effect on long-term health outcomes to inform action and address gaps. This study aimed to assess the outcomes of digital health interventions for HPV vaccination and cervical cancer screening and treatment in Rwanda. The objectives of this study were as follows: 1) to assess the outcomes associated with using an e-tracker to collect HPV vaccination data, including HPV vaccination coverage, in Rwanda; 2) to assess the outcomes associated with the use of digital health solutions for cervical cancer services in Rwanda, including cervical cancer screening coverage in Rwanda; and 3) to examine the improvement in data quality and accuracy resulting from the use of digital health solutions for HPV vaccination and cervical cancer services in Rwanda.

METHODS

Research settings

Rwanda has 30 districts across four provinces (South, North, East, and West) and the capital city, Kigali. The Rwandan healthcare system operates in both public and private sectors. The public sector has three organizational levels: the central level (the Ministry of Health, its affiliated institutions, and referral hospitals), the intermediate level

(provincial and district hospitals), and the peripheral level (health centers, health posts, and community health workers) [29]. In Rwanda, HPV vaccination started in 2011. Screening and vaccination are provided at all primary levels (3,16). District hospitals handle biopsies and precancerous lesion treatment, referring advanced cases to tertiary care for further treatments and diagnostics [3,30].

Study design and data sources

This study used a mixed methods approach, combining a descriptive cross-sectional analysis of secondary data and qualitative interviews. For the quantitative approach, research was conducted using secondary data from healthcare facilities and relevant national databases that are used for HPV vaccination and cervical cancer screening and treatment in Rwanda. Vaccination data was retrieved from national immunization databases, including the e-tracker system for individual data and the health management information system (HMIS) for aggregate data. Both systems are built into the DHIS-2 platform, global goods that are widely used in LMICs. Since 2019, the e-tracker has been used to record individual data for all routine immunizations, and in 2022, the e-tracker began recording HPV vaccination data. The HMIS has been utilized to record aggregate data on routine immunization since 2015. Cervical cancer data was extracted from the HMIS, mUzima, and OpenMRS. The mUzima android app is employed to record individual data, functioning as an interface for OpenMRS where primary data is recorded and then synchronized from mUzima to OpenMRS. This system has been in use since 2020. Estimates of the number of eligible girls for HPV vaccination and women eligible for cervical cancer screening were extracted from the national census undertaken in 2022 (https://www.statistics.gov.rw/datasource/fifth-population-and-housing-census-2022). This data was used to calculate vaccination and screening coverage. We considered data from before and after the introduction of digital health interventions to evaluate trends in data completeness, data quality, vaccination, and screening rates.

The qualitative phase of this study involved conducting face-to-face interviews with key informants using a semi-structured interview guide to understand the outcome of introducing digital health system from the perspectives of the system users' including acceptability and satisfaction in HPV and cervical cancer service delivery. These interviews took place at selected healthcare facilities that were providing HPV vaccination and cervical cancer services (screening and treatment) across different levels of healthcare in Rwanda, including central level institution (Rwanda Biomedical Center). A purposeful sampling strategy was used to select 15 participants. Participants were chosen from three health centers (Kicukiro, Kibuye, and Hanika Health Centers), two hospitals (Kibagabaga and Butaro Hospitals), as well as participants from the Rwanda Biomedical Center (RBC). The selection included nurses, data managers, medical doctors, and program managers, ensuring a comprehensive representation of healthcare institutions. The sample size adhered to the principle of data saturation, with participants enrolled until no new information emerged. The interviews were conducted in Kinyarwanda and were audio-recorded for analysis.

Data management and analysis

In the quantitative phase of the study, electronic data was exported into Microsoft Excel for cleaning, verification of missing data, and editing for inconsistent information. Data analysis was conducted using both Excel and STATA 17.0 software. Descriptive statistics, such as vaccination coverage rate and screening uptake, were used to describe the data. These measures were also represented graphically. The vaccination coverage was calculated as a percentage of girls aged between 11 and 15 years who had been vaccinated relative to the total number of eligible girls. Cervical cancer screening coverage was calculated as a percentage of women aged over 35 years who underwent cervical cancer screening compared to the total number of all eligible women.

In the qualitative phase of the study, audio recordings were transcribed verbatim and translated appropriately into English with back translation for interviews translated from Kinyarwanda to English. This translation approach aimed to preserve the intended meaning and explanation. Transcripts were organized and managed in Word documents and Excel spreadsheets. Data analysis consisted of familiarization with data through careful reading and re-reading of transcripts by the principal investigator (PI) and an experienced qualitative researcher to identify preliminary codes. The

qualitative researcher and the PI collaboratively developed the codebook, which was validated by member checking with the research team members involved in collecting the qualitative data to ensure an appropriate interpretation. Key concepts derived from the codes were grouped together to form categories and subcategories. Linkages were established by identifying themes and facilitating the process of charting, mapping, and connecting to central themes. Throughout the analysis, anonymous quotations were utilized to illustrate and exemplify the identified themes.

This study obtained approval from the Rwanda National Ethic Committee (RNEC) (Approval Notice: No.156/RNEC/2023). Informed consent was obtained from all participants interviewed, ensuring their privacy and confidentiality throughout the study. As secondary data were already collected and anonymized, no additional informed consent was required for the quantitative study.

RESULTS

HPV vaccination and cervical cancer screening coverage

The data from HMIS showed that over the last three years (2020–2022), the proportion of girls aged between 11 and 15 years who received both doses of HPV vaccine increased from 75 to 80% (Figures 1 and 2). This increase correlated with the introduction of the e-tracker for HPV vaccination recording in 2022. Additionally, the proportion of women who received cervical cancer screening increased from 1 to 16% over the last five years (2018–2023). This rise was especially notable in 2020, shortly after the implementation of OpenMRS in cervical cancer services.

Data reporting, timeliness, and completeness

We conducted correlation analysis (Figure 2) and found that cervical cancer data recorded in mUzima and OpenMRS in the last four years (2020–2023) significantly correlated with data reported in HMIS, with an R-squared value of 0.9979 and a p-value of less than 0.001 signifying the data quality improvement brought by introducing and implementing digital health interventions.

HPV vaccination data reporting has consistently remained high since 2018, reaching 99 % and maintaining 100 % since 2021 (Figure 3). Nationally, the reporting rate for cervical cancer has been slowly improving, rising from 50 percent in 2018 to 63 percent in 2023. However, when we examine a specific case like Kibagabaga District Hospital, which provides cervical cancer services and effectively utilizes mUzima and OpenMRS integrated with HMIS, its reporting rate for cervical cancer screening data significantly increased Additionally, timely reporting showed considerable improvement, rising from 0 percent in 2019 to 63 percent in 2022 (Figures 4, 5 and 6).

Between 2020 and 2023, the comparison of cervical cancer screening and follow-up data between HMIS, mUzima, and OpenMRS revealed

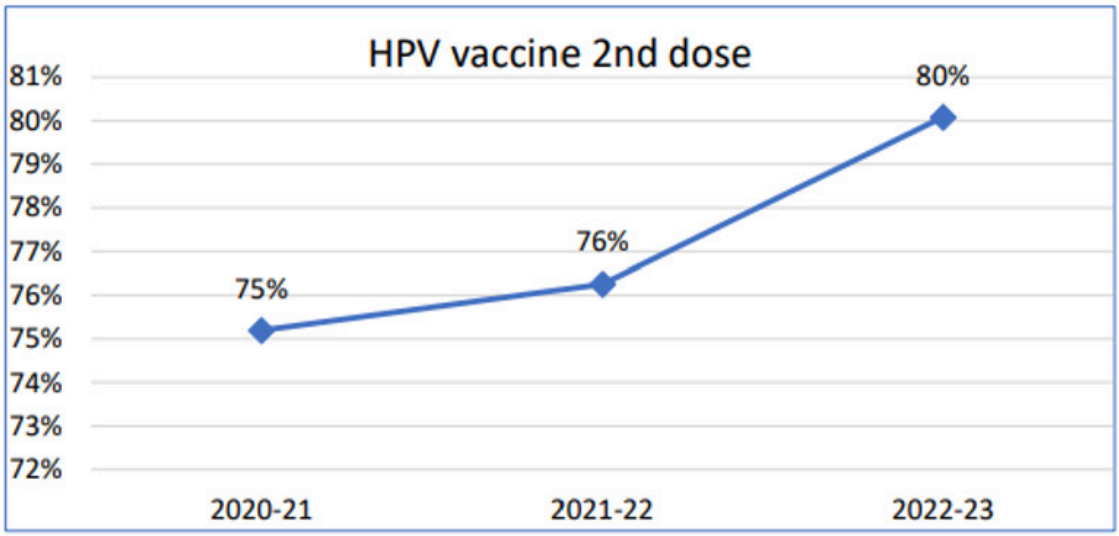


Figure 2: Proportions of eligible girls who received a second dose of HPV vaccine

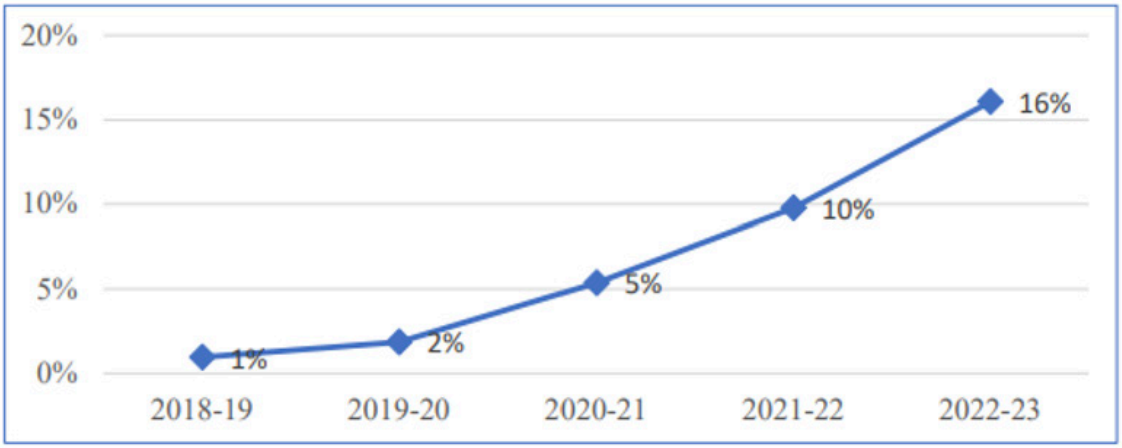


Figure 2: HPV vaccination and cervical cancer screening coverage within the last 5 years

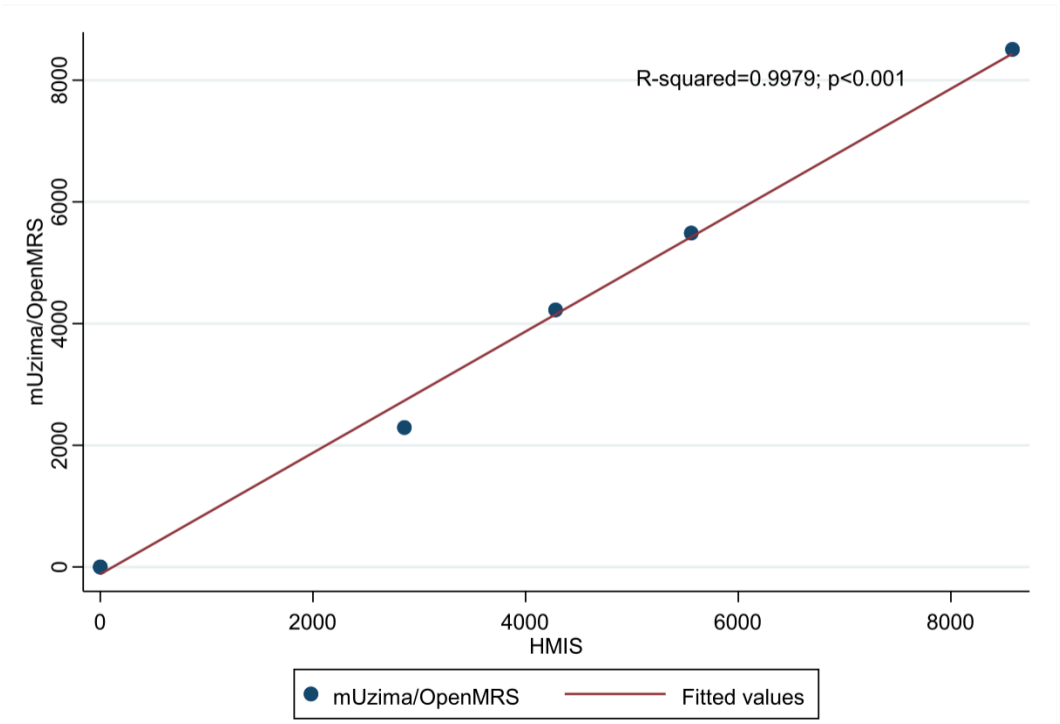


Figure 3: Correlation between mUzima/OpenMRS and HMIS data (2019-2023)

that mUzima and OpenMRS had more data that was not equally reported in HMIS, specifically data concerning screened women and follow-up (Table 1). These findings suggest that mUzima and OpenMRS capture more comprehensive data on cervical screening and follow-up, potentially indicating a valuable contribution to the overall effectiveness of cervical cancer services.

In evaluating data completeness, we assessed five indicators: HIV status, phone number/contact person, sector, cell, and village. Our findings indicate that data completeness in mUzima and OpenMRS is generally good, with phone number/contact accounting for the highest percentage of missing value at 10 percent (Table 2). While this suggests that mUzima and OpenMRS serves as a dependable data source, there is room for improvement to achieve 100 percent data completeness.

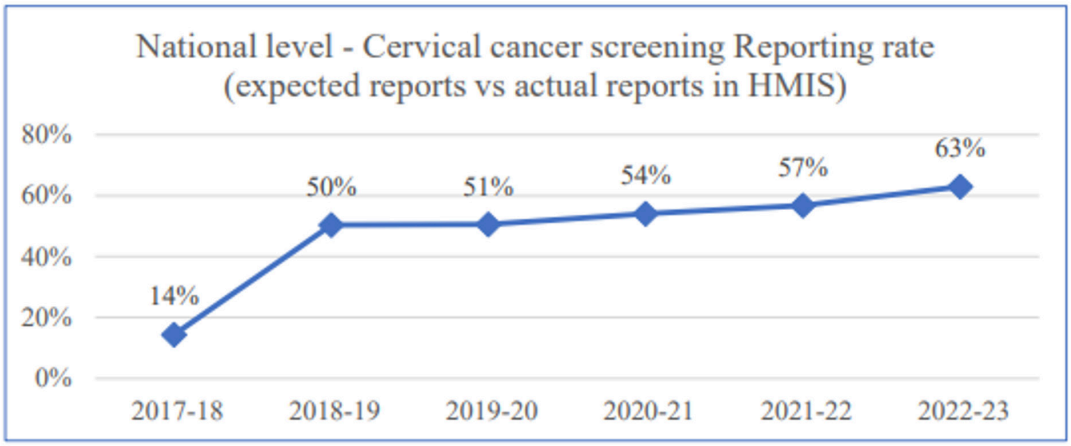
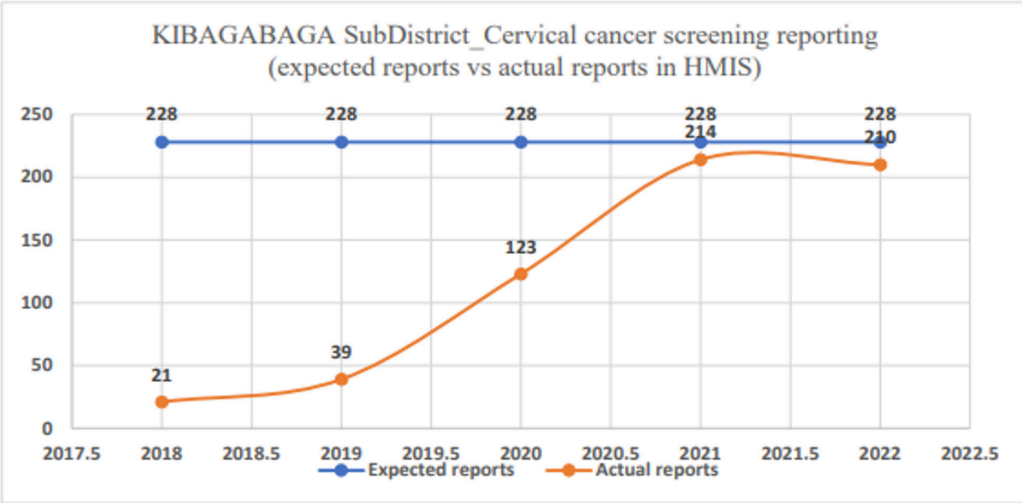


Figure 4: Cervical cancer reporting rate within HMIS



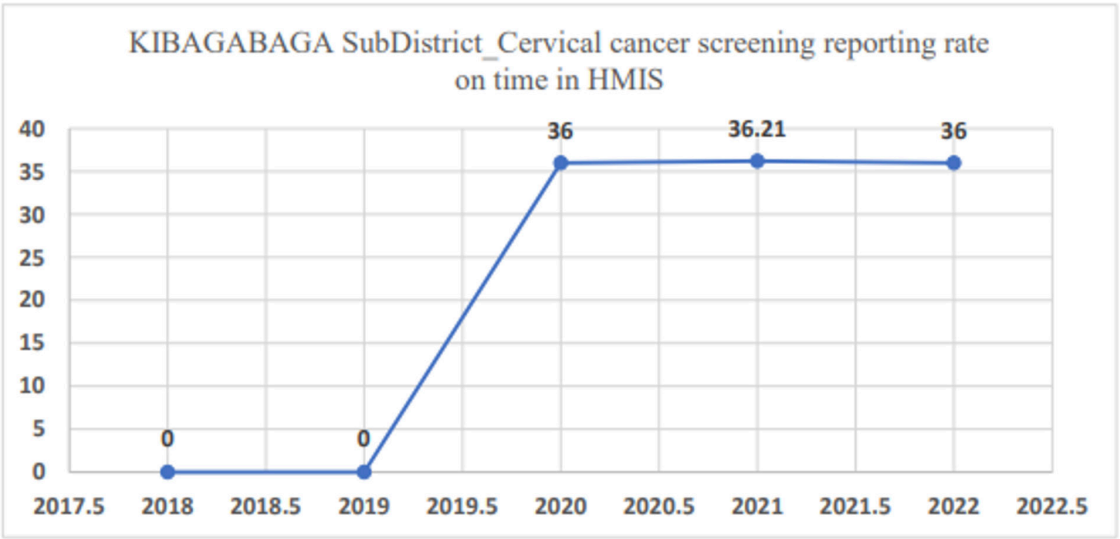


Figure 6: Cervical cancer data reporting and timeliness

Qualitative findings

Fifteen participants, including healthcare providers, data managers, and program managers engaged in HPV vaccination and cervical cancer screening and management, were interviewed. The participants had a mean age of 38 ± 5 years, with an average experience of 11.8 ± 6 years. The analysis identified four prominent themes. Additional themes are explored in another paper. This study focuses solely on one theme: Positive end-user experience, acceptability, and satisfaction with digital health solutions. This theme includes the following sub-themes:

Improvement over using registers: Digital health solutions significantly improve efficiency compared with traditional register-based systems. They streamline appointment scheduling and patient tracking, leading to increased immunization and screening coverage. Participants highlighted the effectiveness of these tools, particularly in simplifying appointment scheduling and follow-up monitoring, contributing substantially to enhanced HPV vaccination and cervical cancer screening coverage.

"Yes, e-tracker has been incredibly helpful. The ability to know who is scheduled to come each day allows us to proactively reach out to those who miss their appointments and ensure they receive the vaccine. This is a significant improvement from the time when we used registers. It was challenging to go through multiple registers to identify those who didn't attend. Thanks to e-tracker, our efficiency has increased, leading to a higher number of vaccinations and improved coverage." – KII (1), Nurse

"*mUzima has good, easy, and accessible storage, and you can access it from anywhere if you have an internet connection. It also provides reminders for appointments to the providers. If we miss patients for follow-up, we can retrieve their information and give their contact details to the community health workers to figure out what happened, helping the patient and ensuring they receive proper care"* KII (6), Medical doctor.

Digital health solutions save time for both clients and healthcare workers: The adoption of digital health solutions has resulted in time savings for both healthcare providers and patients, ensuring adherence to guidelines, enhancing healthcare access, and improving reporting. They have significantly improved operational efficiency, reducing the time spent on serving individual clients, thus increasing the capacity to attend to a larger number of patients daily and enabling report generation with high-quality data. One notable benefit is reduced patient waiting times at healthcare facilities, which enhances both patient experience and job satisfaction among nurses.

"For example, here we conduct vaccinations twice a week. Parents no longer spend extra time in health centers, and they are happy to come without hesitation." – KII (3), Nurse

"E-tracker is very effective; it helps me produce reports on time." – KII (2), Data manager

Enhanced data management and security: Key informants acknowledged the positive impact of digital health interventions on data storage and management. Previously, reliance on registers made retrieving information uncertain and time-consuming, as it necessitated searching through multiple registries. Digital systems have simplified the process of accessing patient information, now requiring only the patient identifier. This enhances data security and reduces information loss.

"E-tracker significantly enhances data management and ensures the quality of stored information. It enables rapid tracking of a child's vaccination history. In the past, using registers meant searching through numerous records, often taking hours, especially if the parent couldn't recall the vaccination year. However, with the unique identifier code, all the necessary information is readily available." – KII (2), Data manager

"The use of the mUzima and OpenMRS system has significantly eased our processes and increased data security compared to the time when we relied on papers and registers." – KII (7), Data manager

"Using registers was risky; the papers could be torn, lost, or damaged. But now, with e-tracker, you have secure data that won't be lost" – KII (2), Data manager.

"Today, the verification process is easy. The quality of data has improved significantly. Previously, we used to conduct supervision at health centers to identify any discrepancies we have observed in data and reporting. Now, we can sit at the central level and compare the data from HIMS and e-tracker to identify any discordance. It is easier to

Table 1: Comparison between mUzima and HIMS

	Year	mUzima/OpenMRS	HMIS
Women screened with HPV and have Results	2019	0	0
	2020	3,127	3,156
	2021	7,622	7,269
	2022	4,905	4,430
	Sep-2023	1,888	916
	Total	**17,542**	**15,771**
Women tested positive for HPV	2019	0	0
	2020	821	826
	2021	1,983	1,797
	2022	1,096	947
	Sep-2023	540	423
	Total	**4,440**	**3,993**
Women tested positive for HPV and Received follow-up	2019	0	0
	2020	622	518
	2021	1,158	746
	2022	794	245
	Sep-2023	279	394
	Total	**2,853**	**1,903**

correct individual data than aggregate data" – KII (9), Immunization program manager.

Increased access to data: It was mentioned that the use of digital systems, in addition to enhancing data storage, has significantly increased the accessibility of data for diverse purposes. The patient information necessary for proper follow-up is now easily obtainable through systems that facilitate synchronization and interoperability.

"mUzima is a great system because it allows synchronization. The data entered in mUzima is transferred to OpenMRS. All screenings are registered in mUzima and synchronized, then transferred to OpenMRS oncology. It helps us a lot as data managers to do triangulation, as we can access all information using the same patient codes. We no longer need transfer sheets for patients registered in mUzima; the data entered at the health center can be accessed at the district hospital level." – KII (8), Data manager.

DISCUSSION

This study used HPV vaccination and cervical cancer data obtained from relevant databases, namely e-tracker, OpenMRS, and HMIS, to evaluate the outcomes of digital health solutions for HPV vaccination and cervical cancer in Rwanda. Additionally, qualitative interviews were conducted with healthcare providers, data managers, and program managers. Overall, implementing these digital health solutions improved data reporting and coverage for HPV vaccination and cervical cancer screening.

According to the HMIS data, the proportion of girls aged between 11 and 15 years who received both doses of the HPV vaccine increased from 75 percent to 80 percent during the last three years (2021–2023). Additionally, the proportion of women who received cervical cancer screening increased from 1 percent to 16 percent over the last five years (2018–2023).

While this notable improvement in HPV vaccination became particularly apparent in 2022, this increase was correlated with the introduction of an e-tracker for recording HPV vaccinations. A substantial increase in cervical cancer screening has also been observed over the past five years. Notably, this upward trend began in 2020, and was correlated with the introduction of mUzima and OpenMRS. It is well established that the implementation

Table 2: Data completeness in mUzima/OpenMRS

Type of Observation	%
HIV Status missing	1%
Phone Number or Contact person missing	10%
Sector missing	3%
Cell missing	4%
Village missing	8%

of digital health solutions enhances healthcare delivery and coverage [31]. The role of digital health solutions in improving vaccination coverage has been documented in various countries [32–36]. The mechanism explaining this coverage improvement mainly lies in increased monitoring and the ability to identify eligible children for vaccination, enabling the sending of reminders or outreach efforts [32,33,35,37,38]. Additionally, educational materials have been influential in shaping parental behaviors [32].

It is important to note that while digital health solutions may have played a role, the rise is likely attributed to a combination of factors, making it an additive effort rather than solely dependent on their introduction [39–41]. These increases may result from concurrent efforts to advance preventive healthcare, including improved accessibility due to political commitment, awareness campaigns, enhanced healthcare infrastructure, and digital health [42,43].

Cervical cancer data recorded in mUzima and OpenMRS over the last four years (2020–2023) show a significant consistency with data reported in HMIS. This strong correlation highlights the reliability and consistency of digital health records [44,45]. The national reporting rate has gradually improved, with a significant increase at Kibagabaga District Hospital since 2020, correlating with the adoption of mUzima and OpenMRS. Kibagabaga Hospital provides comprehensive cervical cancer services. It was among the first hospitals to adopt and implement the mUzima and OpenMRS, unlike several other hospitals that have not yet embraced it. The substantial improvement in reporting rates at Kibagabaga District Hospital shows the localized impact of digital health intervention at specific healthcare facilities before extending this impact to the national level, which includes hospitals not yet using mUzima and OpenMRS. The high reporting rate suggests the effectiveness of digital health solutions in ensuring accurate and timely information [44,45].

Comparison of cervical cancer screening data between HMIS and mUzima/OpenMRS revealed mUzima disparities, particularly in screened and follow-up cases. These differences indicate potential challenges in interoperability, data synchronization, and reporting protocols. Enhancing interoperability between digital health solutions could address these issues [22,46] mainly through adopting standard-based health information exchange system architectures and platforms. This effort requires further investments but has the potential to decrease errors, facilitate monitoring and reporting, ensure timeliness, and increase the efficiency of care delivery, all at a lower cost [47–50].

Other challenges associated with implementing digital health solutions, described in Rwanda and various other settings, include technical issues and gaps in staff training [51–54]. Addressing these challenges is crucial to achieving the sustainability of digital health solutions [54]. Therefore, we recommend regular system maintenance, increased investment in maintenance, the effort to enhance interoperability, and continuous staff training. Policymakers should focus on long-term investment in infrastructure and personnel to ensure the sustainability of digital health programs [54].

A limitation of this study was the use of multiple, sometimes incomparable, data sources as well as reliance on secondary data with encountered issues like duplicate and missing data. Therefore, we performed data cleaning, which involved addressing duplicates and missing data through deduplication. Collaboration with data providers also helped mitigate biases and gaps in the secondary data. We conducted sensitivity analyses to assess the robustness of the results and to understand the impact of data quality issues.

Future studies should consider data harmonization, which involves standardizing data from different sources to ensure comparability and imputation for missing data.

CONCLUSION

This study highlights the positive impact of deploying digital health solutions on HPV vaccination and cervical cancer screening in Rwanda. The introduction of the e-tracker for HPV vaccination records and the adoption of the OpenMRS significantly contributed to a rise in cervical cancer screening rates, which increased from 1% in 2018 to 16% in 2023. Qualitative insights from key informant interviews underscored the crucial role of these digital tools in enhancing access to preventive and screening services. Overall, these findings suggest that digital health solutions can be instrumental in improving vaccination and screening coverage, providing a promising pathway for advancing cervical cancer prevention efforts in Rwanda and other low- and middle-income countries.

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