Implementation and evaluation of a community health workers-led digital integrated diseases screening system to provide healthcare for patients at community level in Rwanda

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Summary

Background Community health workers (CHWs) play a vital role in identifying patients within the community. To enhance their decision-making and reduce unnecessary referrals, Rwanda introduced a digital integrated disease screening tool (d-IDS), embedded within the national community Electronic Medical Records (cEMR) system. This study aimed to design, integrate, and evaluate the d-IDS to support its broader national scale-up.

Methods This study employed a pre-post effectiveness-implementation hybrid design to implement the d-IDS and evaluate its effectiveness in improving patient management at the community level in five districts during April–July 2024. The d-IDS was designed into a single decision-support workflow embedded within the cEMR platform, and deployed on CHWs' smartphones. The workflow automatically guides CHWs through case registration, symptom assessment, diagnostic testing, and treatment or referral decisions. The d-IDS tool consolidated the screening processes for tuberculosis, malaria, pneumonia, and diarrhoeal diseases. Referral data extracted from the cEMR following d-IDS implementation and retrospective data from similar period (April–July 2023) collected under the paper-based approach; Standard of Care (SOC), were analysed using Chi-square tests. Qualitative feedback from CHWs were gathered through structured interviews to assess acceptability and feasibility.

Findings The implementation of d-IDS led to a statistically significant 24.2% reduction in overall referrals to health facilities ($p < 0.0001$) when compared to the SOC period. Of the 3060 individuals screened using the d-IDS, 45.6% triggered further assessment, and 1687 (55.1%) were successfully managed by CHWs at the community level. Notably, in Rwamagana district, referral rates dropped from 79.8% to 32.5%, a 59.2% reduction ($p < 0.0001$). CHWs reported that d-IDS improved workflow efficiency, data accuracy, and decision-making compared to the paper-based approach, especially with features like offline functionality and symptom-guided screening protocols.

Interpretation The findings confirm that d-IDS is both feasible and acceptable for CHW use in community settings. It improves community-based patient management and reduces the burden on health facilities. However, close follow-up mechanisms are necessary to ensure early detection of any worsening conditions. These promising results support the future national rollout of d-IDS as a scalable solution to strengthen primary healthcare and CHW-led service delivery.

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Research in context

Evidence before this study

Prior to this intervention, the traditional paper-based screening methods employed by Community Health Workers (CHWs) were time-consuming and associated with inefficiencies, including poor adherence to disease screening guidelines, data management challenges. CHWs had been manually recording patient data in registers and physically delivering this information to health centres, which hindered their productivity as well as delays in data reporting. The introduction of a digital tool markedly improved documentation speed and enabled real-time data transmission, yielding significant timesaving in patient management. This advantage was demonstrated during the COVID-19 pandemic, CHW-led surveillance illustrated the effectiveness of integrating digital tools with rapid diagnostic testing for household-level COVID-19 detection in Rwanda. The Digital Integrated Disease Surveillance (d-IDS) system was subsequently developed to evaluate the effectiveness of digitisation across multiple healthcare conditions, including malaria, pneumonia, diarrhoea, and tuberculosis.

Added value of this study

The added value of this study lies in its demonstration of an innovative, digitally enabled d-IDS system's effectiveness in enhancing CHWs operations. By streamlining workflows and enabling simultaneous screening for multiple conditions, the d-IDS combined parameters into a single workflow guiding to more appropriate clinical decision including referrals. The d-IDS significantly reduced the burden of unnecessary referrals to health facilities, thereby decongesting these facilities and improving efficiency in patient management. The integration of this digital tool within the national cEMR ensured data accuracy and real-time transmission of health information. Since it was entered by the CHW at the point-of-care rather than into the cEMR later, it also empowered CHWs to have real-time guidance at the community level. The study offers pivotal insights into the feasibility and acceptability of a point-of-care user-centred approach to digital health interventions, showcasing the potential for improved health equity and access to care, especially in rural settings, while also highlighting the necessity of ongoing training and support for sustainable outcomes. Overall, the findings provide a potentially replicable model for other low and middle-income countries aiming to leverage digital solutions for strengthening the primary healthcare, particularly focussing at community programs.

Implications of all the available evidence

This study evaluating the d-IDS in routine operations of community-based healthcare system, offer valuable insights for national, regional, and global policy development. The intervention emphasised a user-centric design approach, engaging stakeholders in an iterative development process that incorporated their feedback to better align the system with CHWs workflows and needs. Beyond system functionality, the intervention had important benefits on healthcare service delivery, particularly in optimising patient referrals by reducing unnecessary facility visits while ensuring timely care for severe cases. The integration of the d-IDS system into existing cEMR workflows improved data accuracy, enhanced disease surveillance, and strengthened linkages between CHWs and health facilities. The offline functionality was critical for continuity of service delivery in low-connectivity areas and maintaining data integrity. Furthermore, a robust system improvement cycle, underpinned by regular feedback, effective issue tracking, and timely technical support, significantly enhanced user experience and system performance. While initial training was essential, regular mentorship, supportive supervision, and on-the-job training were crucial for ensuring sustained system adoption.

Introduction

Community Health Workers (CHWs) play a pivotal role in delivering decentralised, community-based healthcare and public health services including operating a robust surveillance system that monitors and collects live health data.[1] As trusted local members, CHWs engage closely with their communities, enabling timely identification and reporting of health-related events, thereby enhancing disease surveillance interventions.[2] In Rwanda, community-based services are operated through nearly 60,000 CHWs.[3]

A significant obstacle faced by CHWs is their reliance on traditional, paper-based vertical screening methods.[4] These methods are often cumbersome and inefficient, involving multiple forms that lead to ineffective documentations of screened and treated diseases. This not only increases the risk of data loss and damage but also complicates the workflows potentially leading to inconsistency and sub-optimal diseases screening. While this pattern is often observed anecdotally— leading to limited adherence to guidelines and over-referral of potentially non-severe cases to health facilities—systematic data to confirm and quantify this issue remain limited.[2,5] Such processes are time and resource-consuming, imposing additional transportation costs on CHWs who must physically deliver patient data to health centres. This results in their intermittent absence from the community, overburdens healthcare facilities, and causes delays for patients awaiting follow-up, ultimately compromising the quality of care.[2,6]

Digitally enabled integrated disease surveillance (d-IDS) offers a transformative solution to the limitations of paper-based screening approach. By consolidating multiple disease assessments into a single, streamlined digital workflow, d-IDS enables CHWs to screen for various conditions simultaneously, enhancing operational efficiency and data quality.[7,8] During the COVID-19 pandemic, Rwanda adopted a digital tool combining rapid diagnostic tests with CHW-led household surveillance, facilitating community-level COVID-19 detection.[7,9] This successful initiative demonstrated the potential of integrating digital tools to support disease detection beyond COVID-19.

Before the introduction of the digital system, CHWs performance reports indicated inconsistent referral patterns, incomplete documentation, and limited feedback loops between CHWs and health facilities.[7] National surveys have also shown disparities in timely case detection and referral completion, particularly for febrile and respiratory conditions, across rural districts.[9] The d-IDS system was therefore expected to improve referral accuracy, timeliness of care, adherence to screening protocols, and equity in service access, thereby strengthening the overall efficiency and quality of community-level disease management.

Digital tools have shown promising results across various contexts. For instance, the Alliance for Malaria Prevention has successfully integrated digital reporting systems for indoor residual spray operators across sub-Saharan Africa, enabling real-time tracking of spray progress during malaria seasons.[10] Similarly, digital interventions in Malawi have improved supply chains for community case management of pneumonia and other common childhood diseases,[11] while Haiti's community-based programs have enhanced malaria treatment and prevention efforts.[10] However, despite these successes, significant gaps remain in scaling digital systems to a national level, highlighting the needs for operational research to address implementation challenges. Thus, the d-IDS system's benefits can extend beyond operational efficiency. By automating data entry, standardising decision-making, and linking real-time information between CHWs and health facilities, the system has the potential to reduce under- and over-referrals, enable timely treatment initiation, and ensure equitable access to care for vulnerable populations. These outcomes are expected to enhance both individual patient management and broader public health responsiveness.[12]

This study aimed to design and evaluate the effectiveness, feasibility and acceptability of implementing an integrated digital clinical decision support system for CHWs in Rwanda. The study assessed the changes in CHWs referrals, timeliness of referral completion, adherence to integrated screening guidelines, and equity in patient access to community-level health services, thereby providing evidence on whether the d-IDS system contributes to more efficient, timely, and equitable health service delivery within Rwanda's community health framework.

Methods

Study design

This study employed a pre-post effectiveness-implementation hybrid design to evaluate the effectiveness of the d-IDS in improving patient management at the community level and its implementation outcomes, including feasibility and acceptability among CHWs. A hybrid effectiveness-implementation design refers to a mixed methodological approach that concurrently assesses the effect of an intervention on defined quantitative outcomes i.e., referral rate (effectiveness), and the processes influencing its real-world uptake, feasibility, and acceptability (implementation) (Table 1). This design allows simultaneous assessment of clinical effectiveness and implementation performance under programmatic conditions. The study compared CHW service delivery outcomes during d-IDS implementation period (April–July 2024) with retrospective data from similar period (April–July 2023) collected under the paper-based approach Standard of Care (SOC). An overview of health services/conditions covered by CHWs as of June 2023 is shown in Supplementary Appendix: Table S1. This study fully adheres to the Standards for Quality Improvement Reporting Excellence (SQUIRE), with compliance mentioned in the Supplementary Appendix 2.

Quantitative methods

Study sites and setting

This study was conducted in five districts due to their high incidence of combined burden of d-IDS focused conditions (i.e., TB, malaria, pneumonia, and diarrhoeal diseases) considering urban districts; Nyarugenge, Gasabo, and Kicukiro in Kigali City as well as rural areas; Muhanga in the Southern Province, and Rwamagana in the Eastern Province. The study areas were comprised of 36 health centres and 304 villages, in total. In the selected villages, 600 CHWs representing around 10.0% of total CHWs participated (Supplementary Appendix: Table S2).

Digital tool and workflow design

The d-IDS workflow was designed in collaboration with expert disease program leads from Rwanda Biomedical

Outcome category	Outcome name	Study component	Definition	Quantitative specification (numerator/denominator/ measurement)	Qualitative data source (open-ended question)
Effectiveness	Referral rate	Quantitative	Proportion of screened patients referred to a health facility	Numerator: Number of patients referred. Denominator: Total number of patients screened. Measurement: Automatically captured from d-IDS system records.	N/A
Effectiveness	Referral completion	Quantitative	Proportion of referred patients who completed referral at a health facility	Numerator: Number of referred patients attending facility. Denominator: Total referred patients. Measurement: Facility verification and d-IDS follow-up records.	N/A
Implementation	Acceptability	Qualitative	Perceived satisfaction with the digital screening tool	N/A	"How did you feel about using the digital screening tool in your daily work?"
Implementation	Usability	Qualitative	Perceived ease of use and navigation of the tool	N/A	"What aspects of the tool were easy or difficult to use?"
Implementation	Feasibility	Qualitative	Factors enabling successful adoption of the tool	N/A	"What factors helped you use the digital screening tool effectively?"
Implementation	Perceived workload	Qualitative	Perceived impact of the tool on CHWs' workload	N/A	"How did using the digital tool affect your workload compared to the paper system?"
Implementation	Perceived effectiveness (patient convenience)	Qualitative	CHWs' perceptions of the tool's usefulness in identifying and referring patients	N/A	"In what ways did the digital tool help or hinder patient identification and referral?"
Implementation	Implementation challenges (system limitations)	Qualitative	Barriers encountered during implementation	N/A	"What challenges did you experience while using the digital screening tool?"

Table 1: **Definition and measurement of effectiveness and implementation outcomes.**

Centre (RBC) to integrate community-level algorithms for four priority diseases with potential overlapping symptoms, including malaria, pneumonia, Tuberculosis (TB) and diarrhoeal diseases.[13–16] These conditions were selected based on their high public health burden, contribution to under-five and communicable disease mortality, and their suitability for community-based management. According to national annual health reports in Rwanda, malaria remained one of Rwanda's leading causes of outpatient consultations.[13] Although national incidence declined to 76 cases per 1000 mortality in the financial year (FY) of 2021/2022 following scale-up of home-based management and universal insecticide-treated nets distribution, the disease continues to exhibit seasonal and geographic variability requiring strengthened surveillance and early detection.[14,17] TB notification rates nearly doubled between FY 2021/2022, increasing from 5943 to 9422 cases in 2022/2023, underscoring the importance of community-based screening to facilitate early diagnosis and treatment initiation.[15] Diarrhoea and pneumonia remain major contributors to under-five morbidity and mortality, with diarrhoea prevalence estimated at 12.7% and pneumonia accounting for 7% of national mortality and 16% of all health centres consultations.[16] These conditions disproportionately affect children from low-income and rural households, emphasising the need for integrated, equitable screening systems at the community level (Supplementary Appendix: Section 2).

The d-IDS tool was therefore designed to enhance early identification, standardised screening, and appropriate referral for these four priority conditions. The algorithms were harmonised into a single decision-support workflow validated by program experts at RBC. the digitalised version was developed by Fionet (https://www.fio.com/), embedded within the national community Electronic Medical Records (cEMR) platform, and deployed on CHWs' smartphones (Supplementary Appendix: Figure S1). The workflow automatically guides CHWs through case registration, symptom assessment, diagnostic testing, and treatment or referral decisions, enabling real-time data capture and bidirectional feedback between community and health facility levels.

The implementation process of d-IDS in Rwanda

Before the study commenced, the central-level team from RBC, Ministry of Health, FIND, Society for Family Health (SFH), Johns Hopkins Program for International Education in Gynaecology and Obstetrics (JHPIEGO), and representative from CHWs participated in User Acceptance Testing with the Fionet team. This ensured that the system met field requirements. Introduction meetings were then held at each HC, and attended by HC leadership, central-level supervisors, and all CHWs in the HC's catchment area. These meetings explained the study, including the selection process, ensuring that all stakeholders understood the study's objectives and importance to the community, and informed about the study benefits which facilitated a smooth implementation process (Supplementary Appendix: Section 3). Note that only selected sites piloted the d-IDS embedded in the cEMR during the study period.

Participants screening and enrolment by CHWs

Eligible participants were community members presenting to CHWs with at least one symptom listed in the integrated algorithm for malaria, pneumonia, TB or diarrhoeal diseases. Participants were identified and registered using the cEMR system. The system embedded a baseline registry of all national household members, obtained through the Rwanda Ministry of Local Governance. Participants were registered into the cEMR if they weren't already registered. To determine whether a participant is registered on the cEMR, a search was made in the system using the participant's national ID card. The screening pathway for a cEMR-naïve patient only began once they're registered on the cEMR. Basic demographic information including sex, age, and household characteristics, was collected through self-report by study participants. Information was retrieved from the system and updated if needed from individuals who were previously registered on the cEMR; to ensure that everyone had all their medical data captured in a single longitudinal record, and to eliminate duplication of records for one individual.

After confirming a patient was registered in the system, CHWs asked eligible participants about their symptoms; certain symptoms created a 'flag' for the different conditions included in the d-IDS workflow (Fig. 1). These were mapped based on the existing national guidelines for community-level management of these conditions. Any individual over the age of 5 would be eligible for only malaria and TB at the community level for uncomplicated cases, the over 5 workflow is indicated in Fig. 2. When the d-IDS tool flagged symptoms suggestive of malaria, CHWs conducted a rapid diagnostic test, and if positive without additional danger signs, treatment was initiated immediately. Positive screenings for pneumonia or diarrhoeal disease also led to immediate treatment per programmatic guidelines. Individuals with TB-related symptoms were referred to health facilities for further testing, following national TB guidelines. For females, pregnancy status was assessed first; if pregnant, they were screened for specific maternal danger signs. Those with any flagged danger signs received immediate emergency referral before entering the general screening pathway (Fig. 2). Females who responded no to all the signs continued to integrated symptom screening. Any danger signs that were included in the integrated symptom screening list were pre-filled when proceeding to that step, to avoid repeating the question (in this case, fever would be pre-filled as "no"). However, for children between the ages of 2 months and 5 years, they underwent a separate workflow, and were eligible for malaria, pneumonia and diarrhoea management at community level only if cases are not marked as severe (Fig. 3).

Statistics

Data from the d-IDS and SOC periods were extracted from the cEMR and national CHW reporting systems, respectively. The data were organised and stored in a database consisting of multiple tables, each corresponding to different attributes. SQL queries were used to merge these various tables, and the exported data were utilised to generate report tables using R (version 4.4.0). Descriptive statistics were used to summarise demographic characteristics. Chi-square tests compared proportion of patients managed at the community level by CHWs and referred appropriately between the two periods. Percentage change was calculated as the relative difference between post- and pre-intervention values, divided by the pre-intervention value, expressed as a percentage:

$$\text{Percentage change} = \frac{(\text{Post-intervention \%} - \text{Pre-intervention \%})}{\text{Post-intervention \%}} \times 100$$

This formula reflects the proportional increase or decreases from the baseline (pre-intervention) period to the post-intervention period. Differences in proportions were calculated using the z-statistic and reported with 95% confidence intervals (CIs). A p-value less than 0.05 was considered statistically significant.

Qualitative methods

Study design

A descriptive qualitative study using an exploratory design was conducted to assess the feasibility and acceptability of the d-IDS system among CHWs after its implementation.

Participants and sampling

CHWs who participated in the d-IDS intervention were purposively selected to ensure representation across sex, district, and experience levels. Prior to the study, CHWs underwent training delivered in two phases: an initial Training of Trainers (ToT) sessions followed by cascade training to CHWs on d-IDS. All training sessions followed a standardised curriculum (Supplementary Appendix: Section 4). After the intervention was implemented, CHWs were interviewed on the feasibility and acceptability of the digital tool using semi-structured interviews (SSIs) and focus group discussions (FGDs). Feasibility was assessed by exploring

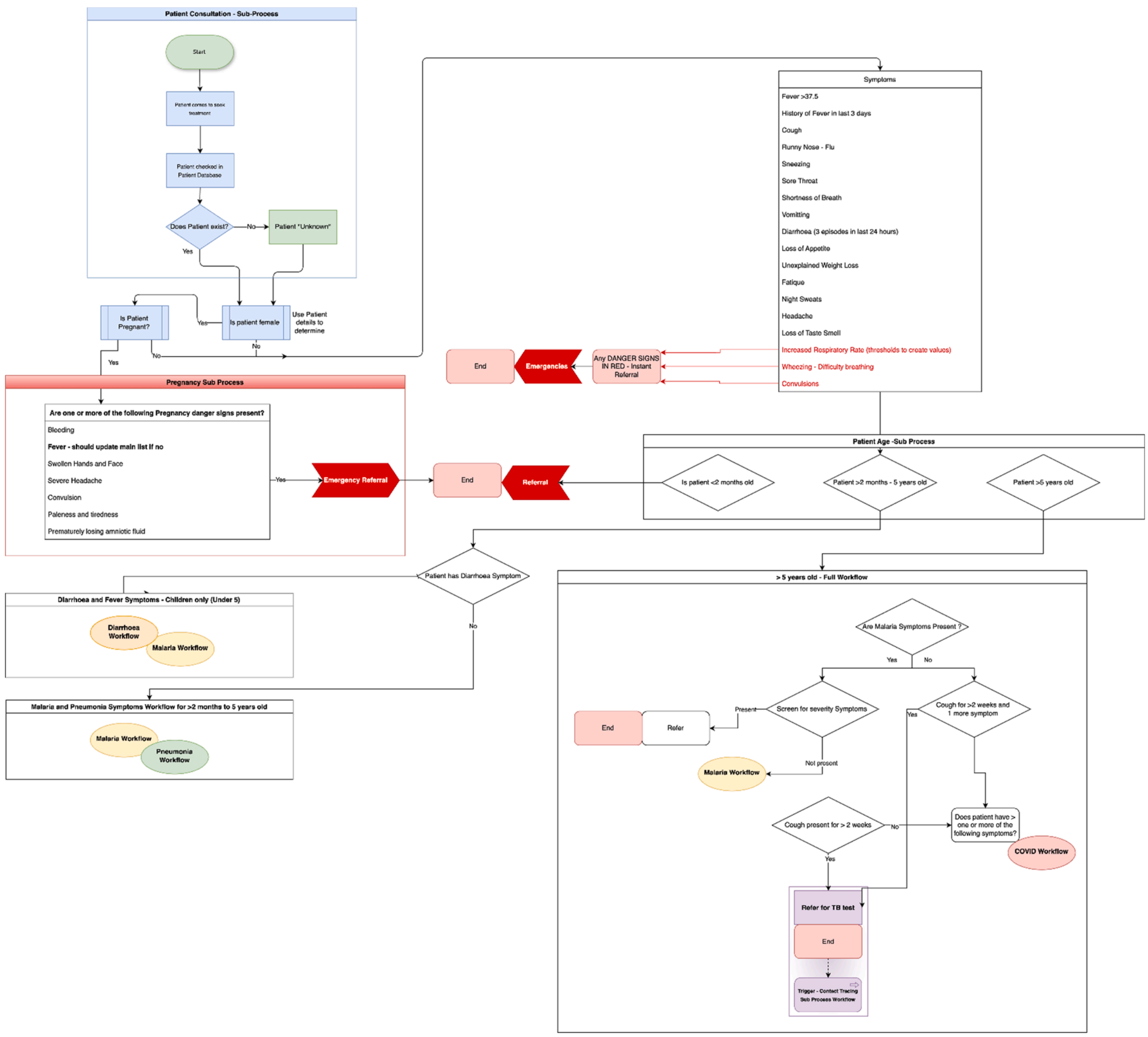

Fig. 1: Simplified workflow illustrating the integrated digital disease-screening system.

operational challenges encountered during routine use of the d-IDS, including technical and connectivity constraints, reliance on paper-based workarounds, frequency of disruptions, and user-identified areas requiring improvement to enable sustained field implementation. While acceptability/usability were assessed through qualitative interviews with CHWs examining perceived usability, perceived usefulness, willingness to support implementation, comfort with digital case tracking, adequacy of training, technical challenges, perceived accuracy and reliability, motivation effects, and overall perceptions of the d-IDS on infectious diseases screening. The qualitative tools are found in (Supplementary Appendix: Section 5).

Analysis

All interviews and FGDs were audio-recorded, transcribed verbatim, and translated into English. Thematic analysis was conducted using an inductive–deductive approach. Codes were developed iteratively, and themes were refined to reflect core implementation dimensions, including feasibility, usability, and acceptability.

Ethics

All procedures in this study were conducted in accordance with Declaration of Helsinki. The Rwanda National Ethical Committee (RNEC) approved the study the study protocol (RNEC 479/2024). Participants enrolled in this study received detailed information on the study and procedures in Kinyarwanda. Enrolment in this study was voluntary for the CHWs who signed informed consent forms for the qualitative component after orientation by the study team. Additionally, all patients received similar quality of care regardless of their participation in the study and no personal

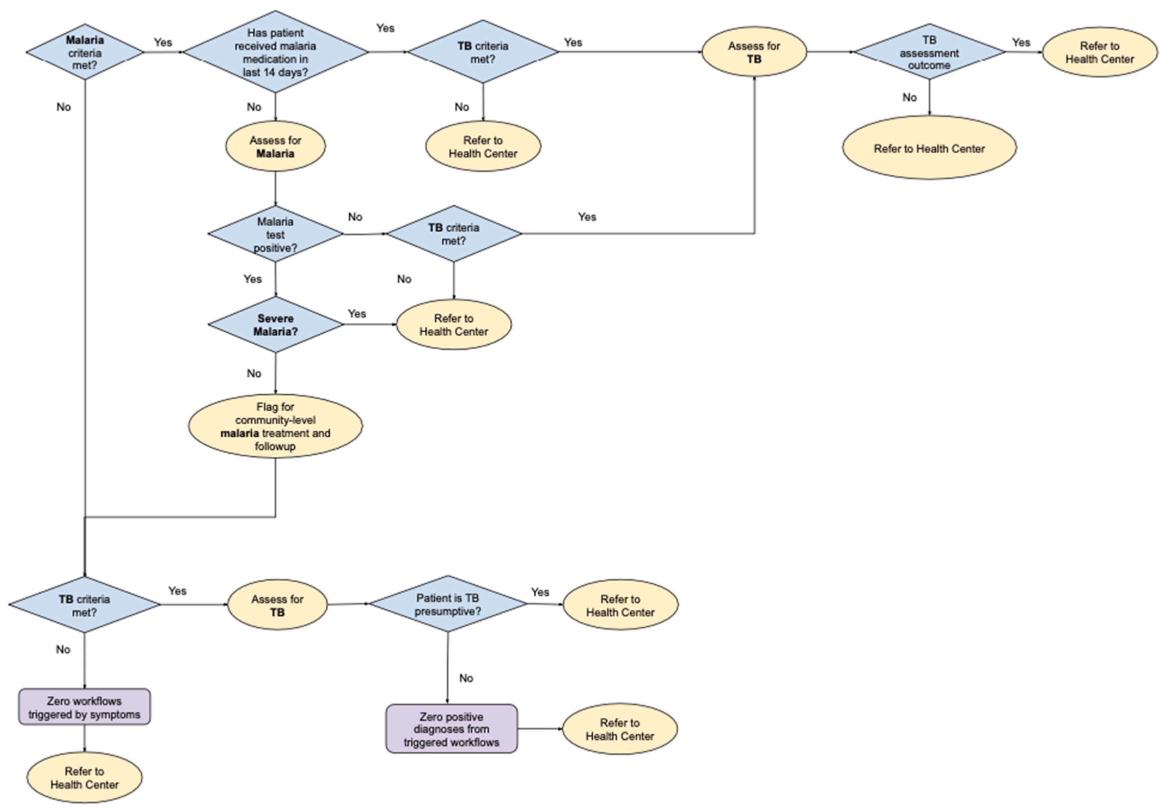

Fig. 2: Over 5 years workflow.

identifiers were shared to protect the patient's privacy and confidentiality.

Role of funders

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Screening and management of patients at the community level

During the study period, CHWs provided healthcare services to 3060 individuals for general routine services (general assessment, growth assessment, nutrition status, TB screening and community-based directly observed therapy, malaria, pneumonia, and diarrhoea) (Fig. 4). The majority of patients were males; 1620 (52.9%), and over half; 1691 (55.3%) were aged above five years. The highest number of patients were recorded in Gasabo district; 1270 (41.5%), which also contributed the largest share of IDS-triggered cases; 606/1395 (47.7% [45.0%–50.5%]); with slightly more females 317 (52.3%) than males 289 (47.7%) (Fig. 5, Table 2).

Of the total individuals screened, 1687 (55.1% [53.4%; 56.9%]) were managed at the community level by CHWs, and 1373 (44.9% [43.1%; 46.6%]) were referred. CHWs managed the majority of patients with most of the managed cases were in rural areas, ranging from 253 (67.5% [62.7%; 72.2%]) in Rwamagana (Eastern province) to 113 (49.3% [42.9%; 55.8%]) in Nyarugenge (an urban district in Kigali) (Table 3). Fever was the most symptom reported by the patients that triggers the d-IDS (Supplementary Appendix: Table S3).

Among the total patients triggered the d-IDS; 1395 (45.6% [43.8%–47.4%]), those who triggered the d-IDS for at least one of the four target diseases were 735 (24.0% [22.5%–25.6%]) malaria, 431 (14.1% [12.9%–15.3%]) TB, 187 (6.1% [5.3%–7.0%]) pneumonia, and 80 (2.6% [2.1%–3.2%]) diarrhoea. Of all the IDS-triggered conditions, TB had the highest proportion of cases managed at the community level 318 (73.8% [69.6%–77.9%]), followed by pneumonia 124 (66.3% [59.5%–73.1%]), malaria 464 (63.1% [59.6%–66.6%]), and diarrhoea 39 (48.8% [37.8%–59.7%]) (Table 4, Supplementary Appendix: Table S4).

The d-IDS also flagged multiple conditions among 249 (8.0%) of the screened patients, 53 (21.3%) cases were related to key diseases and 196 (78.7%) related to the general assessments. The most common combinations were diarrhoea and pneumonia (24 cases), pneumonia and malaria (15 cases), and TB with

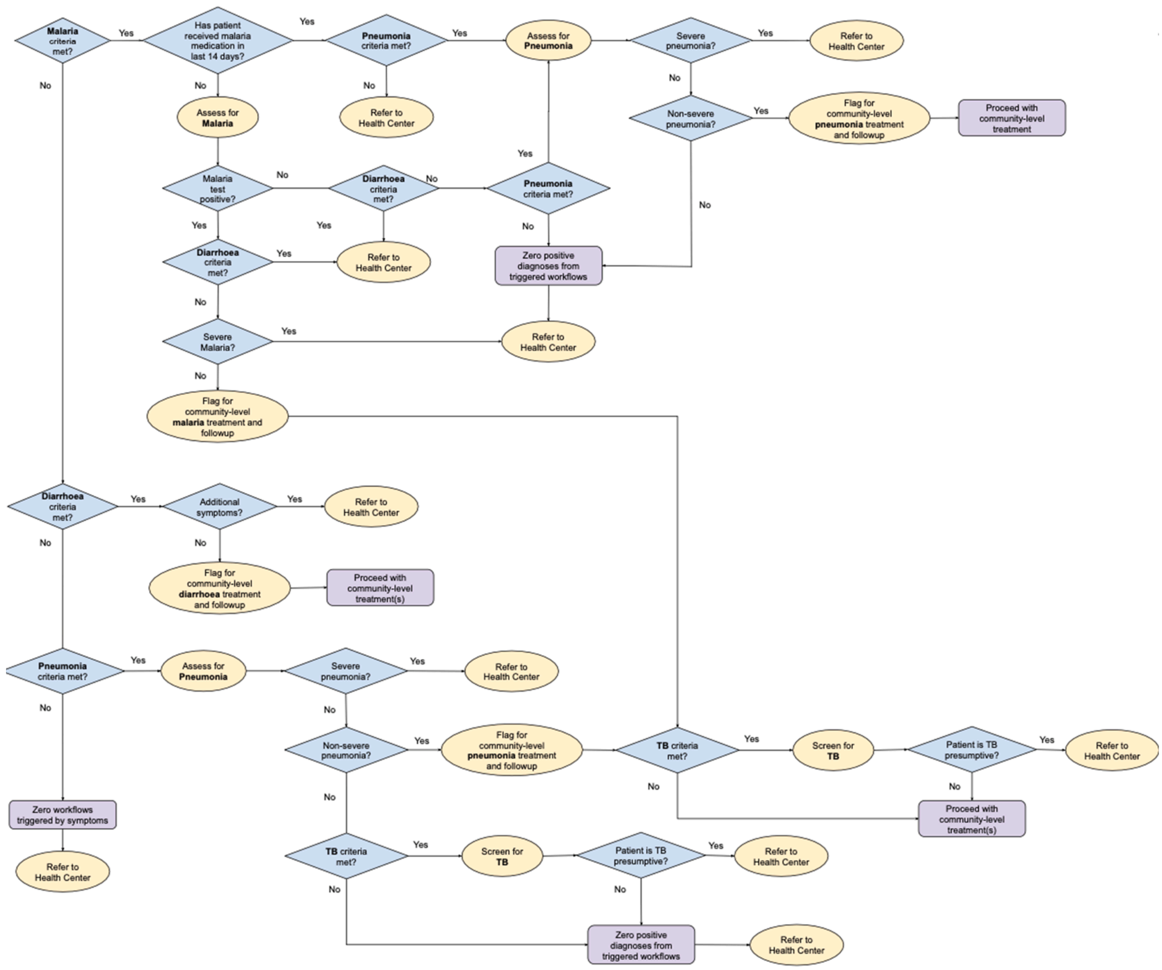

Fig. 3: Under 5 years workflow.

malaria (6 cases). Less frequent combinations included pneumonia with TB and malaria with diarrhoea (each triggered in 4 cases). Pneumonia was the most commonly overlapping condition across combinations (Fig. 6).

Effectiveness assessment through comparison of SOC (April–July 2023) and d-IDS (April–July 2024) referral rates

The comparison of referral rates between SOC period and the d-IDS intervention period revealed a substantial

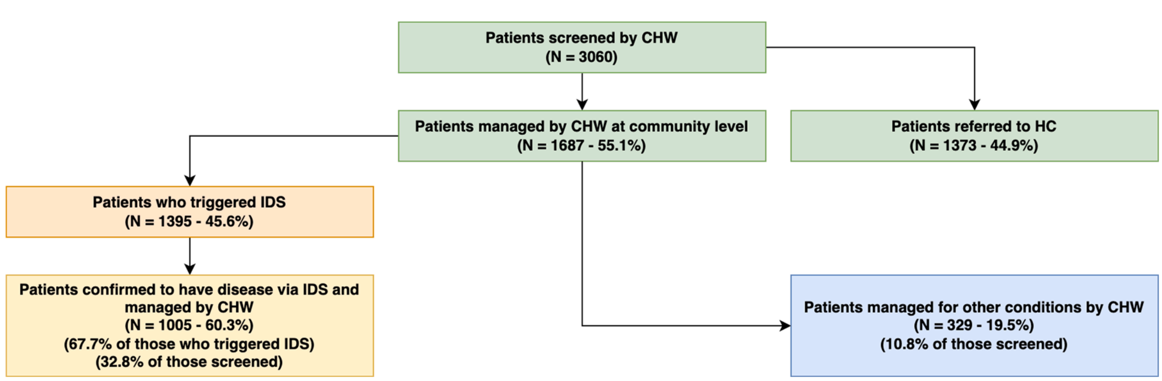

Fig. 4: Schematic of patients who were screened, referred and managed by CHWs.

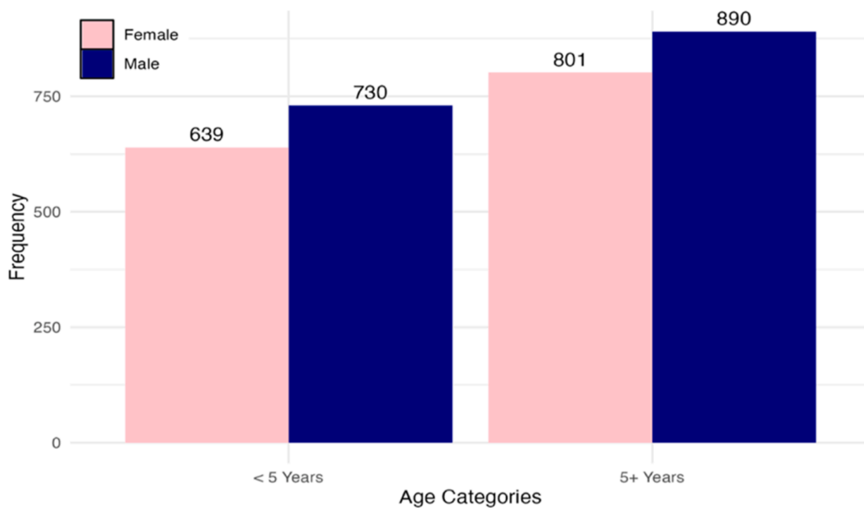

Fig. 5: Distribution of patients by age* and sex. * Results in this section are presented and analysed according to age categories in the standard of care which are <5 years and >5 years.

reduction in patient referrals to health facilities by 24.2% [22.1%–26.6%]. During the SOC period, only 40.8% (95% [40.2%–41.3%]) of individuals who visited CHWs were managed at the community level. In contrast, this proportion increased significantly to 55.1% [53.4%–56.9] during the d-IDS intervention period ($p < 0.0001$), indicating improved capacity for community-based care. Less than half of the patients 44.9% [43.1%–46.6%] were referred to health facilities under the d-IDS system, compared to a higher referral rate during the SOC period; 59.2% [58.7%; 59.8%] (Table 5). Importantly, the d-IDS system provided visibility on the reason for referral (As shown in Table 4), data that is not captured under the analogue SOC reporting. However, the reduction in referral rates was not uniform across districts.

The highest reduction rate in the numbers of patients managed by the CHWs or referred to health care facilities was seen in Rwamagana; 234.2% [228.3%–239.0%] and 59.3% [53.9%–64.7%], respectively (Table 5, Fig. 7). This district also demonstrated a three-fold increase in community-based management, rising from 20.2% [19.1%; 21.3%] during the SOC period to 67.5% [62.7%; 72.2%] during the d-IDS period ($p < 0.0001$).

Qualitative assessment of the d-IDS: CHWs feedback and program insights

d-IDS acceptability: perceived benefits compared to paper-based systems

The d-IDS system was widely recognised by CHWs as a significant improvement over the traditional paper-based system. A large number—93.8%—agreed that the system was time-saving, and 89.0% reported that it improved their knowledge and provided decision-making guidance during patient screening and management. Additionally, 81.2% of CHWs noted that the digital system enhanced data accuracy and patient follow-up, citing fewer omissions and more structured, complete entries.

Importantly, 96.2% of CHWs reported that the system improved patient convenience, including

District	Received, n (%)	Females		Males		Triggered integrated screening [95% Lower CI—Upper CI]
		Screened	Triggered d-IDS	Screened	Triggered d-IDS	
GASABO	1270 (41.5%)	605 (47.6%)	317 (52.4%)	665 (52.4%)	289 (43.5%)	606 (47.7% [45.0%–50.5%])
KICUKIRO	510 (16.7%)	234 (45.9%)	113 (48.3%)	276 (54.1%)	130 (47.1%)	243 (47.6% [43.4%–52.0%])
MUHANGA	676 (22.1%)	311 (46.0%)	138 (44.4%)	365 (54.0%)	160 (43.8%)	298 (44.1% [40.4%–47.9%])
NYARUGENGE	229 (7.5%)	113 (49.3%)	56 (49.6%)	116 (50.7%)	55 (47.4%)	111 (48.5% [42.1%–54.9%])
RWAMAGANA	375 (12.3%)	179 (47.7%)	65 (36.3%)	196 (52.3%)	72 (36.7%)	137 (36.5% [31.8%–41.5%])
Total	**3060 (100%)**	**1442 (47.1%)**	**689 (22.5%)**	**1618 (52.9%)**	**706 (23.1%)**	**1395 (45.6% [43.8%–47.4%])**

Table 2: **Distribution of patients by location and sex.**

District	Received, n	Managed [95% Lower CI—Upper CI]	Referred [95% Lower CI—Upper CI]
GASABO	1270 (41.5%)	668 (52.6% [49.8%; 55.3%])	602 (47.4% [44.7%; 50.2%])
KICUKIRO	510 (16.7%)	271 (53.1% [48.8%; 57.5%])	239 (46.9% [42.5%; 51.2%])
MUHANGA	676 (22.1%)	382 (56.5% [52.8%; 60.3%])	294 (43.5% [39.8%; 47.3%])
NYARUGENGE	229 (7.5%)	113 (49.3% [42.9%; 55.8%])	116 (50.7% [44.2%; 57.1%])
RWAMAGANA	375 (12.3%)	253 (67.5% [62.7%; 72.2%])	122 (32.5% [27.8%; 37.3%])
Total	**3060 (100%)**	**1687 (55.1% [53.4%; 56.9%])**	**1373 (44.9% [43.1%; 46.6%])**

Table 3: Distribution of cases managed or referred in each district.

shortened time to results and reduced need for facility visits, making it especially valuable for patients in remote areas. While paper-based systems are also not network-dependent, CHWs appreciated d-IDS's offline functionality, allowing data entry in low-connectivity areas and automatic syncing once connected. The d-IDS also facilitated collaboration between CHWs and facility-based nurses, with 84.5% of CHWs reporting improved coordination. Furthermore, 98.0% felt the system boosted their self-confidence and strengthened

Districts	Patients screened by CHWs via d-IDS, n (%)	Diseases triggered d-IDS [95% Lower CI—Upper CI]	
	Malaria	**Managed Malaria**	**Referred Malaria**
GASABO	262 (35.6%)	162 (61.8% [55.9%–67.7%])	100 (38.2% [32.3%–44.1%])
KICUKIRO	166 (22.6%)	96 (57.8% [50.3%–65.3%])	70 (42.2% [34.7%–49.7%])
MUHANGA	168 (22.9%)	105 (62.5% [55.2%–69.8%])	63 (37.5% [30.2%–44.8%])
NYARUGENGE	65 (8.8%)	44 (67.7% [56.3%–79.1%])	21 (32.3% [20.9%–43.7%])
RWAMAGANA	74 (10.1%)	57 (77.0% [67.4%–86.6%])	17 (23.0% [13.4%–32.6%])
Total	735 (24.0%)	464 (63.1% [59.6%–66.6%])	271 (36.9% [33.4%–40.4%])
	Pneumonia	**Managed Pneumonia**	**Referred Pneumonia**
GASABO	57 (30.5%)	37 (64.9% [52.5%–77.3%])	20 (35.1% [22.7%–47.5%])
KICUKIRO	10 (5.3%)	8 (80.0% [55.2%–104.8%])	2 (20.0% [−4.8% to 44.8%])
MUHANGA	62 (33.2%)	40 (64.5% [52.6%–76.4%])	22 (35.5% [23.6%–47.4%])
NYARUGENGE	4 (2.1%)	0 (0.0% [0.0%–0.0%])	4 (100% [100%–100%])
RWAMAGANA	54 (28.9%)	39 (72.2% [60.3%–84.2%])	15 (27.8% [15.8%–39.7%])
Total	187 (6.1%)	124 (66.3% [59.5%–73.1%])	63 (33.7% [26.9%–40.5%])
	Tuberculosis	**Managed Tuberculosis**	**Referred Tuberculosis**
GASABO	154 (35.7%)	117 (76.0% [69.2%–82.7%])	37 (24.0% [17.3%–30.8%])
KICUKIRO	116 (26.9%)	83 (71.6% [63.3%–79.8%])	33 (28.4% [20.2%–36.7%])
MUHANGA	70 (16.2%)	52 (74.3% [64.0%–84.5%])	18 (25.7% [15.5%–36.0%])
NYARUGENGE	52 (12.1%)	35 (67.3% [54.6%–80.1%])	17 (32.7% [19.9%–45.4%])
RWAMAGANA	39 (9.0%)	31 (79.5% [66.8%–92.2%])	8 (20.5% [7.8%–33.2%])
Total	431 (14.1%)	318 (73.8% [69.6%–77.9%])	113 (26.2% [22.1%–30.4%])
	Diarrhoea	**Managed Diarrhoea**	**Referred Diarrhoea**
GASABO	41 (51.3%)	19 (46.3% [31.1%–61.6%])	22 (53.7% [38.4%–68.9%])
KICUKIRO	3 (3.8%)	1 (33.3% [−20.0%–86.7%])	2 (66.7% [13.3%–120%])
MUHANGA	17 (21.3%)	12 (70.6% [48.9%–92.2%])	5 (29.4% [7.8%–51.1%])
NYARUGENGE	9 (11.3%)	4 (44.4% [12.0%–76.9%])	5 (55.6% [23.1%–88.0%])
RWAMAGANA	10 (12.5%)	3 (30.0% [1.6%–58.4%])	7 (70.0% [41.6%–98.4%])
Total	80 (2.6%)	39 (48.8% [37.8%–59.7%])	41 (51.3% [40.3%–62.2%])
	General assessment	**Managed General assessment**	**Referred General assessment**
GASABO	756 (46.5%)	333 (44.0% [40.5%–47.6%])	423 (56.0% [52.4%–59.5%])
KICUKIRO	215 (13.2%)	83 (38.6% [32.1%–45.1%])	132 (61.4% [54.9%–67.9%])
MUHANGA	359 (22.1%)	173 (48.2% [43.0%–53.4%])	186 (51.8% [46.6%–57.0%])
NYARUGENGE	99 (6.1%)	30 (30.3% [21.3%–39.4%])	69 (69.7% [60.6%–78.7%])
RWAMAGANA	198 (12.2%)	123 (62.1% [55.4%–68.9%])	75 (37.9% [31.1%–44.6%])
Total	1627 (53.2%)	742 (45.6% [43.2%–48.0%])	885 (54.4% [52.0%–56.8%])
Total Screened	**3060 (100%)**	**1687 (55.1% [53.4%–56.9%])**	**1373 (44.9% [43.1%–46.6%])**

Table 4: Patients triggered the d-IDS who were managed at the community level or referred.

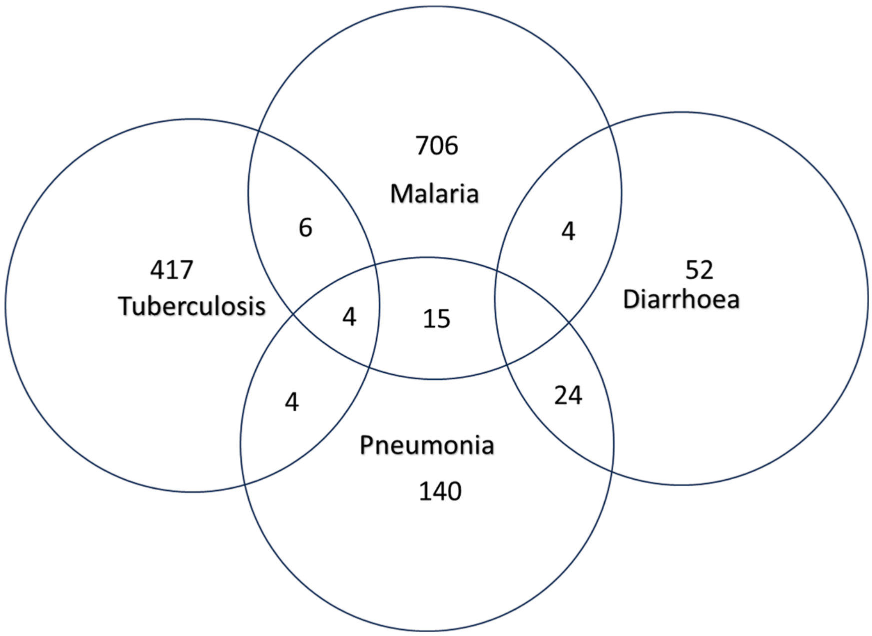

Fig. 6: Diseases combinations flagged by d-IDS. Numbers indicate participants with individual disease and co-infections.

community trust, attributing this to more accurate information, faster service delivery, and support for local languages—an element highlighted by 91.2% as improving communication and usability (Table 6).

d-IDS feasibility: learning curve, digital literacy, and system limitations

Despite the overwhelmingly positive reception, the implementation of d-IDS was not without challenges. Around 32.3% of CHWs reported that the system had rigid features or gaps that limited flexibility, and 23.5% specifically mentioned difficulty editing entries or accessing reports. These limitations were frustrating for many users, particularly when they made data entry mistakes. Although such restrictions aim to ensure data integrity, several CHWs suggested time-limited editing windows with change-tracking to allow corrections while maintaining accountability.

Connectivity issues were another major concern, with 34.7% of CHWs reporting internet access barriers that hindered certain system functions—such as household registration and updates—which require online access. Additionally, 46.0% found the system "sophisticated", especially during the early adoption phase. However, a readiness survey preceding d-IDS implementation showed that 25.3% CHWs could not

District	SOC-based (April–July 2023)		d-IDS-based (April–July 2024)		Percentage change[a]		p-value[b]
	Managed	Referred	Managed	Referred	Managed	Referred	
Gasabo	4948 (43.1% [42.2%; 44.0%])	6534 (56.9% [56.0%; 57.8%)	668 (52.6% [49.8%; 55.3%])	602 (47.4% [44.7%; 50.2%])	22.0% [18.0%–25.7%]	−16.7% [−21.4% to −13.1%]	<0.0001
Kicukiro	3761 (44.8% [43.7%; 45.8%])	4633 (55.2% [54.1%; 56.3%])	271 (53.1% [48.8%; 57.5%])	239 (46.9% [42.5%; 51.2%])	18.5% [11.7%–25.5%]	−15.0% [−21.4% to −9.1%]	0.0003
Muhanga	2626 (49.2% [47.9%; 50.6%)	2706 (50.8% [49.2%; 52.1%])	382 (56.5% [52.8%; 60.3%])	294 (43.5% [39.8%; 47.3%])	17.2% [10.2%–19.2%]	−14.4% [−19.1% to −9.2%]	0.0004
Nyarugenge	1174 (41.2% [39.4%; 43.0%])	1675 (58.8% [57.0%; 60.6%])	113 (49.3% [42.9%; 5.8%])	116 (50.7% [44.2%; 57.1%])	19.7% [8.9%–29.8%]	−13.8% [−22.5% to −5.8%]	<0.0001
Rwamagana	1052 (20.2% [19.1%; 21.3%])	4157 (79.8% [78.7%; 80.9%])	253 (67.5% [62.7%; 72.2%])	122 (32.5% [27.8%; 37.3%])	234.2% [228.3%–239.0%]	−59.3% [−64.7% to −53.9%]	<0.0001
Total	**13,561 (40.8% [40.2%; 41.3%])**	**19,705 (59.2% [58.7%; 59.8%])**	**1687 (55.1% [53.4%; 56.9%])**	**1373 (44.9% [43.1%; 46.6%])**	**35.0% [32.8%–37.8%]**	**−24.2% [−26.6% to −22.1%]**	**<0.0001**

[a]Percentage change between SOC and d-IDS referral rates [95% Lower CI—Upper CI]. [b]Chi-Square test p-value.

Table 5: **Effectiveness of the d-IDS based on comparison of retrospective manual-based versus prospective d-IDS-based patients' management.**

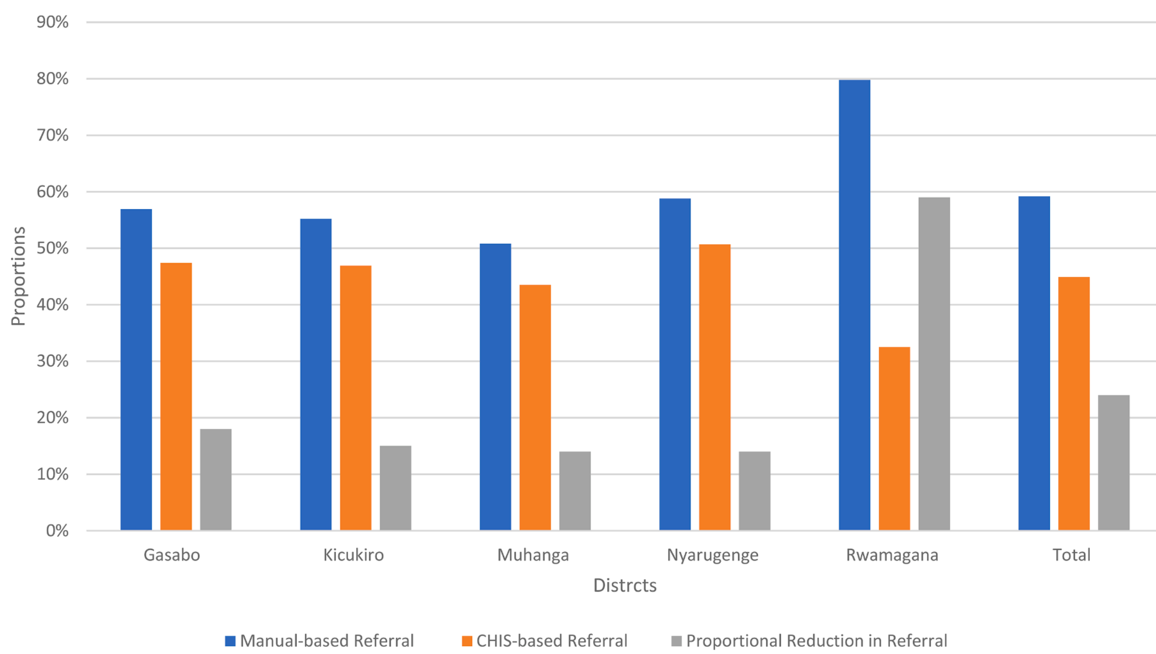

Fig. 7: Proportions of patients' referral by Community Health Workers to healthcare facilities when using paper-based and digitalised systems, and the proportional reduction in referral when digital system is used.

access mobile applications, 32.0% were unable to make a phone call on a smartphone, 74.8% did not know how to seek training on smartphone use, and 49.1% reported not using mobile internet. These findings point to a critical need for sustained digital literacy support, especially for new users, to ensure full adoption and effective system use (Table 6, Fig. 8).

Discussion

Our findings demonstrate a significant increase in patient management at community level during the d-IDS intervention period compared to the SOC phase. This shift was more pronounced in rural districts, suggesting that the d-IDS may help reduce urban-rural disparities in access to high quality of care and enhance

Assessment points among CHWs[a]	Agree	Neutral	Disagree
Acceptability: advantages (Electronic versus paper-based)			
Time saving	563 (93.8%)	14 (2.3%)	23 (3.8%)
Improved data accuracy	487 (81.2%)	96 (16.0%)	17 (2.8%)
Knowledge improvement and guidance of CHWs	534 (89.0%)	39 (6.5%)	27 (4.5%)
Patient convenience (shortened time to result/travel)	577 (96.2%)	19 (3.2%)	4 (0.7%)
Facilitated collaboration with nurses	507 (84.5%)	56 (9.3%)	37 (6.2%)
Boosted CHWs' self-confidence and community trust	588 (98.0%)	4 (0.7%)	8 (1.3%)
Local language in digital tool eases work	547 (91.2%)	32 (5.3%)	21 (3.5%)
Feasibility and challenges			
Digital system rigidity and feature gaps	194 (32.3%)	162 (27.0%)	244 (40.7%)
Editing issues and accessing reports	141 (23.5%)	103 (17.2%)	356 (59.3%)
Internet connectivity problems	208 (34.7%)	90 (15.0%)	302 (50.3%)
System perceived as "sophisticated"	276 (46.0%)	180 (30.0%)	144 (24.0%)
Sustainability and concerns			
Potential decrease in referral attendance	216 (36.0%)	210 (35.0%)	174 (29.0%)
Insufficient training of CHWs	384 (64.0%)	108 (18.0%)	108 (18.0%)
Expansion of system to more users (positive sentiment)	414 (69.0%)	114 (19.0%)	72 (12.0%)
Enhanced data capture and storage	486 (81.0%)	66 (11.0%)	48 (8.0%)

[a]Total CHWs assessed = 600 CHWs.

Table 6: **Qualitative assessment of the d-IDS and perceptions and opinions about the digital tool among CHWs.**

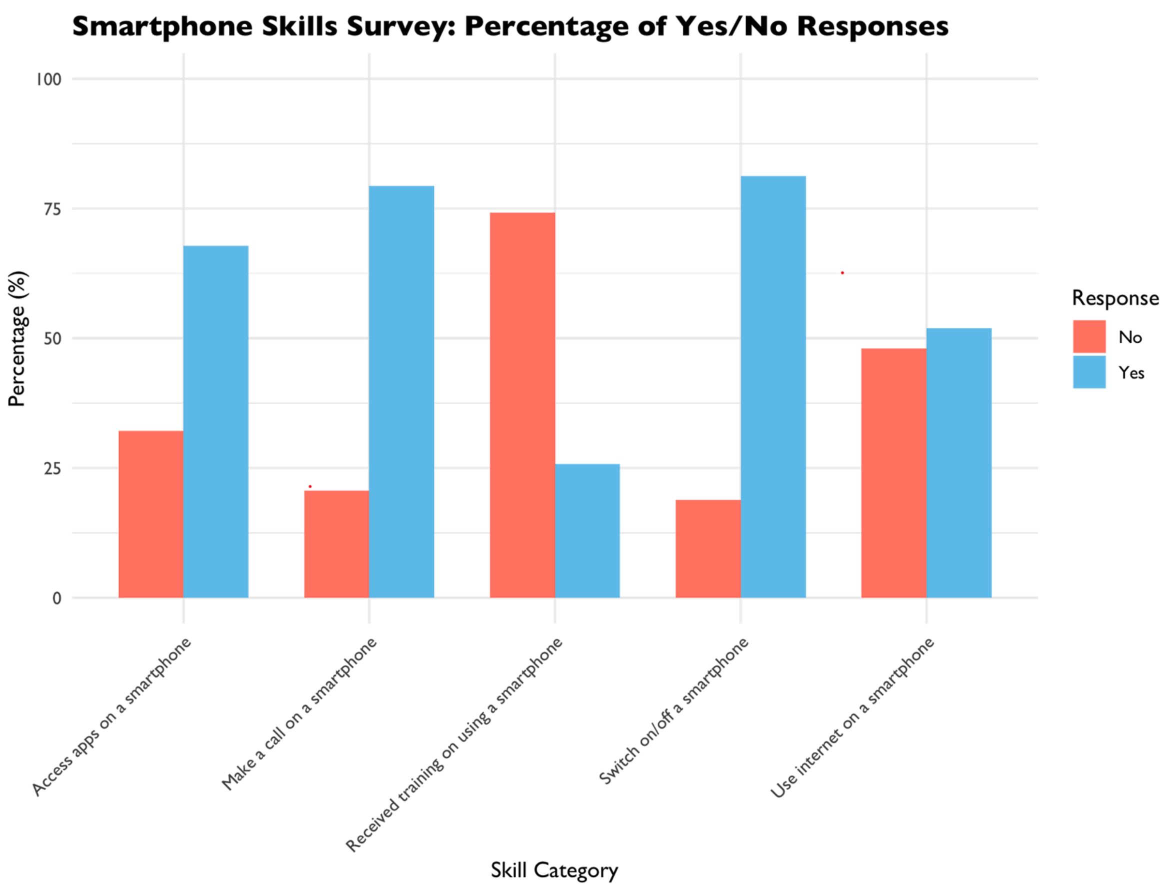

Fig. 8: Smartphone skills survey among the CHWs.

equity in service delivery. For instance, community-based management in Rwamagana increased threefold. Such improvements not only reduce barriers to accessing care—such as long travel distances—but also empower CHWs to manage more cases within their communities. Concurrently, a significant reduction in referrals to health facilities was observed across all study districts. Reducing unnecessary referrals helps decongest overburdened health centres, shortens patient waiting times, minimises out-of-pocket costs, and builds public trust in CHWs, especially when patients receive timely diagnosis and treatment locally. In low- and middle-income countries facing chronic shortages of healthcare workers, like Rwanda, enabling community-level management contributes to broader goals of health system resilience, cost savings, and early detection of infectious diseases—ultimately reducing morbidity, mortality, and nosocomial transmission.[18,19]

Importantly, d-IDS also strengthens clinical governance by ensuring national guidelines are embedded and followed during every screening. CHWs are guided through step-by-step decision trees with built-in warning flags that indicate when a referral is necessary. At the same time, the absence of warning signs provides assurance that a case can safely be managed at the community, reducing the pressure to refer patients simply due to diagnostic uncertainty or time constraints.[19,20] While fewer referrals could potentially raise concerns about missed severe cases, our study found no evidence of adverse outcomes among patients managed at the community level. The tool's capacity to screen for danger signs prior to integrated symptom screening provides a built-in safeguard against under-referral. This was also seen in other interventions such as ASyMSmeso which enabling smartphone-monitoring of symptoms and showed significant improvements in assessment and the referral of care.[21] However, ongoing monitoring remains essential to ensure that reduced referrals do not result in delayed care or worsened outcomes for patients who may deteriorate after initial contact. For instance, in Kenya, the use of mHealth tools at the household level enabled better identification of danger signs, though many CHWs still relied on their own judgement.[22,23] In contrast, the d-IDS algorithm minimises the risk of missed or inappropriate referrals by preventing symptom bypass and ensuring that clinical outcomes are systematically supported within the system. Nevertheless, Ongoing oversight is crucial to verify that the decline in referral rates does not inadvertently result in delayed treatment or adverse outcomes for individuals whose conditions may worsen after the initial screening. Maintaining this equilibrium between automated safety protocols and efficient case flow is key to ensuring that community-level care remains both responsive and high-performing.

The d-IDS system has been found offering several advantages over the traditional paper-based system (i.e., SOC). It allows CHWs to simultaneously screen for multiple diseases—malaria, TB, pneumonia, and diarrhoea—within a streamlined workflow. This improves diagnostic accuracy, supports comprehensive patient management, facilitates early triage between severe and non-severe cases, and enabling CHWs to contribute more effectively to disease surveillance and case detection efforts, by allowing them to manage mild and moderate cases independently while alerting for severe signs.[24] Furthermore, the integration of d-IDS within the cEMR system improves data visibility and storage, enabling clinicians at higher-level facilities to access patient records prior to referral. This reduces redundancy, improves continuity of care, and allows for better trend analysis and outbreak detection. For instance, the real-time data transmission capabilities could support early identification of potential outbreaks such as the Marburg virus disease recently reported in Rwanda on September 2024.[25] Early disease detection at the community level reduces the burden on higher-tier healthcare facilities, allowing for more efficient resource allocation and improved patient outcomes. The goal of achieving Universal Health Coverage (UHC) by 2030 requires robust primary healthcare systems, particularly in rural and underserved areas.[26] The d-IDS improves access to early disease detection and preventive care, reducing hospital congestion and healthcare costs such as Uganda's mTrac system, which uses SMS-based reporting for real-time disease tracking.[27]

The development and piloting of the d-IDS for CHWs in Rwanda represents a significant advancement in public health surveillance and disease management. This system aligns with global health priorities of leveraging digital health technologies to improve disease detection, response, and overall healthcare delivery in resource-limited settings.[26] Many African countries face similar healthcare challenges, including limited access to healthcare facilities, a high burden of communicable and non-communicable diseases, and an overreliance on paper-based health systems.[28–30] The cEMR, if successfully scaled, will improve healthcare delivery across multiple sectors, including maternal and child health, infectious disease surveillance, and chronic disease management. This intervention serves as a model for other African nations accelerating digital health transformation and improving healthcare outcomes.[8,31–33]

Despite these advantages, implementation challenges persist. CHWs reported increased workload due to system learning demands, indicating a need for more intuitive system interfaces. While editing restrictions are standard for data integrity, introducing a time-bound window for authorised edits with audit trails could offer a balanced solution. Some CHWs described the tool as "sophisticated," highlighting the importance of user-centred design. Also, digital literacy remains a key barrier, underscoring the need for continuous, locally adapted training and technical support. Small-group sessions, mentorship models, and cell-level digital support teams—such as those involving the Ministry of ICT—could promote sustained engagement and ownership. To support scale-up, the qualitative assessment emphasised the importance of decentralised, topic-specific and extensive training for CHWs. By strengthening local capacity and reducing reliance on external technical resources, Rwanda can build a more sustainable and responsive digital health infrastructure. Looking forward, further research should assess the long-term effects of d-IDS on patient health outcomes, health system costs, and user satisfaction. Understanding how digital tools influence clinical decision-making, especially in cases where referral is deferred, will be critical for validating their safety and effectiveness.

A key limitation of this study is the absence of follow-up data, making it difficult to assess the clinical outcomes of patients managed in the community during the d-IDS implementation. Although the tool includes built-in warning signs to guide referrals, the reduced referral rate cannot be conclusively interpreted as beneficial without knowing whether all necessary referrals were made. The pre-post design also introduces interpretive constraints: participating CHWs may not reflect the broader workforce, as they could be more motivated or digitally proficient, and early-phase implementation may have influenced referral behaviour. Additionally, comparisons with retrospective SOC data were limited by the manual system's lack of disaggregated CHW-level data and documented referral reasons, which precluded alignment of pre-intervention observations with CHWs participating in the d-IDS pilot. As small number of CHWs piloted the d-IDS, the number of patients screened in the intervention period was much lower than in the aggregated retrospective dataset. This imbalance between pre-intervention and intervention samples may introduce bias in estimated outcomes and therefore warrants cautious interpretation of the observed reduction in referrals. Further analyses will be required as a larger number of CHWs transition to the d-IDS platform.

In conclusion, this intervention provides a compelling model for leveraging digital health interventions to enhance disease surveillance and management at the community level. Scaling up such systems can contribute significantly to achieving health equity and strengthening health systems, if challenges related to infrastructure, digital literacy, and system flexibility are proactively addressed. Continued operational research and stakeholder engagement will be essential to refine these digital solutions and ensure their integration into the national health strategies.

Contributors

J.C.S.N, P.A., J.B.M, and R.K. conceptualised and designed the study. J.C.S.N., K.S., G.R., M.F.M., J.K., E.H. S.M., B.N., J.B.B., P.M., and M.W.G. participated in implementation and data collection. G.R., N.S.M., A.M., and J.C.S.N. analysed data. N.B. developed digital figures visualisation. J.C.S.N., K.S., A.A., and N.S.M. wrote the initial draft of the manuscript. E.E.S., S.U., E.R., S.G, J.B.M., B.N., R.M.M., R.T.L., A.T., A.A. V.F., S.M., P.A., R.K., and C.M.M. revised critically the manuscript. All authors contributed to the revision of the manuscript and approved the final version. J.C.S.N., G.R., A.M., and N.S.M. accessed and verified the underlying data.

Data sharing statement

All of the data generated or analysed during this study are included in this published article. The raw data supporting the findings in this study are also available from the corresponding author (jclaude.ngabonziza@rbc.gov.rw) upon request.

Declaration of interests

S.G. and R.T.L. declare consulting fees from the Gates Foundation. The authors declare no further competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ebiom.2026.106168.

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