

INTERVENTION STRATEGIES AND IMPLEMENTATION DETERMINANTS OF ROUTINE HEALTH DATA QUALITY IMPROVEMENT IN INFECTIOUS DISEASE PROGRAMS IN LOW AND MIDDLE-INCOME COUNTRIES: A SCOPING REVIEW

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ABSTRACT

Infectious disease surveillance, program monitoring, and policy decision-making in low- and middle-income countries (LMICs) require high-quality routine health data. Data quality gaps continue to undermine the utility of routine health information systems despite large investments. Many existing studies have assessed data quality outcomes independently, but very few have attempted to synthesize how and why intervention strategies and implementation determinants combine to affect sustainable improvements. This scoping review aimed to map intervention strategies designed to improve routine health data quality in infectious disease programs and to identify key implementation determinants shaping their effectiveness across LMIC health system contexts. A scoping review was conducted following PRISMA-ScR guidance. Peer-reviewed studies examining interventions targeting routine health data quality in LMICs were identified through systematic searches of PubMed, Scopus, and ScienceDirect. Eligible studies included quantitative, qualitative, mixed-methods, and program evaluation designs reporting at least one data quality dimension. Data were synthesized using narrative and thematic analysis to categorize intervention strategies and examine implementation determinants across health system levels. Twenty-four studies met the inclusion criteria. When the function was analyzed separately by dimension, intervention strategies were grouped into four categories as follows: (1) capacity strengthening; (2) design and implement a digital health system directly linked to the health sector capacity; (3) design and implement data validation and feedback mechanisms; develop governance-level reforms. The best evidence of improvement in completeness, accuracy, and timeliness came from interventions that combined digital technologies with workforce training and supervisor feedback. Effectiveness, however, was largely dictated by implementation determinants: organizational data-use culture, interoperability constraints, human resource stability, infrastructure readiness, and governance alignment. Fragmented systems and parallel reporting mechanisms frequently limited sustainability. Improving routine health data quality in LMIC infectious disease programs extends beyond technical system enhancements and requires alignment among technological, organizational, and behavioral determinants. By integrating intervention typologies with implementation determinants, this review provides a systems-oriented synthesis to inform context-responsive, sustainable strategies for strengthening data quality.

Keywords: data quality; digital health interventions; health information systems; low- and middle-income countries (LMICs); routine health data

INTRODUCTION

The functioning of the health system at the highest level usually depends on reliable, routine health data, particularly for infectious disease surveillance, program monitoring, and evidence-informed decision-making in low- and middle-income countries (LMICs) (Byrne & Heywood, 2023; Hung et al., 2020; Tilahun et al., 2021). Routine health information systems (RHIS) provide data on disease trends and service delivery, intervention coverage, and public health response at the facility (service availability), district (population need), and national level (Amouzou et al., 2021; Florentino et al., 2024). In low- and middle-income country (LMIC) contexts – where endemic patterns of burden related to infectious diseases continue to be an important cause of morbidity and mortality, accurate, complete & timely routine data are the bedrock for efficient resource allocation, adaptive policy, and health system responses (Tilahun et al., 2021).

Despite sustained investments to strengthen RHIS, routine health data in many LMICs remain affected by significant quality gaps (Adane, Adege, Ahmed, Anteneh, Ayalew, Berhanu, Berhanu, Getnet, et al., 2021; Amouzou et al., 2021; Chekol et al., 2023; Harrison et al., 2020). There are many common challenges, such as under-reporting, inaccurate reporting, late data submissions to systems, lack of uniformity across parallel data sources, and low utilization of data in decision-making processes (Adane, Adege, Ahmed, Anteneh, Ayalew, Berhanu, Berhanu, Getnet, et al., 2021; Chekol et al., 2023; Harrison et al., 2020). Importantly, these limitations are not just technical deficiencies but reflect major systemic constraints embedded in health systems. Increasingly, there is evidence of interdependent drivers: insufficient workforce capacity; poorly integrated digital systems and parallel paper-electronic reporting systems; poor supervision and feedback cycles; low levels of interoperability (not just software) and organizational cultures not sufficiently conducive to data use (Chekol et al., 2023; Harrison et al., 2020; Tolera et al., 2024). It suggests that more and better data do not necessarily lead to more effective use of data, emphasizing the behavioral, governance, and structural determinants of routine data quality outcomes (Amare et al., 2025; Lee et al., 2021; Lemma et al., 2020; Tilahun et al., 2021) instead.

In response, a host of interventions have been implemented over the past decade. EHRs (Lee et al., 2021; Lemma et al., 2020) represent a digital health approach to standardize reporting, while improving timeliness and integration; mobile reporting platforms for sub-national and national infectious disease surveillance have also been developed (Ahn et al., 2021; Ukponu et al., 2019). Meanwhile, non-digital approaches (Wong et al., 2020) (human-resource training, supportive supervision and feedback systems on data quality audits, governance reforms) have served to strengthen processes of data production that encourage a culture of use of data (Hanifah et al., 2022; Yilma et al., 2024; Deussom et al., 2022; Gimbel et al., 2017). In fact, data emerging since the completion of this work indicate that more systematic approaches to embedding technology alongside capacity strengthening and supervisory reinforcement could result in sustained improvements in completeness, accuracy, and timeliness (Kirk et al., 2021; Olu-Abiodun et al., 2025). Despite the managerial levers, implementation outcomes are heterogeneous across contexts; system functioning in practice depends on the readiness of infrastructure, stability of human resources, alignment between governance and health care operations, and engagement of users with systems (Karamagi et al., 2022; Kirk et al., 2021; J. Lee et al., 2021b).

Many studies have either evaluated data quality in general and individual interventions, but the evidence on how intervention strategies interact with broader implementation determinants across health system levels remains less coherent. Little is known about how specific technological,

organizational, and behavioral factors interactively influence the effectiveness and sustainability of routine data quality improvement efforts in low- and middle-income country (LMIC) infectious disease programs. Therefore, a systems-oriented synthesis is required to go beyond solitary technical solutions and promote integrated strategies that link intervention design with contextual implementation determinants.

This scoping review aimed to systematically map intervention strategies implemented to enhance routine health data quality in infectious disease programs in LMICs and to identify key implementation determinants that may affect their effectiveness. This review combines typologies of interventions with system-level determinants to advance from descriptive assessments to an analytical framework that can support sustainable, context-sensitive routine improvements in data quality.

Research Question

What intervention strategies have been implemented to improve routine health data quality in infectious disease programs in LMICs, and what implementation determinants influence their effectiveness?

METHOD

This scoping review was conducted in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews). A review protocol was developed prior to study commencement to guide methodological procedures; however, the protocol was not registered.

Eligibility Criteria

Studies were considered eligible if they met the following criteria:

1. **Population:** Studies examining routine health data used for infectious disease surveillance, monitoring, or reporting in low- and middle-income countries (LMICs), as defined by the World Bank classification. Both facility-based and community-based health system contexts were included.
2. **Interventions:** Articles describing, assessing or evaluating an intervention to improve routine health data quality. Eligible interventions included capacity-building initiatives, digital health innovations, data validation mechanisms, supervisory feedback systems, data quality audits, governance strengthening, and performance monitoring strategies. Interventions were classified as standalone when consisting of a single primary strategy, and as hybrid when combining two or more implementation components
3. **Outcomes:** Studies reporting at least one data quality dimension, including completeness, accuracy, timeliness, consistency, concordance, reliability, or data use for decision-making.
4. **Included study designs:** Empirical studies of any design, including randomized controlled trials, quasi-experimental studies, observational studies, qualitative research, mixed-methods studies and program evaluations.

Only articles published in English were included. No publication-year restrictions were applied during the search process to capture the evolution of interventions over time. However, all studies meeting the final inclusion criteria were published between 2015 and 2025.

Studies were excluded if they: focused exclusively on high-income countries, did not involve infectious disease routine data, did not assess interventions targeting data quality improvement, were editorials, commentaries, or opinion pieces without empirical data.

Information Sources and Search Strategy

A literature search was conducted using PubMed, Scopus, and ScienceDirect. A search strategy that included both Medical Subject Headings (MeSH) and free-text keywords pertaining to routine health information systems, infectious disease data quality, and real-time and recent interventions in LMIC contexts was constructed. Each database adapted Boolean operators. The complete search strategy is shown in Table 1.

Table 1.
Search String Strategy

Data Base	Search String
Scopus	((TITLE-ABS-KEY("routine health data" OR "routine data" OR "routine health information system*" OR "RHIS" OR "health management information system*" OR "HMIS" OR "surveillance data") AND TITLE-ABS-KEY("infectious disease*" OR "communicable disease*" OR "tuberculosis" OR "HIV" OR "malaria" OR "dengue" OR "measles" OR "COVID-19") AND TITLE-ABS-KEY(intervention* OR program* OR "capacity building" OR training OR "audit and feedback" OR "data quality assessment" OR mHealth OR eHealth OR "digital health" OR "information system" OR "data verification" OR "data validation") AND TITLE-ABS-KEY("data quality" OR "data accuracy" OR "data completeness" OR "timeliness" OR "data consistency" OR "data use" OR "data utilization") AND TITLE-ABS-KEY("low-income countr" OR "middle-income countr" OR "developing countr" OR Africa OR Asia OR "Sub-Saharan Africa" OR Indonesia OR India)) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (LANGUAGE,"English"))
Pupmed	((((((((((routine health data[Title/Abstract]) OR (routine data[Title/Abstract])) OR (routine health information system[Title/Abstract])) OR (RHIS[Title/Abstract])) OR (health management information system[Title/Abstract])) OR (HMIS[Title/Abstract])) OR (surveillance data[Title/Abstract])) AND (((((((infectious disease[Title/Abstract]) OR (communicable disease[Title/Abstract])) OR (tuberculosis[Title/Abstract])) OR (HIV[Title/Abstract])) OR (malaria[Title/Abstract])) OR (dengue[Title/Abstract])) OR (measles[Title/Abstract])) OR (COVID-19[Title/Abstract])))) AND (((((((((((intervention[Title/Abstract]) OR (program[Title/Abstract])) OR (capacity building[Title/Abstract])) OR (training[Title/Abstract])) OR (audit[Title/Abstract] AND feedback[Title/Abstract])) OR (data quality assessment[Title/Abstract])) OR (health[Title/Abstract])) OR (eHealth[Title/Abstract])) OR (digital health[Title/Abstract])) OR (information system[Title/Abstract])) OR (data verification[Title/Abstract])) OR (data validation[Title/Abstract])))) AND (((((((data quality[Title/Abstract]) OR (data accuracy[Title/Abstract])) OR (data completeness[Title/Abstract])) OR (timeliness[Title/Abstract])) OR (data consistency[Title/Abstract])) OR (data use[Title/Abstract])) OR (data utilization[Title/Abstract])))) AND (((((((low income country[Title/Abstract]) OR (middle income country[Title/Abstract])) OR (developing country[Title/Abstract])) OR (Africa[Title/Abstract])) OR (Asia[Title/Abstract])) OR (Sub-Saharan Africa[Title/Abstract])) OR (Indonesia[Title/Abstract])) OR (India[Title/Abstract]))))
Science Direct	"routine health data" AND "infectious disease" AND intervention AND "data quality"

Study Selection

All records were exported to Mendeley for reference management, and duplicates were removed before screening. The selection of studies was conducted in two steps:

1. Title and abstract screening

Two reviewers independently screened records against predefined eligibility criteria.

2. Full-text review

Potentially eligible studies were assessed independently by the same reviewers. Reasons for exclusion at this stage were documented systematically.

Disagreements were resolved through discussion and consensus. When necessary, a third reviewer adjudicated. Inter-rater reliability was assessed using Cohen's kappa coefficient. The study selection process is presented in a PRISMA-ScR flow diagram.

Data Extraction

A standardized data extraction form was developed in Microsoft Excel. Extracted variables included study characteristics (author, year, country, design, and setting), targeted infectious disease(s), type of intervention, intervention structure (standalone or hybrid), data quality dimensions addressed, reported outcomes, and implementation determinants (e.g., workforce capacity, infrastructure readiness, leadership support, and feedback mechanisms). Two reviewers extracted data in duplicate, with any discrepancies resolved through discussion and consensus.

Data Synthesis and Analysis

Data were synthesized using narrative descriptive analysis and thematic mapping. Findings were categorized by intervention type, intervention structure (standalone vs hybrid), data quality dimension, implementation determinants, and geographic and health system context. Given the heterogeneity of study designs and reported outcomes, meta-analysis was not performed. In line with scoping review methodology, a formal risk-of-bias assessment was not conducted.

Reporting the Results

Findings were reported in accordance with PRISMA-ScR guidance and presented in narrative and tabular formats. The synthesis mapped intervention characteristics, standalone versus hybrid structures, data quality dimensions addressed, geographical distribution, implementation determinants, and remaining evidence gaps relevant to strengthening routine health information systems in LMICs.

RESULT AND DISCUSSION

Study Selection

The literature search yielded 59 records across three electronic databases (PubMed = 28; Scopus = 27; ScienceDirect = 4). Following the removal of 11 duplicates, title and abstract screening identified 48 unique records. Seven records were excluded from the screening process, as shown in Figure 4. A total of 41 reports were identified for retrieval, of which 3 could not be retrieved. Thus, 38 full-text articles were screened for eligibility. After completing the full-text assessment, an additional 28 articles were excluded because they did not assess any interventions to improve data quality (n = 8), did not report relevant outcomes related to data quality (n = 3), or were unavailable in full text (n = 17). Finally, 10 studies passed the eligibility criteria and were selected for the final review. Study selection, screening, eligibility assessment, and inclusion processes were presented in the PRISMA flowchart in Figure 1.

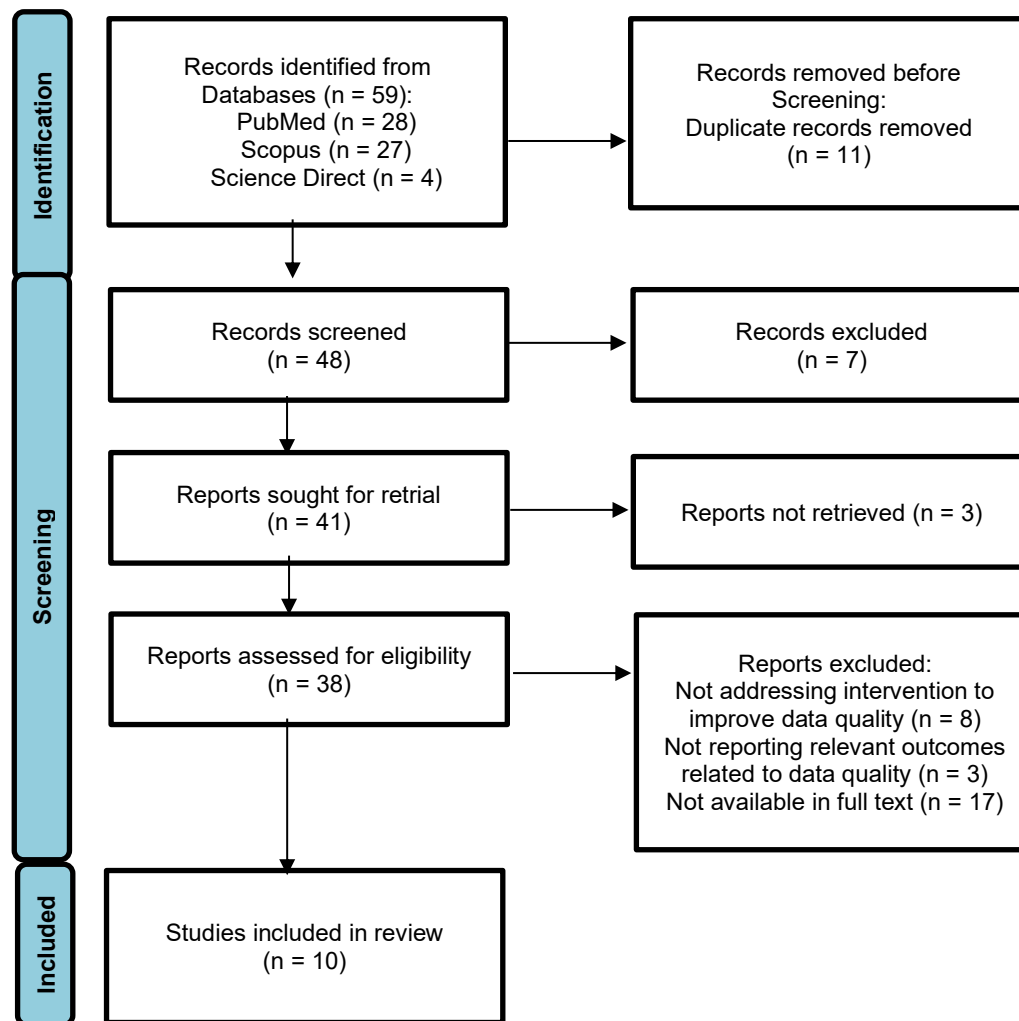


Figure 1: PRISMA Flowchart of The Study

In the end, 10 studies were included in the final synthesis following eligibility assessment. All selected articles were published between 2015 and 2025 and introduced active interventions aimed to enhance routine health data quality in the LMIC context. Geographically, the majority of studies were conducted in sub-Saharan Africa (n = 7, 70%), with some evidence from Latin America (11%) and multi-country LMIC settings (20%). In terms of disease focus, the most common program types targeted were HIV and tuberculosis, reflecting a vertical system that emphasizes randomized surveys of disease compared with target-oriented universal disease surveillance programs. Other studies focused on malaria surveillance and collective reporting of other communicable diseases through routine health information systems. Table 1 provides a detailed summary of study characteristics, interventions, methodological approaches, and key findings.

Table 1.
Summary of Active Interventions to Improve Routine Health Data Quality in LMICs

No	Author (Year)	Setting	Target Disease(s)	Study Design	Intervention Description	Data Quality Dimensions	Main Findings	Implementation Challenges
1.	Cherutich et al. (2016)	Kenya	HIV	Cluster randomized trial	Smartphone-based digital data collection (ODK)	Timeliness, completeness	Improved reporting speed and reduced data loss	Missing sensitive partner data
2.	O'Hagan et al. (2017)	Malawi	ANC, HIV, ARI	National cross-sectional assessment	Training, supervision, and structured data quality checks	Accuracy, completeness	Improved data reliability in priority indicators	Weak supervision structures
3.	Coelho et al. (2024)	Zambia	HIV	Qualitative implementation study	EMR strengthening with monitoring mechanisms	Accuracy, completeness, timeliness	Enhanced data monitoring and decision support	Weak longitudinal tracking systems
4.	Mukamba et al. (2020)	Rwanda	HIV	Cross-sectional study	Clinical alerts embedded in the EHR system	Completeness, accuracy, timeliness	Improved viral load documentation completeness	Low user adaptation
5.	Fraser et al. (2024)	Multi-country SSA	HIV	Program evaluation	Near point-of-care viral load reporting integration	Timeliness, documentation quality	Faster turnaround time	Weak documentation of follow-up
6.	Boeke et al. (2021)	South Africa	TB	System evaluation study	Electronic TB Register implementation	Completeness, accuracy, reliability	Improved electronic recording, but persistent gaps	Limited system integration
7.	Podewils et al., (2015)	Rwanda	Immunization	Cross-sectional study	DHIS2-based electronic tracking system	Accuracy, consistency, completeness	Progressive improvement in reporting completeness	Parallel paper systems
8.	Uwera et al. (2025)	Kenya	HIV	Retrospective system analysis	Kenya EMR implementation	Completeness, usability	Low utilization limited potential gains	Shared logins, poor adoption
9.	Ngugi et al. (2021)	Brazil	TB	Longitudinal analysis	Training and structured equity-focused reporting reforms	Completeness	Improved completeness of demographic data	Not reported
10.	Collins et al. (2020)	Guinea	Cholera, Measles, Yellow fever	Implementation study	DHIS2 implementation with training and technical support	Completeness, sensitivity	Strengthened reporting structure, but possible underreporting	Limited sensitivity, staff capacity constraints

Typology of Interventions

Ten studies were included and could be divided into the following four areas: (1) Digital health system strengthening (n=7), (2) Training and capacity building (n=3), (3) Supervision and monitoring mechanisms (n=3), (4) Strengthening of diagnostic-linked or laboratory systems (n=2) in labs. Digital health interventions were the most common tactics adopted. These were electronic

medical records (EMRs), District Health Information System version 2-based platforms, smartphone-based reporting tools, electronic disease registers, and embedded clinical decision-support alerts. Most of these were aimed at optimizing data capture, reducing reporting networks, and ensuring that internal routine reporting systems are internally consistent. Many studies employed multi-component approaches that combined strengthening digital systems with structured training, supervision, or validation processes by a field-based outreach team, consistent with a move away from the click-to-use paradigm of single-component implementation toward hybrid implementation models.

Training and capacity building on documentation improvement, indicator interpretation, and standards for reporting compliance. Supervision and monitoring systems were often included as key components of broader system-strengthening activities, helping to center accountability in reporting processes and performance tracking. Laboratory or diagnostic-linked interventions had positive effects on the flow of data between testing platforms and systems for reporting results, resulting in timely medical record documentation.

Data Quality Dimensions

The most common data quality dimension targeted in the included research was completeness (n=8), followed by accuracy (n=6), and timeliness (n=5). Few studies directly addressed consistency or concordance across reporting systems (n=4) and just a handful examined reliability or continued use of data to inform decisions (n=3). The most frequent improvements in completeness were related to the introduction of digital systems and to systematic supervision. The improvements in accuracy were associated with the validation features, automated alarms, and better documentation processes. Timeliness gains were noted mostly in interventions that used electronic reporting systems or diagnostic-linked reporting platforms.

Implementation Determinants

Across the 10 included studies, diverse contextual and system-level factors were identified as affecting the implementation and effectiveness of data quality improvement interventions. Capacity of the health workforce was proposed as a determinant in 6/10 studies (Health Workforce Capacity (n=6). The reasons reported were limited skills in data management, limited or no initial training, and high institutional-level turnover, which affected uptake of interventions and reporting. Infrastructure and readiness for technology were addressed in 5 out of the studies (n=5), especially for implementers of digital systems. The common challenges were internet connectivity issues, inconsistent electricity supply, and hardware unavailability. Three studies (n=3) explicitly described supportive leadership and governance in relation to sustained adherence; facility-level engagement and supervision at the district level were associated with ongoing compliance and monitoring mechanisms. Four studies (n=4) reported including feedback and accountability mechanisms, particularly in interventions with audit-review processes or structured supervisory feedback. All studies (n=8) reported at least one contextual determinant influencing implementation success, suggesting that outcomes were related to both system readiness and institutional support.

Standalone vs Hybrid Interventions

The 10 studies summarized were either standalone (single-component) or hybrid (multi-component) interventions.

Standalone Interventions

Three studies (n=3) delivered single-component interventions. The interventions included only one strategy, such as: (1) Only deployment of a digital reporting solution, (2) A training program delivered in a structured manner without reinforcement of the system, (3) A relative-focused audit undergoes an actual activity. In these studies, improvements in one or two dimensions of data quality were typically reported, mainly completeness and timeliness.

Hybrid Interventions

Seven studies (n=7) included hybrid interventions with two or more components. Common combinations included: (1) Digital systems and training, (2) Digital plus supportive supervision, (3) Audit-feedback aligned with capacity development. Of these seven hybrid studies, 5 reported improvements in three or more data quality dimensions (accuracy, consistency, and timely completion of data for decision-making) following the implementation of a national HIS. Hybrid interventions included more structured feedback mechanisms and ongoing reinforcement from a supervisor or manager. Conclusions Overall, most of the included studies (70%) used hybrid approaches, which were associated with greater multidimensional improvements in data quality than standalone strategies.

Geographical and Health System Contexts

Table 2.
Categorization of Included Studies by Intervention Type, Data Quality Dimensions, and Geographical Context

Category	Sub-category	Study Numbers
1. Types of Interventions	Digital health strengthening (EMR, DHIS2, electronic registers, mobile reporting, clinical alerts)	1, 3, 4, 6, 7, 8, 9
	Training/capacity building (Structured training and documentation improvement)	2, 3, 10
	Supervision/monitoring mechanisms (Supportive supervision, monitoring, performance tracking)	2, 3, 5
	Laboratory / diagnostic-linked strengthening (Near-POC systems, lab-reporting integration)	4, 5
2. Data Quality Dimensions Addressed	Completeness	1, 2, 3, 4, 6, 7, 8, 10
	Accuracy	2, 3, 4, 6, 7, 9
	Timeliness	1, 4, 5, 7, 8
	Consistency / Concordance	3, 4, 6, 9
	Data Use for Decision-Making	3, 7, 8
3. Implementation Determinants	Workforce capacity (training gaps, staff turnover, data management skills)	2, 5, 6, 8, 9, 10
	Infrastructure/technology readiness (connectivity, electricity, hardware constraints)	1, 6, 7, 8, 10
	Leadership/governance support (facility engagement, district oversight)	3, 4, 7
	Feedback/accountability mechanisms (audit systems, review meetings, supervisory feedback)	3, 4, 6, 9
4. Intervention Structure	Standalone (digital-only or training-only approach)	1, 5, 10
	Hybrid (combination of digital tools, training, supervision, and/or audit-feedback)	2, 3, 4, 6, 7, 8, 9
5. Geographical Contexts	Sub-Saharan Africa (single-country studies: Kenya, Malawi, Zambia, Rwanda, South Africa, Guinea)	1, 2, 3, 4, 6, 7, 8, 10
	Sub-Saharan Africa (multi-country initiatives: Cameroon, Democratic Republic of Congo, Kenya, Malawi, Senegal, Tanzania, Zimbabwe)	5
	Latin America (Brazil)	9

Regarding geographic distribution, most included interventions were conducted in sub-Saharan Africa (n=8). Of the included studies, one was conducted in Latin America (Brazil), and another used multi-country implementation in low- and middle-income settings. The majority of Sub-Saharan African settings face enduring structural and operational obstacles to routine health information systems, including parallel reporting systems, suboptimal interoperability, infrastructural instability, and human resource limitations. Common across settings, interventions were typically integrated into public-sector health systems and often delivered through vertically funded infectious disease programs (primarily HIV and tuberculosis). The majority of interventions targeted facility- and district-level reporting systems integrated into routine service delivery.

This scoping review synthesized evidence from 10 studies (2015–2025) that analyzed interventions to improve the quality of routine health data in low- and middle-income countries (LMICs). All of the 3 big themes can be summarised as follows: (1) digital system strengthening dominated, (2) hybrid approach vs standalone or face-to-face standalone strategies with success, and (3) context matters for implementation.

Digitalization as the Predominant but Insufficient Strategy

The most common intervention domain was digital health system strengthening (7 of 10 studies). These were electronic medical records (EMRs), District Health Information Software 2 (DHIS2)-based platforms, electronic disease registers, and mobile reporting applications. Digitalization was consistently associated with improvements in completeness (n = 8 studies overall) and timeliness (n = 5 studies), but with only moderate improvements in data accuracy across the 6 studies reporting on accuracy. Some of these studies questioned healthcare providers' ability to independently ensure continuous data quality improvement. Of the 7 digital-focused studies, 5 reported implementation barriers such as intermittent internet access, hardware unavailability and low user capacity. This study suggests that while digital transformation is crucial, it will not solve the systemic challenges faced by routine health information systems (RHIS) (Boeke et al., 2021; Cherutich et al., 2016; Coelho et al., 2024; Mukamba et al., 2020; Podewils et al., 2015). Therefore, digital solutions are mostly structural enablers but not end-to-end solutions.

Further, the results support that the main problem with RHIS in many LMICs is not just the lack of technology but also the absence of health system capacity to develop a sustainable data culture (Lee et al., 2023; Lemma et al., 2020). Digitalization without changes in governance, user behavior, and institutional commitment risks creating “data-rich but information-poor systems” that generate vast volumes of data but fail to convert them into high-quality, useful information for decision-making (Bezerra et al., 2020). Therefore, digital transformation should be presented as an element of a systemic approach to improve the quality of healthcare services through the use of accurate, timely, and responsive data (Werner et al., 2023).

Hybrid Approaches Demonstrated Broader Impact

One of the main findings was that multi-component interventions accounted for 70% (n = 7) of the included studies and were more likely to result in improvements across multiple data quality dimensions (Boeke et al., 2021; Cherutich et al., 2016; Coelho et al., 2024; Mukamba et al., 2020; Ngugi et al., 2021; Podewils et al., 2015; Uwera et al., 2025). Hybrid interventions generally integrated a digital system with training (n=3) (Coelho et al., 2024; Collins et al., 2020; O'Hagan et al., 2017), supportive supervision (n=3) (Coelho et al., 2024; Fraser et al., 2024; O'Hagan et al., 2017), or an audit-feedback mechanism (n=2) (Fraser et al., 2024; Mukamba et al., 2020). With

respect to the seven hybrid studies, five reported having improved three or more data quality dimensions in terms of accuracy, consistency, and data use for decision-making. By contrast, the three standalone interventions ($n = 3$) typically improved only one or two dimensions, usually completeness and timeliness (Coelho et al., 2024; Collins et al., 2020; O'Hagan et al., 2017). This pattern suggests that addressing technical (system design)/behavioral determinants (health worker practices, accountability, supervision) is associated with more substantial improvements. These findings are consistent with an implementation science perspective that jointly recognizes the imperative of multi-level system reinforcement and avoids solely technical inputs.

The results of this review support the assertion that investments to improve RHIS data quality need not be limited to a technologically driven approach, and such measures should take into consideration health information management processes and organizational culture. Multi-component interventions seem to synergize by holistically improving technical infrastructure, user competencies, supervision processes, and accountability mechanisms, which, in turn, support sustained process improvement across multiple dimensions of data quality (Lee et al., 2021a; Leon et al., 2020). This must also be expected given the multidimensional nature of data quality challenges in LMIC settings; as such, single-focus strategies alone are unlikely to be successful. Thus, future RHIS strengthening should focus on integrated intervention models that combine digital innovation with ongoing capacity development, supportive leadership, and institutionalized feedback mechanisms to promote a long-term data use culture and system sustainability (Lee et al., 2021a; Leon et al., 2020).

Persistent Emphasis on Technical Data Quality Dimensions

Across the ten studies, completeness ($n = 8$) (Boeke et al., 2021; Cherutich et al., 2016; Coelho et al., 2024; Collins et al., 2020; Mukamba et al., 2020; O'Hagan et al., 2017; Podewils et al., 2015; Uwera et al., 2025), followed by accuracy ($n = 6$) (Boeke et al., 2021; Coelho et al., 2024; Mukamba et al., 2020; Ngugi et al., 2021; O'Hagan et al., 2017; Podewils et al., 2015) and timeliness ($n = 5$) (Cherutich et al., 2016; Fraser et al., 2024; Mukamba et al., 2020; Podewils et al., 2015; Uwera et al., 2025) were the most commonly evaluated dimensions. In contrast, only four studies assessed consistency across platforms ($n = 4$) (Boeke et al., 2021; Coelho et al., 2024; Mukamba et al., 2020; Ngugi et al., 2021), and only three studies evaluated reliability or sustained data use for decision-making ($n = 3$) (Coelho et al., 2024; Podewils et al., 2015; Uwera et al., 2025). This imbalance indicates the persistent nature of interventions that focus on compliance rather than on facilitating common data-use routines. Reporting metrics benefit from improvements in completeness and timeliness, but the move from “data reporting” to “data-informed decision-making” is incomplete, with just a limited assessment of dependability and usage.

These data highlight a significant gap between data production and its meaningful use in health systems. The fact that most RHIS interventions are still focused on producing indicators of completeness and timeliness, rather than on fostering a culture of analytical use of data for evidence-based decision-making, suggests continued concerns that individuals running the RHIS are focused only on meeting reporting requirements and administrative performance goals (Adane, Adege, Ahmed, Anteneh, Ayalew, Berhanu, Berhanu, Getnet, et al., 2021; Hoxha et al., 2020; Leon et al., 2020). Consequently, health systems may increase their rates of diagnostic and therapeutic reporting without necessarily increasing the reliability, interoperability, utility, or usability of the information produced (Kawakyu et al., 2023). This imbalance highlights the necessity of future interventions that go beyond traditional reporting metrics and prioritize data interpretation,

harmonization across platforms, and institutional mechanisms to promote the regular use of data for planning, monitoring, and policymaking (Adane et al., 2021; Maïga et al., 2019).

Contextual Determinants Shaping Implementation Outcomes

Ten studies (n = 10) reported at least one contextual determinant impacting implementation effectiveness, eight of which (n = 8) were explicitly stated in the study. We found workforce capacity constraints in six studies (n = 6) (Boeke et al., 2021; Collins et al., 2020; Fraser et al., 2024; Ngugi et al., 2021; O'Hagan et al., 2017; Uwera et al., 2025), infrastructure readiness challenges in five (n = 5) (Boeke et al., 2021; Cherutich et al., 2016; Collins et al., 2020; Podewils et al., 2015; Uwera et al., 2025), leadership and governance support and feedback/accountability mechanisms in three (n = 3) (Coelho et al., 2024; Mukamba et al., 2020; Podewils et al., 2015), and two studies (n = 4) (Boeke et al., 2021; Coelho et al., 2024; Mukamba et al., 2020; Ngugi et al., 2021) each. These results show that the intervention's success depended heavily on system readiness and institutional support. Even well-designed digital platforms faltered when introduced into environments with minimal training, poor supervision, or limited infrastructure. Few studies, if any, reflected some of the more persistent structural challenges in RHIS—such as parallel reporting systems, limited interoperability, and resource constraints—as evidenced by the predominance (n = 8) of studies carried out in Sub-Saharan Africa. This focus illustrates the critical needs in LMIC settings, but highlights our relatively sparse comparative evidence from other contexts.

These results highlight the extent to which RHIS interventions are shaped by the health system context in which they are implemented. The recurring themes of workforce limitations, poor infrastructure, and inadequate support from governance indicate that data quality enhancement is not only a technical issue but also an institutional or systemic one. Digital innovations are introduced into fragile health systems in many LMICs, with fragmented reporting structures, high human resource workload, and limited financial and technical resources, which significantly limit the sustainability of interventions at scale (Kaboré et al., 2022; Yew et al., 2025). The concentration of evidence from Sub-Saharan Africa also reflects the need and potential to strengthen RHIS in this context, as well as a lack of comparative evidence in resource-limited countries outside Sub-Saharan Africa (Fraser et al., 2024). Thus, for sustainable improvements in data quality and use, future RHIS strategies should consider how best to take a systems approach that integrates technological capacity with institutional governance, interoperability, and long-term workforce development (Leon et al., 2020).

Implications for Health System Strengthening

Performing well in the revised HSPK means, at best, that integrated system-level pathways for improving health data quality must be identified. Structural investments in digital infrastructure should be supported by structured training, supervision, and governance reinforcement. Standalone interventions are more likely to deliver multidimensional and sustained improvement when integrated into hybrid implementation models. Efforts to strengthen data quality should also focus not just on meeting reporting requirements, but also on institutionalizing the regular use of data for decision-making at the facility and district levels.

Limitations

Several limitations should be considered. First, 10 studies met our inclusion criteria, limiting the diversity of the evidence synthesis. Second, between-studies comparability was limited by heterogeneity in study design, outcome definitions, and approaches to data quality measurement. Third, numerous interventions were tested only in local settings or facility-based systems rather than in national systems, potentially reducing the generalizability of the results. The short evaluation periods in many studies prevented extrapolation to long-term sustainability. Importantly, reliance on conventional data sources, which are often subject to reporting bias (e.g., missing requirements), might yield incorrect or biased impact estimates.

Firstly, this study was a scoping review; therefore, it did not conduct a formal quality appraisal or meta-analysis, so pooled effect sizes could not be quantified. Longitudinal multisite evaluations, coupled with standardized data-quality measurement frameworks, will be necessary to assess the longer-term sustainability, scalability, and cost-effectiveness of hybrid models for improving data quality in clinical settings.

CONCLUSION

This scoping review provides evidence that interventions can improve routine health data quality, including completeness, accuracy, timeliness, and usability, through training, digital health tools, supervisor feedback systems, and methodological frameworks across infectious disease programs and health system contexts. Digital tools – like DHIS2, electronic health records, or point-of-care reporting systems are found to have particular potential in creating robust mechanisms for data reporting and use; however, their strength is conditional on the existence of adequate infrastructure, human resources for implementation, and continued supervisory support. Notably, there are still challenges, including underreporting, inconsistencies between paper-based and electronic records, and limited incorporation of private-sector and subnational data sources. Key areas for future work include an emphasis on scalable, context-specific interventions, improved standardization of data quality metrics, and fostering a culture of data use at facility and system levels to ensure that routine health information systems adequately support program planning, monitoring processes, and equitable health outcomes.

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REFERENCES

- Adane, A., Adege, T., Ahmed, M., Anteneh, H., Ayalew, E., Berhanu, D., Berhanu, N., Beyene, M., Bhattacharya, A., Bishaw, T., Cherinet, E., Dereje, M., Desta, T., Dibabe, A., Firew, H., Gebrehiwot, F., Gebreyohannes, E., Gella, Z., Girma, A., ... Janson, A. (2021). Routine health management information system data in Ethiopia: consistency, trends, and challenges. *Global Health Action*, 14. <https://doi.org/10.1080/16549716.2020.1868961>
- Adane, A., Adege, T., Ahmed, M., Anteneh, H., Ayalew, E., Berhanu, D., Berhanu, N., Getnet, M., Bishaw, T., Busza, J., Cherinet, E., Dereje, M., Desta, T., Dibabe, A., Firew, H., Gebrehiwot, F., Gebreyohannes, E., Gella, Z., Girma, A., ... Lemma, S. (2021). Exploring data quality and use of the routine health information system in Ethiopia: a mixed-methods study. *BMJ Open*, 11. <https://doi.org/10.1136/bmjopen-2021-050356>
- Ahn, E., Liu, N., Parekh, T., Patel, R., Baldacchino, T., Mullavey, T., Robinson, A., & Kim, J. (2021). A Mobile App and Dashboard for Early Detection of Infectious Disease Outbreaks: Development Study. *JMIR Public Health and Surveillance*, 7. <https://doi.org/10.2196/14837>
- Amouzou, A., Faye, C., Wyss, K., & Boerma, T. (2021). Strengthening routine health information systems for analysis and data use: a tipping point. *BMC Health Services Research*, 21. <https://doi.org/10.1186/s12913-021-06648-1>
- Bezerra, A., Greati, V., Campos, V., Silva, I., Guedes, L., Leitao, G., & Silva, D. (2020). Enabling Interactive Visualizations in Industrial Big Data. *IFAC-PapersOnLine*. <https://doi.org/10.1016/j.ifacol.2020.12.292>
- Boeke, C. E., Joseph, J., Atem, C., Banda, C., Coulibaly, K. D., Doi, N., Gunda, A., Kandulu, J., Kiernan, B., & King'wara, L. (2021). Evaluation of near point-of-care viral load implementation in public health facilities across seven countries in sub-Saharan Africa. *Journal of the International AIDS Society*, 24(1). <https://doi.org/10.1002/jia2.25663>
- Byrne, E., & Heywood, A. (2023). Use of routine health information systems data in developing and monitoring district and facility health plans: a scoping review. *BMC Health Services Research*, 23. <https://doi.org/10.1186/s12913-023-09914-6>
- Chekol, A., Ketemaw, A., Endale, A., Aschale, A., Endalew, B., & Asemahagn, M. (2023). Data quality and associated factors of routine health information system among health centers of West Gojjam Zone, northwest Ethiopia, 2021. *Frontiers in Health Services*, 3. <https://doi.org/10.3389/frhs.2023.1059611>
- Cherutich, P., Golden, M., Betz, B., Wamuti, B., Ng'Ang'A, A., Maingi, P., MacHaria, P., Sambai, B., Abuna, F., & Bukusi, D. (2016). Surveillance of HIV assisted partner services using routine health information systems in Kenya. *BMC Medical Informatics and Decision Making*, 16(1). <https://doi.org/10.1186/s12911-016-0337-9>
- Coelho, R., Rocha, R., & Hone, T. (2024). Improvements in data completeness in health information systems reveal racial inequalities: longitudinal national data from hospital admissions in Brazil 2010-2022. *International Journal for Equity in Health*, 23(1), 143. <https://doi.org/10.1186/s12939-024-02214-3>
- Collins, D., Rhea, S., Diallo, B. I., Bah, M. B., Yattara, F., Keleba, R. G., & MacDonald, P. D. M. (2020). Surveillance system assessment in Guinea: Training needed to strengthen data quality and analysis, 2016. *PLOS ONE*, 15(6). <https://doi.org/10.1371/journal.pone.0234796>
- Deussom, R., Mwarey, D., Bayu, M., Abdullah, S., & Marcus, R. (2022). Systematic review of performance-enhancing health worker supervision approaches in low- and middle-income countries. *Human Resources for Health*, 20. <https://doi.org/10.1186/s12960-021-00692-y>
- Florentino, P., Bertoldo, J., Barbosa, G. C. G., Cerqueira-Silva, T., Oliveira, V., De Oliveira Garcia, M. H., Penna, G., Boaventura, V., Ramos, P., Barral-Netto, M., & Marcilio, I. (2024). Impact

- of Primary Health Care Data Quality on Infectious Disease Surveillance in Brazil: Case Study. *JMIR Public Health and Surveillance*, 11. <https://doi.org/10.2196/67050>
- Fraser, H. S. F., Mugisha, M., Bacher, I., Ngenzi, J. L., Seebregts, C., Umubyeyi, A., & Condo, J. (2024). Factors Influencing Data Quality in Electronic Health Record Systems in 50 Health Facilities in Rwanda and the Role of Clinical Alerts: Cross-Sectional Observational Study. *JMIR Public Health and Surveillance*, 10, e49127. <https://doi.org/10.2196/49127>
- Gimbel, S., Mwanza, M., Nisingizwe, M., Michel, C., Hirschhorn, L., Hingora, A., Mboya, D., Exavery, A., Tani, K., Manzi, F., Pemba, S., Phillips, J., Kante, A., Ramsey, K., Baynes, C., Awoonor-Williams, J., Bawah, A., Nimako, B., Kanlisi, N., ... Pio, A. (2017). Improving data quality across 3 sub-Saharan African countries using the Consolidated Framework for Implementation Research (CFIR): results from the African Health Initiative. *BMC Health Services Research*, 17. <https://doi.org/10.1186/s12913-017-2660-y>
- Hanifah, N., Sanjaya, G. Y., Nuryati, N., Chrysantina, A., Saputro, N. T., & Mardiansyah, M. (2022). Using District Health Information System (DHIS2) for Health Data Integration in Special Region of Yogyakarta. *Jurnal Pengabdian Kepada Masyarakat (Indonesian Journal of Community Engagement)*. <https://doi.org/10.22146/jpkkm.40379>
- Harrison, K., Rahimi, N., & Danivaro-Holliday, C. (2020). Factors limiting data quality in the expanded programme on immunization in low and middle-income countries: A scoping review. *Vaccine*. <https://doi.org/10.1016/j.vaccine.2020.02.091>
- Hoxha, K., Hung, Y., Irwin, B., & Grépin, K. (2020). Understanding the challenges associated with the use of data from routine health information systems in low- and middle-income countries: A systematic review. *Health Information Management Journal*, 51, 135–148. <https://doi.org/10.1177/1833358320928729>
- Hung, Y., Hoxha, K., Irwin, B., Law, M., & Grépin, K. (2020). Using routine health information data for research in low- and middle-income countries: a systematic review. *BMC Health Services Research*, 20. <https://doi.org/10.1186/s12913-020-05660-1>
- Kaboré, S. S., Ngangue, P., Soubeiga, D., Barro, A., Pilabré, A. H., Bationo, N., Pafadnam, Y., Drabo, K., Hien, H., & Savadogo, G. (2022). Barriers and facilitators for the sustainability of digital health interventions in low and middle-income countries: A systematic review. *Frontiers in Digital Health*, 4. <https://doi.org/10.3389/fdgth.2022.1014375>
- Karamagi, H., Muneene, D., Droti, B., Jepchumba, V., Okeibunor, J., Nabyonga, J., Asamani, J., Traore, M., & Kipruto, H. (2022). eHealth or e-Chaos: The use of Digital Health Interventions for Health Systems Strengthening in sub-Saharan Africa over the last 10 years: A scoping review. *Journal of Global Health*, 12. <https://doi.org/10.7189/jogh.12.04090>
- Kawakyu, N., Coe, M., Wagenaar, B., Sherr, K., & Gimbel, S. (2023). Refining the Performance of Routine Information System Management (PRISM) framework for data use at the local level: An integrative review. *PLOS ONE*, 18. <https://doi.org/10.1371/journal.pone.0287635>
- Kirk, K., McClair, T., Dakouo, S., Abuya, T., & Sripad, P. (2021). Introduction of digital reporting platform to integrate community-level data into health information systems is feasible and acceptable among various community health stakeholders: A mixed-methods pilot study in Mopti, Mali. *Journal of Global Health*, 11. <https://doi.org/10.7189/jogh.11.07003>
- Lee, J., Lynch, C. A., Hashiguchi, L. O., Snow, R. W., Herz, N. D., Webster, J., Parkhurst, J., & Erundu, N. A. (2021a). Interventions to improve district-level routine health data in low-income and middle-income countries: A systematic review. *BMJ Global Health*, 6(6). <https://doi.org/10.1136/bmjgh-2020-004223>
- Lee, J., Lynch, C., Hashiguchi, L., Snow, R., Herz, N., Webster, J., Parkhurst, J., & Erundu, N. (2021b). Interventions to improve district-level routine health data in low-income and middle-

- income countries: a systematic review. *BMJ Global Health*, 6. <https://doi.org/10.1136/bmjgh-2020-004223>
- Lee, N., Singini, D., Janes, C., Grépin, K., & Liu, J. (2023). Identifying barriers to the production and use of routine health information in Western Province, Zambia. *Health Policy and Planning*, 38, 996–1005. <https://doi.org/10.1093/heapol/czad077>
- Lemma, S., Janson, A., Persson, L. Å., Wickremasinhe, D., & Källestål, C. (2020). Improving quality and use of routine health information system data in low- And middle-income countries: A scoping review. *PLoS ONE*, 15(10 October), 1–16. <https://doi.org/10.1371/journal.pone.0239683>
- Lemma, S., Janson, A., Persson, L., Wickremasinghe, D., & Källestål, C. (2020). Improving quality and use of routine health information system data in low- and middle-income countries: A scoping review. *PLoS ONE*, 15. <https://doi.org/10.1371/journal.pone.0239683>
- Leon, N., Balakrishna, Y., Hohlfeld, A., Odendaal, W. A., Schmidt, B.-M., Zweigenthal, V., Anstey Watkins, J., & Daniels, K. (2020). Routine Health Information System (RHIS) improvements for strengthened health system management. *Cochrane Database of Systematic Reviews*, 2020(8). <https://doi.org/10.1002/14651858.CD012012.pub2>
- Maïga, A., Jiwani, S., Mutua, M., Porth, T., Taylor, C., Asiki, G., Melesse, D., Day, C., Strong, K., Faye, C., O'Neill, K., Amouzou, A., Pond, B., & Boerma, T. (2019). Generating statistics from health facility data: the state of routine health information systems in Eastern and Southern Africa. *BMJ Global Health*, 4. <https://doi.org/10.1136/bmjgh-2019-001849>
- Mukamba, N., Beres, L. K., Mwamba, C., Law, J. W., Topp, S. M., Simbeza, S., Sikombe, K., Padian, N., Holmes, C. B., & Geng, E. H. (2020). How might improved estimates of HIV programme outcomes influence practice? A formative study of evidence, dissemination and response. *Health Research Policy and Systems*, 18(1). <https://doi.org/10.1186/s12961-020-00640-7>
- Ngugi, P., Babic, A., & Were, M. C. (2021). A multivariate statistical evaluation of actual use of electronic health record systems implementations in Kenya. *PLoS ONE*, 16(9 September), 1–14. <https://doi.org/10.1371/journal.pone.0256799>
- O'Hagan, R., Marx, M. A., Finnegan, K. E., Naphini, P., Ng'ambi, K., Laija, K., Wilson, E., Park, L., Wachepa, S., Smith, J., Gombwa, L., Misomali, A., Mleme, T., & Yosefe, S. (2017). National assessment of data quality and associated systems-level factors in Malawi. *Global Health Science and Practice*, 5(3), 367–381. <https://doi.org/10.9745/GHSP-D-17-00177>
- Olu-Abiodun, O., Faturoti, A., Adepoju, A., Adeloye, D., Adebisi, A., & Abiodun, O. (2025). Effectiveness and challenges of digital tools implementation for enhancing infectious disease surveillance data quality in low- and middle-income countries: A systematic review protocol. *PLOS One*, 20. <https://doi.org/10.1371/journal.pone.0330904>
- Podewils, L. J., Bantubani, N., Bristow, C., Bronner, L. E., Peters, A., Pym, A., & Mametja, L. D. (2015). Completeness and Reliability of the Republic of South Africa National Tuberculosis (TB) Surveillance System. *BMC Public Health*, 15(1). <https://doi.org/10.1186/s12889-015-2117-3>
- Tilahun, B., Teklu, A., Mancuso, A., Endehabtu, B., Gashu, K., & Mekonnen, Z. (2021). Using health data for decision-making at each level of the health system to achieve universal health coverage in Ethiopia: the case of an immunization programme in a low-resource setting. *Health Research Policy and Systems*, 19. <https://doi.org/10.1186/s12961-021-00694-1>
- Tolera, A., Firdisa, D., Roba, H., Motuma, A., Kitesa, M., & Abaerei, A. A. (2024). Barriers to healthcare data quality and recommendations in public health facilities in Dire Dawa city administration, eastern Ethiopia: a qualitative study. *Frontiers in Digital Health*, 6.

- <https://doi.org/10.3389/fdgth.2024.1261031>
- Ukponu, W., Shallangwa, J., Adamu, H., Mohammed, A., Ihueze, A., Ibrahim, R., Olawepo, O., Yashe, R., Njoku, K., Niyang, M., & Gobir, B. (2019). Outcomes of Mobile Reporting to Enhance Disease Surveillance in 632 Districts of 29 States in Nigeria. *Iproceedings*. <https://doi.org/10.2196/15237>
- Uwera, T., Frøen, J. F., Papadopoulou, E., Rukundo, E., Sibomana, H., Muhire, A., Tumusiime, D. K., & Venkateswaran, M. (2025). Child immunization data quality in Rwanda: an assessment of routine health information system data. *Archives of Public Health = Archives Belges de Sante Publique*, 83(1), 97. <https://doi.org/10.1186/s13690-025-01583-7>
- Werner, L., Puta, C., Chilalika, T., Hyde, S. W., Cooper, H., Goertz, H., Hildebrand, M. R., Bernadotte, C., & Kapnick, V. (2023). How digital transformation can accelerate data use in health systems. *Frontiers in Public Health*, 11. <https://doi.org/10.3389/fpubh.2023.1106548>
- Wong, J., Dang, L., Phan, N., Le, T., Vu, N., Vu, T., James, S., Katona, P., Katona, L., Rosen, J., Wong, F., & Nguyen, C. (2020). Effectiveness of an Automated Error Checking and Feedback System to Improve Text Message Reporting for Disease Surveillance in Viet Nam. *Telemedicine and E-Health*, 27, 448–453. <https://doi.org/10.1089/tmj.2020.0065>
- Yew, S., Trivedi, D., Adanan, N. I. H., & Chew, B.-H. (2025). Facilitators and Barriers to the Implementation of Digital Health Technologies in Hospital Settings in Lower- and Middle-Income Countries Since the Onset of the COVID-19 Pandemic: Scoping Review. *Journal of Medical Internet Research*, 27. <https://doi.org/10.2196/63482>
- Yilma, T., Taddese, A., Mamuye, A., Endehabtu, B., Alemayehu, Y., Senay, A., Daka, D., Abraham, L., Tadesse, R., Melkamu, G., Wendrad, N., Kaba, O., Mohammed, M., Denboba, W., Birhan, D., Biru, A., & Tilahun, B. (2024). Maturity Assessment of District Health Information System Version 2 Implementation in Ethiopia: Current Status and Improvement Pathways. *JMIR Medical Informatics*, 12. <https://doi.org/10.2196/50375>

