

Supplementary Appendix

Table A1. Summary of Database Search

Database	Date of Search	Search strings	Result
PubMed	Initial search – May 15, 2026. Updated search - May 27, 2026.	("disease surveillance"[MeSH] OR "public health surveillance"[MeSH] OR "digital health"[MeSH] OR "digital surveillance" OR "electronic surveillance" OR "mHealth"[MeSH] OR "mobile health" OR "DHIS2") AND ("emerging infectious diseases"[MeSH] OR "communicable diseases"[MeSH] OR "infectious disease*" OR "outbreak*" OR "epidemic*") AND ("developing countries"[MeSH] OR "low-income countries" OR "middle-income countries" OR "Africa"[MeSH] OR "Asia"[MeSH] OR "LMIC*")	160
Web of Science	Initial search – May 15, 2026. Updated search - May 27, 2026	("digital disease surveillance" OR "infectious disease surveillance") AND ("early detection") AND ("LMICs" OR "low- and middle-income countr*")	13
Google Scholar	Initial search – May 15, 2026. Updated search - May 27, 2026	("digital surveillance" OR "mHealth surveillance" OR "DHIS2") AND ("emerging infectious disease*" OR epidemic* OR outbreak* OR pandemic* OR "early warning") AND ("low- and middle-income countr*" OR LMIC* OR "resource-limited setting*" OR "developing countr*")	175

Table A2. Characteristics and Key Findings of Included Studies (*Synthesized by the authors from the included studies*).

Author / Year	Country	Study Design	Sample Size/Study Population	Type of Digital / Surveillance System	Disease(s) Studied	Key Findings
Tetuh et al. (2023) [2]	Multi-country (Africa - 49 of 55 African Union Member States)	Cross-sectional survey	63 respondents	Event-Based Surveillance (EBS) systems - continental capacity assessment using Africa CDC EBS Scorecard	Multiple epidemic-prone diseases (EBS-detected health threats, multi-disease, continental surveillance)	No African Union Member State had optimal EBS capacity. At least 34 countries had some form of EBS; hotline-based EBS was most common while community-based EBS was least implemented. Half of Member States used a One Health approach for early detection. Significant capacity gaps existed in verification, risk assessment, and inter-sectoral coordination.
Njeru et al. (2020) [3]	Kenya	Quasi-experimental study	78 surveillance officers	DHIS2 (District Health Information Software 2) - web-based national surveillance reporting system	IDSR priority diseases (multi-disease reporting)	DHIS2 training significantly improved IDSR reporting completeness and timeliness. Gains were greatest where baseline infrastructure was adequate; barriers included inadequate devices, unreliable internet, and limited ongoing support.
Ssendagire et al. (2023) [4]	Somalia	Descriptive implementation study	District and national health surveillance officers, health facilities, and surveillance reporting units across Somalia (2016–2023)	IDSR system, hybrid paper-based and electronic surveillance reporting	IDSR priority diseases (multi-disease)	Somalia progressively expanded IDSR from 2016 to 2023 with measurable gains in completeness and timeliness, but fragile infrastructure, insecurity, and limited resources remained persistent barriers requiring sustained external support.

Author / Year	Country	Study Design	Sample Size/Study Population	Type of Digital / Surveillance System	Disease(s) Studied	Key Findings
Kaburi et al. (2023) [10]	Ghana	Qualitative study (stakeholder interviews)	22 resource persons	SORMAS (Surveillance Outbreak Response Management and Analysis System) - digital outbreak surveillance and response platform	COVID-19 and multiple priority infectious diseases	SORMAS improved surveillance efficiency during COVID-19. Key facilitators were political endorsement, national leadership, and in-country IT capacity. Main barriers included poor interoperability, unreliable internet/power supply, and dependence on external funding.
Yano et al. (2018) [11]	Thailand	Pilot implementation/descriptive observational study	296 volunteer reporters	PODD (Participatory One Health Disease Detection) - mobile app-based participatory surveillance system	Zoonotic diseases and diseases of animal origin (One Health, multi-disease)	PODD successfully engaged community volunteers for early detection of zoonotic events in both humans and animals. The mobile platform was operationally feasible and highly accepted by users.
Karimurib o et al. (2017) [12]	Tanzania & Kenya	pilot Intervention/implementation study	Community health reporters (human and animal health workers) in rural communities across two African countries	AfyaData, Android smartphone application for community-level One Health disease surveillance	Zoonotic and epidemic-prone diseases (multi-disease; One Health approach)	AfyaData enabled geo-tagged, real-time community reporting across four African countries, improving early detection of zoonotic events and extending surveillance beyond facility coverage.
Olson et al. (2017) [13]	Guatemala	Prospective cohort study	469 children	Mobile phone app-based participatory syndromic surveillance system	Acute febrile illness (AFI) and acute gastroenteritis (AGE)	The app-based system was feasible and effective for real-time rural community-level detection, with high reporting completeness, timeliness, and

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						strong community reporter acceptance.
Kambalam e et al. (2024) [17]	Malawi	Qualitative case study	43 participants	IDSR system - conventional and partially digitized surveillance reporting	IDSR priority diseases (multi-disease)	Supportive supervision, clear reporting structures, and training positively influenced IDSR performance. Persistent barriers included tool stockouts, staffing shortages, poor connectivity, and underutilization of digital tools.
Wu et al. (2026) [18]	Malawi	Action Design Research /implementation study	Multi-sectoral stakeholders including human health, animal health, and environmental health professionals across district and national levels in Malawi	Electronic IDSR One Health surveillance platform (DHIS2-based, integrated human–animal–environment data)	IDSR priority diseases (multi-disease surveillance)	A One Health e-IDSR platform was established through iterative co-design, improving data availability and inter-sectoral coordination. Connectivity and resource constraints posed persistent implementation challenges.
Valerio et al. (2024) [33]	Malawi	Prospective cohort study	740 rural households across villages	Participatory IVR (Interactive Voice Response) surveillance system - mobile-based community reporting	Cholera-like diarrheal disease (CLDD)	Participatory IVR surveillance detected cholera-like disease clusters earlier than conventional facility-based reporting, with geo-referenced data enabling timely spatial outbreak tracking. Average weekly participation was 35%.
El-Khatib et al.	Central African	Non-randomised comparative pilot evaluation	21 health center focal points (n=271)	Argus - SMS-based smartphone disease surveillance application	20 epidemic-prone conditions per	Argus app-based surveillance doubled reporting completeness (31%→81%) and timeliness

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(2018) [34]	Republic (CAR)				IDSR protocol (multi-disease)	(19%→50%) vs. paper-based reporting, with high user usability scores and low annual maintenance costs.
Hirai et al. (2025) [35]	Democratic Republic of Congo (DRC)	Non-randomised comparative implementation study	44 Health workers (30 nursing officers and 14 nurse supervisors)	SORMAS - digital case-based disease surveillance system (facility-level and health zone-level implementation models)	Epidemic-prone diseases: Ebola, cholera, measles, yellow fever, mpox, and others	Data completeness exceeded 80% in both models, but timely reporting was markedly higher under the facility-level model (46%) vs. health zone-level (5%), revealing significant model-dependent performance differences.
Mugasha et al. (2025) [36]	Uganda	Descriptive implementation study	Health workers, district health teams, and national surveillance officers across Uganda; eIDSR rolled out in 100 of 146 districts (2020–2022)	eIDSR (electronic Integrated Disease Surveillance and Response System) - DHIS2-based national digital surveillance platform	IDSR priority diseases (multi-disease national surveillance)	eIDSR was scaled up to 68% of districts by 2022. Upgraded functionalities improved real-time reporting of epidemic-prone disease signals. Reporting completeness and timeliness improved modestly but remained below 80% targets in most regions. Key barriers included poor internet connectivity, limited devices, inadequate workforce, and inconsistent government budgetary support.
Harvey et al. (2021) [37]	Burkina Faso	Machine-learning prediction-model development and validation using	Historical malaria surveillance, meteorological and	Machine learning-based epidemic prediction model (AI early warning system)	Malaria	Machine learning algorithms successfully predicted malaria epidemics using climatic and surveillance variables,

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		retrospective time-series data	environmental datasets from Burkina Faso			demonstrating potential for earlier outbreak preparedness and targeted public health interventions.
Williams et al. (2025) [38]	Multi-country (African Region; 47 countries)	Retrospective observational study	Public health events reported through WHO Epidemic Intelligence from Open Sources (EIOS) platform between 2018 and 2023	WHO Epidemic Intelligence from Open Sources (EIOS) AI-enabled event-based surveillance platform	Multiple infectious disease outbreaks and public health emergencies	EIOS detected outbreaks before official notification through conventional surveillance channels. Automated monitoring enhanced situational awareness and supported earlier outbreak intelligence generation across the African Region.
Edson et al. (2025) [39]	Rwanda	Quantitative descriptive/proof-of-concept surveillance study	Wastewater samples from aircraft arriving at Kigali International Airport (KIA); international travellers as indirect surveillance population	Wastewater-based epidemiology (WBE) with genomic sequencing - digital/laboratory surveillance platform at point of entry	SARS-CoV-2 (COVID-19)	WBE successfully detected SARS-CoV-2 variants in aircraft wastewater before clinical confirmation, demonstrating high sensitivity and cost-effectiveness as a complementary point-of-entry surveillance tool.
Nyenswah et al. (2023) [40]	Liberia	Qualitative study	29 participants	IDSR framework - conventional paper-based and early digital surveillance system	IDSR priority diseases (multi-disease, pre-Ebola context)	Pre-Ebola IDSR implementation in Liberia built district-level capacity but revealed critical pre-existing gaps in infrastructure, training, inter-sectoral coordination, and laboratory capacity that heightened vulnerability to the Ebola crisis.

Table A3. Quality Assessment/Risk of Bias Judgement

Assessment tools were selected according to study design: ROBINS-I for non-randomised studies of interventions; Cochrane EPOC risk-of-bias criteria for interrupted time-series studies; CASP checklists for qualitative and cohort studies; MMAT for mixed-methods and quantitative descriptive studies; PROBAST+AI for prediction-model studies using artificial intelligence methods; and appropriate JBI critical appraisal tools for cross-sectional and other descriptive observational studies.

Author / Year	Study Design	Assessment Tool	Overall Quality Judgement	Main Bias Concerns	Overall Risk of Bias Judgement
Tetuh et al. (2023) [2]	Cross-sectional survey	JBI Checklist for Cross-Sectional Studies	Moderate	Social desirability in scorecard completion; variable reporting capacity across countries; selection of countries assessed may not be representative.	Moderate risk
Njeru et al. (2020) [3]	Quasi-experimental study	ROBINS-I	Moderate	Confounding by concurrent interventions (training + infrastructure); non-random group allocation; data quality limitations in routine records.	Moderate risk of bias
Ssendagire et al. (2023) [4]	Descriptive implementation study	JBI appropriate descriptive/observational checklist	Moderate	No control group; conflict-affected setting introduces reporting disruptions; selection bias in reporting facilities.	Moderate risk
Kaburi et al. (2023) [10]	Qualitative study (stakeholder interviews)	CASP Qualitative Checklist	Moderate	Small, purposive sample (n=22) of stakeholders may under-represent frontline/end-user perspectives; social desirability in interview responses; potential selection bias in stakeholder recruitment.	Moderate risk

Author / Year	Study Design	Assessment Tool	Overall Quality Judgement	Main Bias Concerns	Overall Risk of Bias Judgement
Yano et al. (2018) [11]	Pilot implementation/descriptive observational study	JBI Quasi-Experimental Checklist	Moderate	No control group; selection bias; potential reporting bias; limited long-term outcome assessment; single-province pilot limits generalizability	Moderate risk
Karimuribo et al. (2017) [12]	pilot Intervention/implementation study	JBI Quasi-Experimental checklist	Moderate	Single arm; no comparator group; self-reported disease events; technology adoption bias.	Moderate risk
Olson et al. (2017) [13]	Prospective cohort study	CASP Cohort Checklist	Moderate	Volunteer/participation bias; absence of randomization; potential under-reporting in control areas; co-intervention bias.	Moderate risk
Kambalame et al. (2024) [17]	Qualitative case study	CASP Qualitative Checklist	Moderate	Self-report bias; social desirability; potential non-response bias.	Moderate risk
Wu et al. (2026) [18]	Action Design Research /implementation study	JBI Qualitative Checklist	Moderate	Single-arm case study with no comparator or counterfactual; authors are the platform implementers (self-evaluation, conflict-of-interest risk)	Moderate risk
Valerio et al. (2024) [33]	Prospective cohort study	CASP Cohort Checklist	Moderate-High	Loss to follow-up; potential outcome misclassification;	Moderate risk

Author / Year	Study Design	Assessment Tool	Overall Quality Judgement	Main Bias Concerns	Overall Risk of Bias Judgement
				community reporter variation; no randomization.	
El-Khatib et al. (2018) [34]	Non-randomised comparative pilot evaluation	ROBINS-I	Moderate	Short pilot period; conflict-related reporting disruptions; selection of participating facilities.	Moderate risk of bias
Hirai et al. (2025) [35]	Non-randomised comparative implementation study	ROBINS-I	Moderate	Routine data quality limitations; confounding by health facility access and conflict.	Moderate risk of bias
Mugasha et al. (2025) [36]	Descriptive implementation study	MMAT	Moderate	Confounding by COVID-19 context; limited baseline; data quality issues in routine records.	High risk
Harvey et al. (2021) [37]	Machine-learning prediction-model development and validation using retrospective time-series data	PROBAST+AI	Not separately rated	Limited geographic coverage; limited historical data; potential bias in underlying surveillance data	High risk of bias
Williams et al. (2025) [38]	Retrospective observational study	JB1 appropriate analytical observational checklist	Moderate	Index-test blinding, imperfect reference standard, human-moderation confound, unadjusted confounders	Moderate risk
Edson et al. (2025) [39]	Quantitative descriptive/proof-of-concept surveillance study	MMAT	Moderate	Single-site study; potential sampling bias; detection depends on wastewater flow	Moderate risk

Author / Year	Study Design	Assessment Tool	Overall Quality Judgement	Main Bias Concerns	Overall Risk of Bias Judgement
				variability; limited comparative outcomes.	
Nyenswah et al. (2023) [40]	Qualitative study	CASP Qualitative Checklist	Moderate	Recall bias; key informant selection bias; retrospective documentation; limited generalizability.	Moderate risk

***Notes:** CASP = Critical Appraisal Skills Programme; MMAT = Mixed Methods Appraisal Tool; ROBINS-I = Risk Of Bias In Non-randomised Studies of Interventions; EPOC = Effective Practice and Organisation of Care; PROBAST = Prediction model Risk of Bias Assessment Tool; ITS = Interrupted Time Series; DHIS2 = District Health Information Software 2; IDSR = Integrated Disease Surveillance and Response; EWS = Early Warning System; LMICs = Low- and Middle-Income Countries.*

Table A4. Digital Surveillance and Artificial Intelligence Implementation Readiness Framework (DSIRF-AI). *Developed by the authors from thematic synthesis of included studies and informed by WHO Digital Health Guideline, CFIR, NASSS, and implementation evidence [1, 10, 17, 23-25]*

Readiness Domain	Definition	Example Readiness Indicators
Governance Readiness	Institutional and regulatory capacity	Policy frameworks, coordination mechanisms
Technology Readiness	Digital infrastructure capability	Connectivity, interoperability
Workforce Readiness	Human capability for surveillance operations	Training, analytical capacity
Data Intelligence Readiness	Ability to generate actionable information	Data quality, governance
Algorithmic Readiness	Responsible implementation of AI-supported surveillance	Validation, explainability, oversight
Sustainability Readiness	Capacity to maintain surveillance systems over time	Financing, ownership

Sustainable public health impact occurs when surveillance technologies are implemented within systems that are ready to govern, interpret, operationalize, and sustain surveillance intelligence.

Table A5. Comparison between CFIR, NASSS, WHO digital health, and DSIRF-AI frameworks (Synthesized from included studies). *Source: Developed by the authors based on implementation science literature and evidence synthesis from [23-25].*

Framework	Strength	Gap addressed by DSIRF-AI
CFIR	Implementation determinants	Limited AI surveillance-specific considerations
NASSS	Technology sustainability	Not focused on disease surveillance
WHO Digital Health	Digital intervention guidance	Limited algorithm governance focus
DSIRF-AI	Surveillance + AI readiness	Integrates implementation, AI governance and public health action