Public Health Institutes of the World

IANPHI

Integrated Disease Surveillance Report

Conceptualization And Implementation of Integrated Disease Surveillance Globally:

A SCOPING REVIEW

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ABBREVIATIONS

AMSTAR	Assessment of Multiple Systematic Reviews
BMGF	Bill & Melinda Gates Foundation
CBS	Community Based Surveillance
CDC	Centre for Disease Control
CHW	Community Health Worker
COVID-19	Coronavirus disease 2019
CRVS	Civil Registration and Vital Statistics
EBS	Event-Based Surveillance
FG	Focus Group
HCF	Health Care Facilities
HIC	High Income Country
HMIS	Health Management Information System
IANPHI	International Association of National Public Health Institutes
IBS	Indicator-Based Surveillance
IDS	Integrated Disease Surveillance
IDSP	Integrated Disease Surveillance Program
IDSR	Integrated Disease Surveillance and Response
IHR	International health regulation
IT	Information Technology
KII	Key Informant Interview
LMIC	Low- and Middle-Income Country
MERLA	Monitoring Evaluation Research Learning Adaption
MESH	Medical Subject Heading
MMAT	Mixed Methods Appraisal Tool
MSF	Médecins Sans Frontières
NCD	Non-Communicable Diseases
NPHI	National Public Health Institute
OH	One Health
OR	Operational Research
PHC	Primary Health Care
PHCU	Primary Health Care Unit
PRISMA	Preferred Reporting in Systematic Reviews and Meta-analysis
RQ	Research Question
SCD	Standardized Case Definition
SEED	System for Early warning based on Emergency Data
SOP	Standardized Operating Procedure
USCDC	United States Centers for Disease Control and Prevention
WHO	World Health Organization

PREFACE

The International Association of National Public Health Institutes (IANPHI) was awarded funding from the Bill & Melinda Gates Foundation (BMGF), to explore the status of national surveillance systems in terms of integration of data, the role of National Public Health institutes, and the extent to which Integrated Disease Surveillance (IDS) systems have been developed and operationalized and the evidence base for the effectiveness of IDS.

The international response to the COVID-19 pandemic revealed surveillance systems globally were ill- prepared to identify and manage this emerging public health threat. Morgan et al., 2021 in an article discussing bold disease surveillance changes due to COVID-19, postulated that integrating separate disease surveillance systems would help to strengthen national disease surveillance. However, the evidence base for that proposition, although logical and well argued, has not been clearly established.

The purpose of the project is to identify key priorities that will enable a collaborative approach across sectors for the integration of data, the role of NPHI's and key actors to analyze and interpret evidence for the purpose of early action and response to future pandemics and epidemics.

This study of IDS has been divided into three workstreams and took place between April-October 2022. The study sought IANPHI members' understanding of IDS and the development of IDS systems, developing a framework for IDS and testing its validity against the global literature and against NPHI operational experience. The study has also considered whether lessons learned from the COVID-19 pandemic have or should influence the development of national surveillance systems.

The IANPHI IDS project, funded by the Bill and Melinda Gates Foundation (BMGF) comprised of three workstreams:

1. To use the five core principles of integrated disease surveillance (IDS) set out by Morgan and colleagues, five with the bespoke conceptual framework which include the core principles, to conduct a rapid scoping review to document current state of knowledge and evidence for definitions and characteristics of Integrated Disease Surveillance and assess how these have evolved over time.
2. To survey IANPHI members to develop a clear understanding of current status of IDS across the IANPHI network, mapping variations in definitions and approach to IDS and collecting and collating case studies on how IDS has been developed and is managed.
3. To conduct a focused study on a limited number of Lower-middle income and high-income countries on the state of IDS including challenges and barriers to implementation as well as identifying opportunities.

This report outlines the approach and findings from the first workstream. Findings from the other two workstreams as well as reflections on the findings from complementary projects undertaken by the Robert Koch Institute (an IANPHI member) and Resolve to Save Lives are reflected in the final report. This enables a comprehensive analysis to identify themes for action and change that is required for integration and analysis of surveillance data as an enabler to provide evidence needed to prepare and combat the impact of pandemics and epidemics. This also informs practical, realistic steps that can be implemented, reflecting challenges and opportunities in country resources and support, to strengthen not only IDS systems but also the collaboration across sectors that is required to enable decision making for policy makers and response measures to future pandemics and epidemics.

1. EXECUTIVE SUMMARY

Background

The COVID-19 pandemic has exposed weaknesses in surveillance systems globally. It has been proposed that integrating separate disease surveillance systems would help to strengthen national disease surveillance (Morgan et al., 2021). Whilst strong arguments for greater integration of disease surveillance systems have been made, the evidence base to support integration has not yet been fully developed.

In many countries National Public Health Institutions (NPHIs) play an important role in the organization of national disease surveillance and the International Association of National Public Health Institutes (IANPHI) was funded by the Bill and Melinda Gates Foundation (BMGF) to examine the status of national surveillance systems, the extent to which Integrated Disease Surveillance (IDS) systems have been developed and operationalized and the evidence base for the effectiveness of IDS. This scoping review is part of a research program with 3 key elements, with the other studies being a survey of IANPHI members on the current status of their disease surveillance systems, and a deeper analysis and case studies of the surveillance systems in 7 countries, to highlight the opportunities and challenges of integration.

This paper presents the findings of a review of global literature on IDS.

Aim

Three Research questions (RQs) were asked by the review: 1. How is IDS defined and described in the literature and how has this evolved over the course of the COVID-19 pandemic? 2. What are the key features and pre-requisites of effective IDS systems? 3. What are the challenges and enablers/opportunities for IDS development?

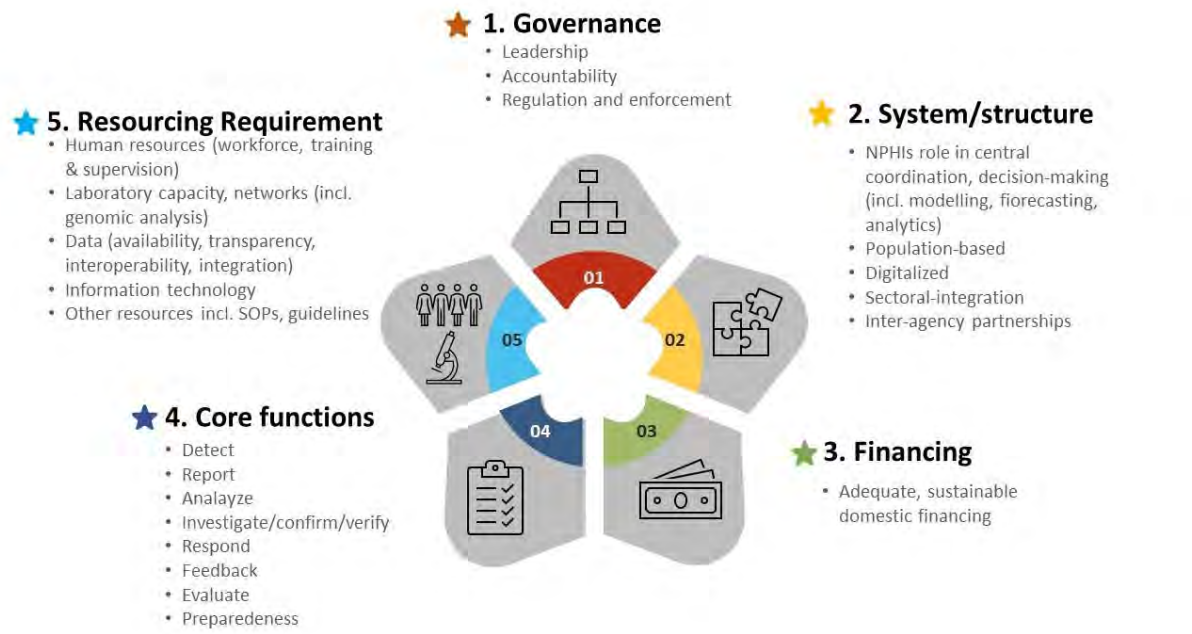
Methods

Scoping review methodology, guided by the scoping review framework proposed by Arksey and O'Malley and following the PRISMA extension for scoping reviews was used to address the three explorative RQs. Two complementary searches were conducted to capture primary studies on IDS not included in previous reviews.

Three databases for publications in English between 1998 and June 2022 were searched, as well as web portals of three selected key organizations. Study selection and assessment was independently conducted by multiple reviewers. One reviewer extracted data, with accuracy checked by a second reviewer. We used a bespoke conceptual framework (figure 1), to guide

the analysis of included articles, based on the initial WHO Integrated Disease Surveillance and Response (IDSR) framework, incorporating Morgan et al. (2021)'s five key domains for IDS: 1) governance, 2) system and structure, 3) financing, 4) core functions, and 5) resourcing requirements.

Figure 1: Framework for IDS



Main results

Eight reviews and five primary studies, published between 2009 and 2021, were included. Five reviews were narrative systematic mixed reviews, two were literature reviews, and one was a systematic scoping review. They included primary studies constituted a mix of qualitative, quantitative, and mixed methods studies. We judged the quality of the included body of evidence to be low to critically low.

Few of the included articles provided a definition of IDS, while others provided various descriptions of IDS highlighting different parts of the system. The concept of integration in the context of disease surveillance was described differently across included articles. There appears to be no common IDS definition or articulation of the parts that constitute an IDS system or definition of disease surveillance integration. No articles were found that reported on the evolution of IDS triggered by the COVID-19 pandemic, although it may still have been too early for such publications at time of this review.

Included articles alluded to features and pre-requisites of effective IDS systems, which are consistent with the categorization of issues set out in the framework for this review. This review

found articles mostly focused on the adequacy of core functions, resources, and system structure of IDS. There were few references to governance and financing.

Articles described the provision of core functions and resourcing requirements as generally inadequate, especially at the health facility and regional levels. Sources of financing of IDS were not outlined in any of the included articles. When mentioned, financing was described as non-sustainable and a major challenge. The enablers/opportunities identified for IDS included: active sharing of data; close cooperation between agencies or different elements of the system (governance); clear reporting channels; integration of categorical disease control programs; increased staff training; and electronic/mobile reporting adoption (resourcing requirements).

Completeness

Most included articles focused on IDS in the African region, with only one in Asia and one in the Middle East. Few articles included IDS implementation in high income countries and most focused solely on human sector surveillance. The articles in this review did not outline the effect of IDS systems on disease control outcomes.

Limitations

The main search was restricted to articles in English and only conducted in two major databases and three selected grey literature sources. The review mainly focused on evidence summaries, therefore relying on the specific aims and quality of the reported outcomes within these articles. The overall low to critically low quality of the included reviews and primary studies with limited representativeness needs to be considered in further interpretations and generalization of the results. The focus of this review was mostly limited to the surveillance aspect of IDS and not the response element described in IDSR.

Implications for practice, and policy

Findings from the reviews appear to support the five key elements and linked sub-functions that are proposed in the conceptual framework. The evidence on surveillance systems highlights the need for sufficient staffing with appropriate skill mix and training, as well as standardized case definitions, protocols and guidance. Integration requires consistent processes and interconnectivity. Electronic solutions can enhance surveillance activities, but dysfunctional technology can be a barrier.

As integration in different countries is likely to vary, what is important for one system in terms of integration (e.g., type of data, degree of integration, and stage in the surveillance process where it occurs) may not be a priority for another system. Consequently, national needs and priorities need to be considered, and a balance should be sought for a flexible surveillance

system.

Further, there are also the questions as to how much integration is optimal in terms of cost, effectiveness and resources, what should be integrated, how should integration be done and what key factors should be considered when integrating systems. Thus, the process of integration needs to be fully understood and its impact assessed through systematic evaluations using empirical data, and future planned and ongoing integration efforts should be evaluated in order to maximize the benefits of IDS, minimize any adverse effects, and to learn lessons on how best to operationalize it in different settings.

Implications for research

For future success of IDS systems, it will be vital to demonstrate measurable benefits of IDS. Current levels of IDS research are inadequate and robust evaluations of the effectiveness of current IDS systems are necessary. Countries should be encouraged to evaluate their IDS systems and all new IDS efforts should, as a minimum, have a basic operations research capacity in place.

A future high-quality systematic review would be useful, perhaps using a realist synthesis approach. There would also be value in conducting in-depth case studies of effective IDS systems.

To understand how IDS functions in pandemics, further research is needed to capture the experiences with IDS during COVID-19 and changes made in response to the pandemic.

Conclusion

Existing evidence for IDS conceptualization and operationalization is fragmented, incomplete, and the included quality of evidence is poor, however, the weakness of the evidence base appears to be primarily an issue of inadequate research and documentation of IDS systems. The review shows a lack of robust evaluation studies on the impact of IDS on disease control. One solution to this knowledge gap is to encourage countries to review and evaluate their IDS systems, to identify gaps and resource needs and report key lessons learned. Sharing of insights between countries may be helpful for countries on a similar implementation journey to learn from one another.

An articulated and shared understanding of the nature of IDS is necessary to enable comparisons between countries and to evaluate their implementation. For this purpose, IDS needs a common definition for standardized technical implementation. Ultimately, future evaluations should be conducted using an agreed IDS definition, robust study designs, and a common evaluation framework for improved comparability across studies.

2. BACKGROUND

Integrated disease surveillance (IDS) has been defined as "a combination of active and passive systems using a single infrastructure that gathers information about multiple diseases or behaviors of interest" (1). Following the re-emergence of large outbreaks of meningitis, cholera, yellow fever and measles in West Africa, the World Health Organization (WHO) African Region in 1998 adopted a strategy called the Integrated Disease Surveillance (IDS) strategy (2) which elaborates extensively on the key role the event- based surveillance (EBS) and Indicator-based surveillance (IBS) play in early warning and response and epidemic intelligence. The aim of the strategy was to support countries to improve their disease surveillance and response capabilities so that they could detect and respond to communicable disease threats in a timely manner (2).

In 2000, the WHO IDS strategy in Africa was renamed Integrated Disease Surveillance and Response (IDSR) to emphasize the essential link between surveillance and response (2). According to the WHO, the IDSR strategy focuses on the provision of comprehensive public health surveillance and response systems for priority diseases, conditions and events at all levels of health systems (3). It aims to make surveillance data (e.g., laboratory data) more usable and to help public health managers and decision- makers improve detection and response to the leading causes of illness, death, and disability. The strategy makes explicit the skills, activities and resources needed at each level of the health system to operate all functions of surveillance. In this review we have used IDS and IDSR interchangeably, but our primary focus is on the concept of integrated disease surveillance rather than the WHO IDSR strategy. This does not detract from the importance of the response element of the surveillance system.

One of the issues identified from the international response to the COVID-19 pandemic was that surveillance systems globally were not well prepared to identify and manage the emerging threat it posed to population health and wellbeing (4). For example, surveillance systems at the national level within countries as well as at the district level were not integrated. It is also not clear the extent to which IDS has been adopted by countries outside the WHO African Region.

Five core principles for integrated disease surveillance were set out by Morgan et al.,2021 that should underpin future improvements to surveillance systems and described the central role that National Public Health Institutes (NPHIs) should have in collating, analyzing and responding to surveillance data (5). Whilst Morgan et al. postulated that integrating separate disease surveillance systems would help strengthen national disease surveillance, the evidence base for that assumption, although logical and well argued, has not been clearly established.

The function of surveillance differs across countries, and National Public Health Institutions (NPHI) play a leading role in many countries. The International Association of National Public Health Institutions (IANPHI) which connects over 100 NPHI globally was commissioned by the

Bill & Melinda Gates Foundation (BMGF) to examine the status of national surveillance systems, the extent to which the concept of Integrated Disease Surveillance (IDS) has been developed and operationalized as part of national surveillance efforts, as well as the evidence base for the effectiveness of IDS.

This global study of IDS took place over seven months between April – October 2022. The study sought to explore IANPHI members' understanding of IDS, and the development of IDS systems globally, developing a framework for IDS and testing its validity against the global literature and against NPHI operational experience. The study has also considered whether the lessons learned from the COVID-19 pandemic have, or should, influence the development of national surveillance systems.

The study involved three workstreams:

1. A scoping review using a bespoke conceptual framework based on the five core principles of IDS set out by Morgan and colleagues (2021) to document the current state of the evidence and approaches to the conceptualization and operationalization of IDS worldwide.
2. A survey of IANPHI members to capture a clear understanding of the current status of IDS across the IANPHI network, mapping variations in definitions and approaches to IDS, as well as collecting and collating case studies on how IDS has been developed and is managed.
3. A focused in-depth qualitative study of several countries on the state of IDS and the opportunities for improvement.

This report describes the process and the results of the first workstream, the scoping review.

2.1. Aim and Scope of the Review

2.1.1. Aim of the Review

The aim of this scoping review was to document the current state of the evidence and approaches to the conceptualization and operationalization of IDS. More specifically we aimed to answer the following research questions (RQ):

1. How is IDS defined and described in the literature and how has this evolved over the course of the COVID-19 pandemic?
2. What are the key features and pre-requisites (workforce, technology, governance and finance, etc.) of effective IDS systems?
3. What are the challenges, and enablers/opportunities for IDS development?

2.1.2. Scope of the Review

We chose to use scoping review methodology as it was judged to be the most suitable approach to address our explorative type of research questions (6). Due to the short project time frame, the review team decided to focus mainly on summarized evidence (e.g., scoping reviews, rapid reviews, systematic reviews, literature reviews, narrative reviews, and meta-analysis) that met set inclusion criteria. In addition, two complementary searches were conducted to capture primary studies on IDS not included in previous reviews.

This scoping review was guided by the framework proposed by Arksey and O'Malley (7), and followed reporting standards of the Preferred Reporting in Systematic Reviews and Meta-analysis (PRISMA) extension for scoping reviews (8). The protocol was registered at the Open Science Framework (https://osf.io/bfh7q/wiki/home/https://osf.io/bfh7q/wiki/home/). A glossary is available in Appendix 1.

3. METHODOLOGY

3.1. Inclusion and Exclusion Criteria

THE FOLLOWING INCLUSION AND EXCLUSION CRITERIA WERE DEVELOPED FOR THE SCOPING REVIEW:

Participants: Any health sector (human or animal health), irrespective of discipline.

Concept: Integrated disease surveillance (IDS). The concept of IDS has been defined by Nsubuga as "a combination of active and passive systems using a single infrastructure that gathers information about multiple diseases or behaviors of interest" (1). However, articles were included regardless of IDS definition used, but also if no definition was provided.

Components of IDS, such as community-based surveillance (CBS), event-based surveillance (EBS), and vertical/disease-specific surveillance, were included, but the main focus was on the integration of different surveillance systems.

Studies of specific disease surveillance were excluded if the integration into the overall IDS, or the broader IDS strategy, was not discussed. Protocols and IDS technical guidelines from Ministries of Health, or the WHO, were excluded as they were not deemed to be primary sources of evidence.

Context: Any country irrespective of country income classification (i.e., high-, middle- and low-income countries)

Study design criteria and outcomes of interest:

- RQ1: any type of review or primary study that provided a definition of IDS, or that described IDS and/or described how it has evolved over the COVID19 pandemic.
- RQ2: any type of review or primary study reporting features or pre-requisites of effective IDS.
- RQ3: any type of review or primary study reporting the implementation or evaluation of IDS.

3.2. Search Strategy

3.2.1. Academic literature search strategy

The search for relevant published literature in electronic databases was conducted in four steps:

Firstly, we conducted a simplified preliminary search in PubMed to identify relevant publications, as well as to test and identify search terms that informed the search strategy development.

The second step consisted of the main search of Medline and Embase databases, which was limited to review articles published in English between 1998 (the year when the WHO Regional Office for Africa (WHO AFRO) first introduced the IDSR strategy), and 12 May 2022. The search strategy was based on review questions and relevant keywords and was developed by an information specialist (CDB) from the UK Health Security Agency Knowledge and Library Services. Search terms and the full search strategy are presented in Appendix 2.

The third step involved searching the Epistemonikos database (on 2 June 2022) for articles on IDS published in the last 10 years, using the term 'integrated disease surveillance'. This was done to identify any relevant primary studies that were published after the search dates of the reviews included in this scoping review, i.e., to capture recent studies that would not have been included in any of the previous reviews.

The fourth step involved a search of Medline and Embase databases (on 9 June 2022) for primary studies describing changes made to IDS due to the COVID-19 pandemic. This was done because the main search did not identify any reviews on the topic. We excluded publications that were not primary studies (e.g., commentaries, letters, responses, editorials, opinion pieces etc.), and studies that did not explicitly mention integrated surveillance in the abstract.

3.2.2. Search of other sources

In addition to the databases searched, we also searched the web portals of selected institutions (on 2 June 2022) including the World Health Organization (WHO), United States Centers for Disease Control and Prevention (USCDC), and Médecins Sans Frontières (MSF). One reviewer (SB) conducted the searches using the terms 'integrated disease surveillance' and produced a list of potentially eligible reports, which were assessed by a second reviewer (GMF).

Due to the short timeframe of this project only literature in the English language was included.

3.3. Data Management and Analysis

3.3.1 Selection of reviews

The citations identified by the searches were imported into the reference management software EndNote (version X9, Clarivate), and duplicates were removed. The citations were thereafter imported to the screening software Rayyan (9), which was used for the screening. The screening of titles and abstracts against the inclusion criteria was conducted by two review authors (from CDB, GB, GMF). All potentially relevant reviews were retrieved in full text and assessed by two review authors. Any uncertainty regarding the eligibility of a review was resolved through discussion among review authors, or when needed, using a topic expert arbitrator (AL). If two, or more, reviews covered the same studies, we included the review that was most recent, and/or the review that contributed the most comprehensive information. We used a matrix to visualize the overlap between reviews, i.e., when they included some of the same studies. The study process is documented in a PRISMA flow chart (10) (See Figure 2).

3.3.2 Data Extraction

Data extraction, using data extraction templates developed and piloted for this review, was conducted by one review author (from JR, JB, and NAH). Another review author (GMF) checked the accuracy of the extracted data. Disagreements were resolved through discussion among the review authors. The data extraction templates were based on a bespoke conceptual framework developed for this project (Figure 1).

As part of the data extraction validation process, we initially assessed the overall study discussions and conclusions. We then reviewed the findings that informed the discussions and conclusion of the study to ensure that the conclusions were based on the main findings.

The following data were extracted: author, year of publication, type of review (or primary study), objectives, search strategy, number of databases searched and search limitations, number of included studies, number and names of countries, IDS definition, IDS features and pre-requisites, details on system types included in the IDS, challenges and enablers/opportunities of IDS implementation, changes made to the IDS during the COVID-19 pandemic, and information on funding and conflicts of interest.

3.3.3 Synthesis of review findings

The findings of the included studies were analyzed using narrative synthesis which is useful when different types of studies are included to not lose the diversity in study designs and contexts (11- 13). We used the three piloted data extraction templates and summary tables, which were based on the conceptual framework (Figure 1; Section 8), to synthesize the data from the review articles for analysis.

3.3.4 Expert and stakeholderconsultation

The scoping review was discussed with members of the project's technical and executive committee at a few meetings during the review process. The committees constituted experts and stakeholders/consumers from a range of organizations and countries. They provided oral feedback on the review at meetings and written comments on draft versions and the final scoping review report, to inform and validate findings, and to ensure the relevance of the review for stakeholders.

3.4. Quality Assessment

3.4.1 Reviews

We could not identify a standardized quality assessment tool for narrative mixed studies reviews. Consequently, we created a set of 13 standard quality criteria for the purpose of quality assessment (Table 1). The criteria, which were partly based on the Assessment of Multiple Systematic Reviews (AMSTAR) tool (14), are frequently used for assessing review quality. As with the AMSTAR tool each item had three response alternatives: yes, no, or partly yes.

To determine the overall quality of included reviews, we used the criteria suggested by AMSTAR (for randomized and non-randomized evidence), to identify five critical and eight non-critical areas from our set of criteria that we judged would work on the various types of narrative mixed studies reviews included in our scoping review. We then used the AMSTAR quality ratings of high, moderate, low and critically low (14), to denote an overall quality rating, which essentially is based on the number of critical and non-critical flaws in a review (See Appendix 7 for details).

Table 1. Criteria for assessing the quality of included reviews, and critical criteria* for determining the overall review quality

1. Clear objective and/or research questions
2. Refers to a published review protocol (with pre-defined methods and selection criteria)*
3. Use of reporting standards (e.g., PRISMA)
4. Inclusion and exclusion criteria (e.g., study design criteria)
5. Duplicate, independent screening and data extraction (or for part of the citations)
6. Adequate literature search (at least two databases) and reports search strategy and/or search terms*
7. Provides a list of excluded studies with justifications for exclusion of individual studies*
8. Description of the main characteristics of included studies
9. Quality assessment of included studies by two review authors independently *
10. Reports on funding of included primary studies
11. Reports funding sources of the review, and potential conflicts of interest of review authors
12. Discusses possible biases, or limitations with the review*
13. Conclusions are based on main results

3.4.2 Primary studies

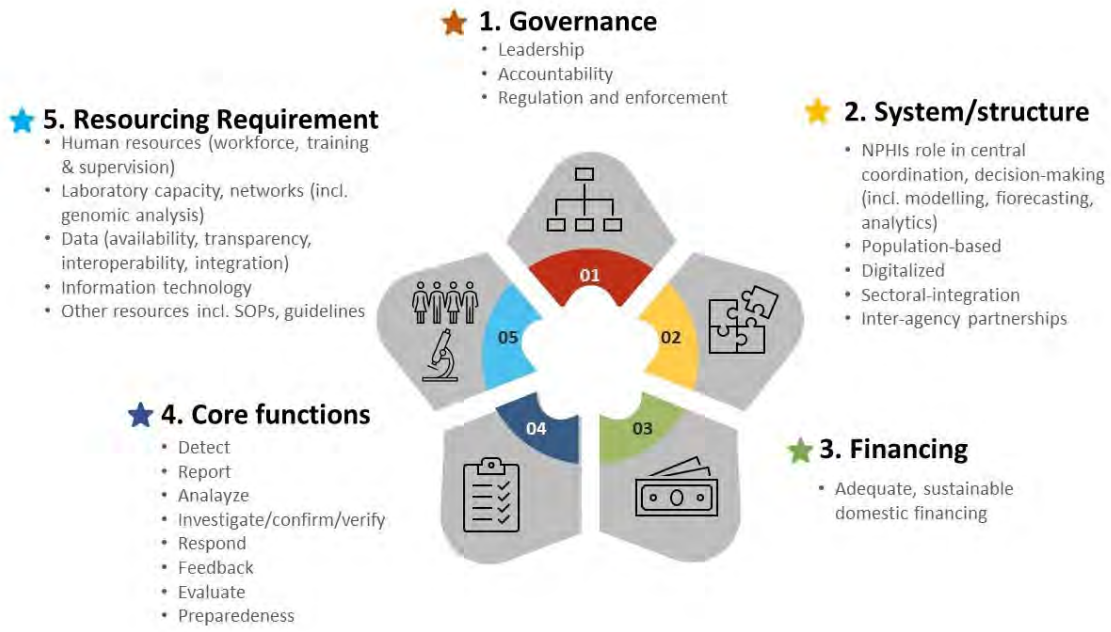
For the quality assessment of included primary studies we used the Mixed Methods Appraisal Tool (MMAT), 2018 version (15) from McGill University, which was constructed for use in systematic mixed studies reviews. Two initial screening questions help the user to decide whether to go on with further assessment. The tool consists of 15 main assessment items: five each for qualitative, quantitative, and mixed methods components. There are three response alternatives to each question: yes, no, and can't tell. The overall quality of included studies may be determined by calculating the percentage of quality criteria met (from 1 yes=20% up to 5 yes=100%). In the case of a mixed methods study, as there are 15 criteria (instead of 5), the overall score cannot exceed the weakest component. For example, if the qualitative part met 20% of the quality criteria, 100% of the quantitative, and 40% of the mixed methods criteria, the overall quality would be 20%.

4. CONCEPTUAL FRAMEWORK FOR THE REVIEW

We devised a bespoke conceptual framework (Figure 1) to guide the analysis of included reviews and primary studies. The framework was based on the initial WHO IDSR framework and incorporated Morgan et al. (2021)'s five principles for IDS (5). Regardless of the type of surveillance (notifiable disease and IDS-like surveillance; pathogen surveillance including sequencing, population-based surveys, vital statistics, sewage and septic surveillance; and specialized programs), the framework considers the integrated vision of an IDS from organizational and operational aspects. It comprises five key domains:

1) Governance, 2) System and structure, 3) Financing, 4) Core functions, and 5) Resourcing requirements.

Figure 1. Conceptual framework for the review



The framework aimed to underscore the importance of governance (e.g., leadership, accountability, regulation and enforcement), system and structure for surveillance (e.g., NPHI's role in surveillance coordination and decision-making, including modelling, forecasting and analytics; population representativeness; use of digital technology including operability of systems; and sectoral integration) and adequacy of financing in addition to the core and resourcing requirements of an IDS system.

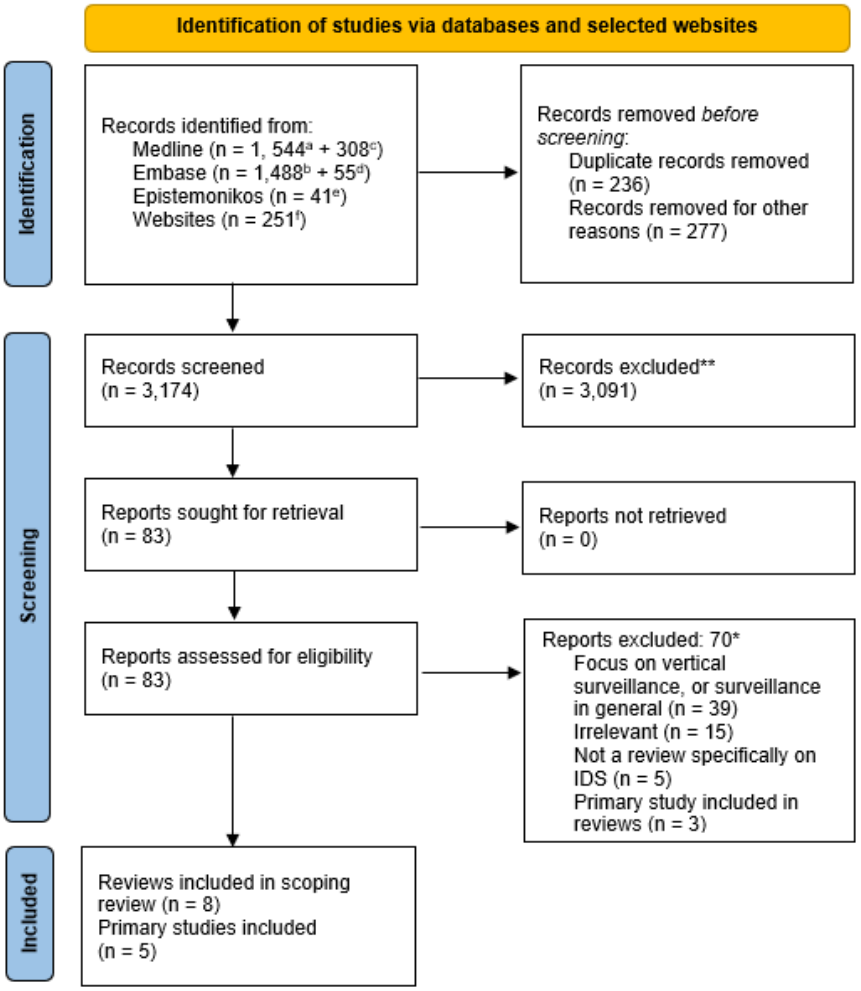
5. RESULTS

5.1. Main Search (Reviews)

The PRISMA study flow chart is presented in Figure 2.

The main search of the Medline and Embase databases retrieved 1,544 and 1,488 citations respectively, of which 464 were removed before screening (217 duplicates and 240 for other reasons). The remaining 2,568 citations were screened by title and abstract, and 2,513 citations were directly excluded at this stage. Full texts of 55 potentially eligible citations were retrieved and scrutinized. Eleven of these were initially judged to be potentially eligible for inclusion, but after further scrutiny, only eight reviews were included (16-23), and 47 citations were excluded with reasons (see Appendix 3. List of excluded studies).

Figure 2. PRISMA study flow chart describing the study selection process



*Six of these studies are not listed among the excluded studies as they should not have been assessed in the first place (i.e., they were included in reviews). a. Main Medline search (reviews); b. Main Embase search (reviews); c. Additional Medline search (primary IDS/COVID-19 studies); d. Additional Embase search (primary IDS/COVID-19 studies); e. Epistemonikos search (primary studies not included in reviews); f. Selected key organizations' web-portals (grey literature).

5.2. Additional Searches (Primary Studies)

5.2.1. Epistemonikos

The search of the Epistemonikos database retrieved a further 31 primary studies. Twenty-four of the 31 original studies, which according to Epistemonikos were not included in any systematic review, were screened against the inclusion criteria. Nine of the 24 citations appeared to be potentially eligible, but after further scrutiny it turned out that six of them were already included in the Wolfe et al. review (23), which left three unique studies for inclusion (24-26). The search also identified 10 reviews, but six of them had been retrieved by our main search, and the other four did not meet our inclusion criteria.

5.2.2. Medline and Embase

The additional searches in Medline and Embase for primary studies describing changes made to the IDS strategy during the COVID-19 pandemic yielded 329 unique citations (340 citations, of which 11 duplicates were removed before screening). 321 citations were directly excluded at the title and abstract screening stage. Eight potentially relevant citations were retrieved in full text, and of these one was judged eligible for inclusion (27)

5.2.3. Grey literature

The search of web portals for selected key organizations (WHO, US-CDC, and MSF) yielded 251 citations, of which eight were judged potentially relevant. Two of these were duplicates, and no additional relevant reports were identified among the other six.

5.3. General Characteristics of Included Articles

5.3.1. Reviews

See Appendix 4. We identified eight reviews published between 2009 and 2021 that were eligible for inclusion in this scoping review (16-23). Five of the reviews self-identified as systematic reviews, two as literature reviews (21;22), and one as a systematic scoping review (20). All were mixed studies reviews, and included quantitative, qualitative and mixed methods studies. The number of studies included in the reviews ranged from 18 to 102 (median: 31 studies). Only two reviews carried out quality assessments of the included studies (16;18).

The number of databases searched by the reviews ranged between one to five (median 2.5 databases). The literature search period spanned from 1900 to 2020. Five of the reviews included grey literature searches. All eight reviews included studies in English, and only one included non-English studies in French (23). The search terms used for all reviews included some component of disease surveillance, but the terms used were quite heterogeneous which reflect their different review aims. Six of the reviews sought to examine the implementation of surveillance. Two reviews were focused on integration issues (16;22). Five looked at the performance of these systems (17-19;21;23).

Only one review (16) looked at surveillance of both communicable and non-communicable diseases. The others covered communicable diseases only, and one review focused specifically on just one disease, dengue (20). In total,34 different diseases or groups of diseases were covered in three reviews (18;21;23) : Measles, Cholera, Malaria, Tuberculosis, Typhoid fever, Diarrhea, Ebola, HIV/AIDS, Meningitis, Meningococcal meningitis, Poliomyelitis/Acute Flaccid Paralysis, Acute respiratory infection, Rabies, Anthrax, Chikungunya, Dysentery, Emerging infectious diseases, Gastroenteritis, Guinea worm disease, Hemorrhagic diseases , Influenza (human, avian), Lassa fever, Legionnaire's disease, Maternal mortality, Neonatal tetanus, Pneumonia, Salmonellosis, Schistosomiasis, Shigella, Sexually-Transmitted Diseases, Tularemia, Varicella, and Yellow fever. The number of studies in which individual diseases were included could not be calculated, as some of the included studies only described the inclusion of 'multiple diseases' or "all communicable diseases in a country", or referred to the included diseases as 'undefined'. The other reviews provided no information on diseases covered by the IDS system.

Five reviews were concerned with IDS in the human sector, three reviews included both human and animal surveillance (One Health) (16;17;22), while no reviews focused solely on animal sector IDS.

Four of the reviews included studies from the African region, of which one covered specifically Sub- Saharan Africa only (17). Three other reviews included studies from both LMICs and HICs (16;21;22), and one review only included studies from India (20).

One of the reviews (20), which focused on dengue IDS in India, provided limited information on the information flow up through the system (from district-state-central surveillance unit), but did not describe feedback going down through the system. The National Centre for Disease control were responsible for the IDS system, and accountable for it to the Indian Ministry of Health and Family Welfare.

All reviews reported solely process outcomes and did not report on cost-savings or saved lives (i.e., effect outcomes) due to IDS implementation.

Matrix of study overlaps between included reviews

A total of 272 primary studies were included in the eight reviews. The Wolfe et al.,2021 (23) and the Mremi et al.,2021 (17) reviews had 13 studies in common (27.6% to 28.9% overlap). Thirteen of the 30 studies included in Ng'etich et al.,2021 (18), were also included in the Mremi et al.,2021(17) review (43.3% overlap). Wolfe et al.,2021, Mremi et al.,2021, and Ng'etich et al.,2021 (17;18;23) had six studies in common. Phalkey et al.,2013 (19) had six studies in common with Mremi et al.,2021 (18.6% overlap). Pilot et al,2019 (20), which included only dengue focused studies from India, showed no overlap with the other reviews. The review by Wendt et al,2013 (22) which had a One Health-focus, only had a single study in common with George et al.,2020 (16). Despite including 102 studies, George et al.,2020 only had three studies in common with Mremi et al.,2021 and two studies in common with Wolfe et al.,2021, Ng'etich et al.,2021, and Phalkey et al.,2013 respectively (See Appendix 5).

5.3.2. Primary studies

See Appendix 6. Five primary studies on IDS published between 2010 and 2021 were identified for inclusion in this review (24-28). Four studies originated from low resource settings in Africa (24-26;28), and one study from Palestine (27). Four addressed the IDS for one specific country, including Palestine, Nigeria, Kenya, and Tanzania (24-27), and one addressed the epidemic preparedness and response for the African region (28).

A mixed-methods approach was used in three out of five primary studies (26;28), with the inclusion of quantitative data from IDS reports, documents, or surveys and qualitative data from interviews discussions or open-ended questions. One of the included primary studies only used qualitative data (27), and one used quantitative data (25).

The IDS in four of the primary studies took place on human surveillance alone, focusing on public/government-sponsored health facilities in two studies (25;26). Two studies assessed the uptake and potential gaps of IDS at the local level (24;25), one on the IDS performance on the regional level (26), and one on epidemic preparedness at the national level (28). One study (27) assessed barriers for the integration of human and animal disease surveillance (One Health) during the COVID-19 pandemic.

Only one of the primary studies described the organization of the IDS system in Zanzibar (Tanzania), the type and flow of information up through the system (community-health facility-district- national - WHO and partners), and the type and flow of feedback, which only reached the district level. An epidemiologic and an HMIS unit were at the national level of the IDS system.

All primary studies reported solely process outcomes and did not report potential cost-savings or saved lives (i.e., effect outcomes) due to IDS implementation.

5.3.3. Funding

All but two of the included reviews reported the sources of funding received for the review production, and seven of the eight reviews reported no conflicts of interest. One review (21) provided no information on funding or conflicts of interest. None of the reviews reported on funding sources or conflict of interest in the included primary studies. For the primary studies included in this scoping review, all reported funding, and no conflicts of interest.

5.4. Emerging Themes from Included Reviews

In this section we have summarized information related to our research questions retrieved from the eight reviews (16-23), and five primary studies (24-28) included in this scoping review: RQ-1: on the definitions or descriptions of IDS, RQ-2: the key features/key requisites of an effective IDS system, and RQ-3: the challenges, and enablers/opportunities of IDS-system implementation. We have used the conceptual framework developed for this project (Figure 1) to analyze the extracted information and to identify emerging themes. It should be noted that some of the results relate to the response part of the system, but this scoping review focuses on the surveillance aspect.

5.4.1. RQ-1: How is IDS defined and described in the literature and how has this evolved over the course of the COVID-19 pandemic?

5.4.1.1. Scope or aim of IDSR in the literature.

See Appendix 7. The reviews varied in their descriptions and definitions given for IDS. One (19) of the eight reviews defined IDS, and four reviews (17;18;20;23) described the aims or the intent of the IDS strategy. Two (24;25) of the five included primary studies described IDS and two studies (26;28) described the goals or intent of IDS. One study (27) provided neither a definition, nor a description of IDS. As with the reviews, the included primary studies varied in their descriptions and definitions given for IDS.

Two of the reviews (18;20) discussed the use of IDS to improve the countries' surveillance systems and responses; two reviews (18;23) indicated that the IDS strategy should be implemented at all levels of the health system, whereas one review (17) described the focus of the IDS strategy at the district level. Three reviews (17;19;20) discussed the use of IDS to integrate surveillance systems and databases, and one review (19) described a focus on multiple diseases or behaviors of interest, while in another review (23) the focus was on priority diseases. None of the reviews included streamlining of processes, improvement of data usability, or the use of standardized tools in their description of IDS. Three reviews included the One Health strategy in their papers (16;20;22).

Three of the primary studies (24-26) included the improvement or strengthening of surveillance and response systems in their description of IDS. One study (28) discussed the use of IDS to "implement a coordinated and integrated approach" to surveillance systems; three studies

(24;25;28) included the improvement of data usability, and three studies described various targets of data collection as: 'primary causes of mortality and morbidity'(24), 'illnesses and disease outbreaks' (25), and 'priority communicable diseases' (28). None of the studies made any mention of the different levels of the health system, streamlining of processes, or the use of standardized tools in their description of IDS. None of the included reviews or primary studies described changes to the IDS system triggered by the COVID-19 pandemic.

Phalkey et al.,2012 (19), used the IDS definition by Nsubuga et al.,2006 as: "a combination of active and passive systems using a single infrastructure that gathers information about multiple diseases or behaviors of interest" (1). The aim of the IDSR strategy described was to "strengthen surveillance and response at each level of the health system by building local capacities; leveraging strengths and expertise through partnerships and co-ordination; training personnel at all levels; developing and implementing plans of action; mobilizing resources; integrating multiple surveillance systems to ensure efficient use of resources; improve the use and flow of surveillance information; strengthen laboratory capacity and involvement; emphasize community and clinician participation; use data thresholds to trigger alerts"(19).

Ng'etich et al.,2021 (18), described the IDS strategy as a "framework providing a platform to improve national public health surveillance and response capacities" with the aim to "strengthen the public health system at community, health facility, district, and national levels to ensure timely detection, confirmation and response to public health threats to alleviate illness, disability and mortality.

Although focused at the district level, Wolfe et al.,2021(23) similarly described the goal of IDSR as a "strategy to develop sufficient surveillance and response capacities at each level of the national health system to produce a flexible priority disease surveillance system" (23). In addition, Wolfe highlighted that a key requirement of the IDSR strategy was the development and dissemination of information products to inform decision-making by policy makers. This included the writing and publication of scientific articles on IDSR (23).

Ibrahim et al.,2020 (24) described IDSR as "a framework implemented to improve the usability of surveillance and laboratory data, and to improve detection and response to the primary causes of morbidity and mortality in African countries". IDSR serves as a planning guide and framework for identifying major public health problems, and for monitoring and assessing the impact of interventions.

Omondi et al.,2020 (25), described IDS in terms of the improvement of data for public health action, and as "a unit of the healthcare that makes surveillance and laboratory data more usable in improving detection and prevention of illnesses and disease outbreaks." IDSR needed "exhaustive data gathering, thorough analysis and proper dissemination of the information for effective decision-making"(25).

The review by Kebede et al.,2010 (28), was focused on trends in communicable diseases and epidemics in the African Region. The review provided a comprehensive description of the process and goal of IDSR to "implement a coordinated and integrated approach to data collection, analysis, interpretation, use and distribution of surveillance information on priority communicable diseases to assist in public health intervention decisions, including timely and appropriate responses to epidemics".

One review by George et al,2020 (16), described system integration as the "sum of all surveillance activities which add up to the broader surveillance system – this can include the merger of surveillance systems with health records databases, sharing databases and merging of surveillance activities and processes". In addition, this review also included a description of One Health surveillance integration as: "surveillance activities that span multiple sectors including human, animal and environmental health and benefit from cross-fertilization and exchange to promote health for all". It also defined the purpose of animal surveillance as: "a tool to monitor disease trends, facilitate control of infection or infestation, and provide data for risk analysis in animal or public health in order to substantiate sanitary measures and to provide assurance to trading partners" as described by the World Organization for Animal Health (OIE).

Sahal et al. (21) described the integrated approach as one that "envisages all surveillance activities as a common public service using similar structures, processes and personnel to carry out many functions". Their review was focused on communicable disease surveillance, and like the review by George et al,2020, described the integration of communicable disease surveillance as the "sum of all surveillance activities that add up to the national surveillance system".

Another review by Mremi et al,2021, detailed the intent of IDS as "a strategy to create and implement a comprehensive, integrated, action-oriented, district-focused public health surveillance for African countries" (17). Saleh et al.,2021 (26), similarly described IDS as "a means towards strengthening epidemiologic surveillance and response in the African region".

A review by Wendt et al,2013 (22), focused on zoonotic disease surveillance and the integration of human and animal disease information. However, no definition or description for IDSR was provided. The authors described the One Health concept as "a global and integrative approach to improve the health and well-being of people, animals and the environment" and "reflects the collaboration in the field of surveillance and monitoring" (22). Another review by Abuzzer et al.,2021 (27), that also covered One Health defined the integration of One Health surveillance as: "as an approach to designing and implementing programmes, policies, legislation, and research with multiple sectors communicating and working together to achieve better public health outcomes."

The review by Pilot et al,2019 (20), described the aims of the Integrated Disease Surveillance

Program (IDSP) in India to improve "overall surveillance procedures and to specifically enhance laboratory networking and quality assurance", as well as "to review case definitions and facilitate the integration of inefficient and vertically operating disease control programs" (20). However, this review was focused on dengue disease surveillance, and not on IDSR specifically. The IDSP's administrative and financial functions, a decentralized state-based surveillance system targeting a few outbreaks prone diseases, was merged with the National Surveillance Program for Communicable Diseases (NSPC). This enabled "the merging of resources and databases for improved operations, better planning and increased effectiveness of infectious disease control" and connected the whole public health reporting system within districts (20).

By comparison, Integrated Disease Surveillance (IDS) was described by the WHO as: "an approach that aims at collecting health data for multiple diseases, using standardized tools". The WHO further elaborates integration as "the efficient use of human resources, and harmonizing different methods, software, data collection forms, standards and case definitions in order to prevent inconsistent information and maximize efforts among all disease prevention and control programs and stakeholders (29)." Using the descriptions of IDSR proposed by WHO (29), six integral parts to the IDS description were identified: (1) improvement of the countries' surveillance system and response, (2) occurring at all levels of the health system, (3) integration and/or streamlining of surveillance activities, (4) improved usability of surveillance data (laboratory data included), (5) collection of data on priority diseases, conditions and events (multiple diseases, or leading causes of mortality and morbidity), and (6) the use of standardized tools. IDSR also incorporates the One Health concept that considers the interface between human health, animal health and the ecosystem.

5.4.1.2. Integration as a concept

Various descriptions of the concept of integration in the context of disease surveillance were provided across the included articles (16;17;20;21;25-27). The degree of integration, stage of the surveillance process when it occurs, as well as the type of data that are integrated, may vary as reported by the different articles:

Abuzerr et al.,2021 (27), highlighted that an integrated One Health surveillance system can involve varying degrees of integration that may occur at different stages of the surveillance process (e.g., at the planning or dissemination of surveillance results stage), and that can take many forms (e.g., across sectors, disciplines, decision-making scales, and public–private partnerships).

George et al.,2020 (16), described how integration may include "merging of health records database with surveillance system, sharing of databases with heterogeneous data to form common indicators or merging of surveillance activities and processes, and changing organizational structures and responses". They further discussed the categorisation of (system)

integration according to four dimensions: interconnectivity, interoperability, semantic consistency and convergent integration (as previously described by Myerson) (16).

Mremi et al.,2021 (17), described the various degrees of (system) integration ranging from interconnectivity (e.g. a simple transfer of files with basic applications), to complex convergent integration that requires merging technology with processes, knowledge, and human performance. Sahal et al.,2009 (21) similarly described the integrated approach as one that "carries out many functions using similar structures, processes and personnel". Saleh et al.,2021 (26) also described integration in terms of surveillance activities and structural organization.

Omondi et al.,2020 (25) on the other hand discussed the integration between individual health and public health interventions after combined analysis of data from health care providers and healthcare workers. Wendt et al.,2015 (22) described the integration of different sectors, i.e., surveillance initiatives which integrate information from humans and animals on zoonotic diseases (One Health).

Six of the other included articles however did not provide a definition or description of the concept of integration (18;19;22-24;28).

The WHO IDSR technical guidelines refer to integration in terms of integration of resources, processes and coordinated action: "the efficient use of human resources and harmonizing different methods, software, data collection forms, standards and case definitions in order to prevent inconsistent information and maximize efforts among all disease prevention and control programmes and stakeholders. Where possible, countries use a common reporting form, a single data entry system for multiple diseases, and common communication channels. Training and supervision are integrated, a common feedback bulletin is used, and other resources such as computers and vehicles are shared between programs for effective use of limited resources. IDSR involves nearly full-time coordination of surveillance activities and joint action (planning, implementation, monitoring, evaluation) whenever it is possible and useful (29).

The WHO IDSR guidelines go on to state that in an integrated system, surveillance activities are coordinated and streamlined (29). Resources are combined to collect information from a single point at each level, rather that maintaining separate vertical activities. Activities are integrated to take advantage of similar surveillance functions, skills, resources and target populations. For example, surveillance activities for acute flaccid paralysis (AFP) and neonatal tetanus can occur at the same time, with a health worker collecting data on both events when visiting facilities (29).

5.4.2. RQ-2: What are the key features and pre-requisites (workforce, technology, governance and finance, etc) of effective IDS systems?

See Appendix 8, and Table 3

5.4.2.1. Governance

Our review found limited information on features of, or pre-requisites for effective IDS governance (leadership, accountability, regulation and enforcement) from the included studies. Ibrahim et al.,2020 (24) stated that the involvement of all health facilities in IDS will produce more reliable data. Phalkey et al.,2013 (19) stressed the importance for IDS to have leadership in place at both central and peripheral levels. Abuzerr et al.,2021 (27) also described the need for improved governance and leadership for an effective surveillance system. For IDS and epidemic preparedness and response, Kebede et al.,2010 (28) highlighted the necessity for government commitment to implement IDS and strengthen country capacity.

5.4.2.2. System and Structure

Within the system and structure domain some important features were highlighted across multiple articles. Digitization and electronic reporting systems were a key feature that could minimize costs while leveraging mobile technology (18) and improve timeliness and quality of surveillance data (21). Effective IDS systems also require strong coordination and communication between sectors for successful integration. Overall organizational structure was another key theme across the included articles. Specifically, an effective organizational system for IDS needs the ability to accommodate both vertical and horizontal information flow (16;19), two-directional information flow (21), and be set up with enough flexibility to respond to new challenges that may arise. Mremi et al.,2021 (17) discussed the need for effective IDS to contain both indicator- and event-based surveillance, and to integrate data from multiple sources. George et al.,2020 (16) succinctly highlighted that for IDS systems to be effective it needs interconnectivity, interoperability, semantic consistency, and convergent integration across sectors.

5.4.2.3. Financing

Few articles (16;18;23;26) touched on the financing domain. The overall theme was the need for adequate, integrated, and sustained funding for an effective IDS. None of the articles discussed domestic financing or the need for country ownership of the IDS system.

5.4.2.4. Core functions

The core functions domain specifically pertains to eight components of the surveillance-response cycle: detect, report, analyze, investigate/confirm, respond, feedback, evaluate, and preparedness. From the articles reviewed; data was the common theme that emerged. The articles highlighted the need for data that is timely, standardized, complete, comparable, accurate, and transparent. The collection of data should include informal and formal sources for timely detection of outbreaks. It should also be collated and compiled in a consistent way that

allows for effective data analysis. The coordination of case definition reporting protocols across programs improves completeness (17). For effective case confirmation data, prompt specimen collection and improved handling, strong case confirmation capacity, quality surveillance reporting, and improved documentation are required. IDS systems also need to be evaluated on a routine basis (21) and require enhanced feedback mechanisms from higher through to lower levels of the system (18). Outbreak/epidemic preparedness involves predicting the occurrence of possible epidemics, as well as possible locations and populations affected, which requires good information on prior risks to inform response plans (17).

5.4.2.5. Resourcing Requirements

Almost every article in this review touched on the resourcing requirements (e.g., human resources, laboratory capacity, data, IT, SOPs) domain for an effective IDS system (Table 3). Sufficient human resources with enhanced training were a central theme (16-18;23-25), as well as the need for enhanced laboratory facilities and capacity. An effective IDS system also requires updated infrastructure including IT systems and records databases that communicate well, supporting technology including computers and other communication equipment, and data management tools (23). Standardization, including clear SOPs (16), protocols and training materials (18), as well as the creation and distribution of all reporting tools across every level of implementation (24) was also highlighted as important for an effective IDS system.

Table 3. Overview of reviews and primary studies reporting features and prerequisites of effective IDS systems

Author Year	Country/ Region	Governance	System/ structure	Financing	Core functions	Resourcing requirement
Reviews						
George et al.,2020 (16)	Worldwide		✓	✓		✓
Mremi et al.,2021 (17)	Sub-Saharan Africa		✓		✓	✓
Ng'etich et al.,2021 (18)	Africa		✓	✓	✓	✓
Phalkey et al.,2013 (19)	LMIC	✓	✓			
Pilot et al.,2019 (20)	India				✓	✓

Sahal et al.,2009 (21)	Worldwide		✓		✓	✓
Wendt et al.,2013 (22)	Worldwide		✓		✓	✓
Wolfe et al.,2021 (23)	Africa		✓	✓		✓
Primary studies						
Abuzerr et al.,2021 (27)	Palestine	✓				
Ibrahim et al.,2020 (24)	Nigeria	✓				✓
Kebede et al.,2010 (28)	Africa	✓				
Omondi et al.,2020 (25)	Kenya					✓
Saleh et al.,2021 (26)	Tanzania			✓		

5.4.3. RQ-3: What are the identified challenges to and enablers/opportunities of IDS development?

See Appendix 9, and Table 4.

5.4.3.1. Governance

Few reviews reported on challenges, or opportunities related to IDS governance. The lack of regulation and coordination (19), and lack of national laws enforcing notifiable disease reporting (20) were reported as impediments to a functional IDS system. Poor leadership and governance were also highlighted as challenges for an effective IDS (27).

None of the included articles specifically discussed challenges related to accountability or sharing of data across databases.

In terms of enablers, Pilot et al.,2019 (20) identified the active sharing of reports across programs, and close cooperation with IDS program authorities, as opportunities that could help to streamline procedures and reduce inefficiencies.

5.4.3.2.System/structure

Some of the system/structure dimension challenges were related to poor or inadequate sector integration and/or coordination of vertical disease surveillance programs (19;20), of other programs and health structures (20), and parallel data collection resulting in overburdening of staff (23). Other challenges included the exclusion of NCDs, weak infrastructures at the district level (19), and overall weak public health systems (28). Poor involvement of the private sector in IDS (19;20), and overall limited participation of public health facilities in IDS were identified as challenges to IDS (20;24). Disparate data, especially for integrated One Health surveillance (e.g., different documentation conventions), were reported to limit system integration (22). Underuse of healthcare- and non- healthcare data (e.g., CRVS data) due to limited integration, was touched upon as a challenge in one review (17). The overall performance of the system was negatively impacted by frequent changes in the programs' functioning, reporting formats and procedures (16;20). The lack of policy coherence was also identified as a challenge with the IDS system (27).

Systems integration has the potential to improve data quality, and the timeliness of data (16). Using or merging the IDS system with existing systems, e.g., the influenza surveillance system (23), or the SEED system (System for Early warning based on Emergency Data) (20), may reduce redundancy, improve effectiveness and enable earlier identification of outbreaks (20;23). Use of electronic reporting systems might improve the timeliness of surveillance data (23), mainly in developed countries where the systems are well established (21). Including community-based surveillance (CBS), as part of the IDS system, also has the potential to strengthen the early detection and reporting capabilities for several priority diseases and events (17;18).

Applying an integrated One Health approach to disease surveillance enables the use of a combination of existing information, which may result in more effective and efficient preparedness and response systems by detecting disease in animals first (syndromic surveillance instead of only diagnostic data). The One Health approach may further help to better assess the magnitude and spread of zoonotic agents, improve the understanding of health risks at the human- animal interface, and to efficiently manage and coordinate health events involving both human and animal sectors and their environment (17;22).

Mremi et al.,2021 (17) reported some successes in integration of the surveillance functions of the categorical (or vertical) disease control programs. Ng'etich et al.,2021 (18) identified that weekly reporting forms increased disease surveillance reports. Clarity on proper reporting channels and reporting dates, an efficient reward system for reporting, and effective reports documentation of public health actions or decisions following data collected from surveillance systems may also improve the system. Ng'etich et al.,2021 (18) further suggest analysis of surveillance data, close monitoring of surveillance performance indicators at regional levels, and routine data analysis centered on surveillance system performance monitoring, as means to

improve data accuracy. Adequate and prompt feedback may also improve surveillance activities (18).

5.4.3.3.Financing

None of the reviews went into any depth discussing domestic financing of IDS systems. It was merely described as non-sustainable and a major challenge (16;18-20;23). Pilot et al.,2019 (20) reported a strong reliance on 'out of pocket' expenditure as a problem. One primary study (27) also described limited financial resources for IDS implementation as a challenge.

5.4.3.4. Core functions

The operationalization of the core functions of surveillance were overall deemed to be inadequate. Challenges especially related to weak case identification, poor data quality, inadequate analysis and reporting, were frequently reported across the reviews included. Less information was provided on the other core functions such as investigation/confirmation, response, feedback, epidemic preparedness and evaluation.

The low use of standardized case definitions (SCDs), weak case identification and recording at primary healthcare centres (PHC) especially for less common diseases (17-19;24), and low motivation among healthcare workers for surveillance (17;26) were frequently reported challenges. Phalkey et al.,2013

(19) identified limited syndromic surveillance as another challenge. There was limited knowledge of terms of reference, surveillance procedures, and case definitions, and a general lack of compliance with standard operating procedures (SOPs) (16).

Poor data quality, paper-based reporting (17-19), and other reporting issues (accuracy, incomplete data, delay in reporting, under- or over-reporting) (20;23;25;28) were consistent themes across included reviews. Limited knowledge on the reporting process (e.g., appropriate reporting channels, correct forms, and dates for report submissions) (18) was also an issue. Frequent changes in reporting formats were another hindrance (19). Different reporting policies, and disparate data reported in different formats with different quality, were identified as challenges to system integration at all levels (16;22).

Effective analysis was hampered by poor data management, limited capacity for analysis and poor analytical skills (17-19;24), and insufficient analysis of routine data. Data from Health Management Information Systems (HMIS) were rarely assessed for quality and rarely analyzed and used for decision- making (17).

Weak diagnostic laboratory capabilities at facilities (23), particularly at the peripheral level, also hampered local investigations and confirmation of disease (19). There was reported to be a limited generation of reliable health information (24), as well as poor use of surveillance data at source (18) and for decision-making in general (19;24). Poor epidemic preparedness, with

inactive response teams and poor coordination of activities were also reported (19). Feedback was reported to be inadequate and/or erratic (18;19;23). It was also neglected at the health facility level (18). The ability to evaluate data for accuracy was noted to be poor, as was the measurement of completeness of data reporting (22). Similarly, there was limited use of outcomes from surveillance performance analysis (18).

Although many issues with the core functions were described, some improvement in the completeness and timeliness of data, as well as the analysis and use of routine HMIS data at sub-national levels in some countries, has been reported (17). There were also reports of training activities at national and regional levels contributing to an overall improvement in data collection, analysis, and interpretation for public health action (21). Similarly, there were reports of feedback mechanisms for sharing national surveillance data, increased national level review and use of surveillance data for the response although many of these functions were still reported to be sub-optimal.

5.4.3.5. Resourcing requirements

The resource requirements were overall deemed to be inadequate, with challenges especially related to the lack of dedicated skilled personnel, and inadequate training and supervision. There were also limited laboratory capacities (and lack of functioning laboratory networks), poor network, technical capability, and inadequate infrastructure (e.g., lack of computers) for realizing web-based reporting, poor quality of data and/or high data complexity and underuse of data, as well as lack of materials (including job aids) and transport facilities.

Almost all reviews and primary studies identified the lack of skilled designated surveillance personnel, inadequate training, and high staff turnover at the peripheries (18;23), as major challenges to a functional IDS system (16-19;23). Limited supervision from the next level up (23;24), or lack of supervision especially at district level was another related problem (18;19). Training was typically limited to regional and national levels. Irregular and partial supervision usually undertaken at the regional and district levels and mostly on vaccine preventable diseases (18;19). All primary studies supported the notion of inadequate human and material resources as major challenges to IDS (24-28).

Limited laboratory capacity (16-19;23;28), and the lack of functional laboratory networks (19;23) was another main challenge identified in the included reviews. Laboratories were said to be ill-equipped (due to limited laboratory supplies and poor knowledge on specimen handling) to provide confirmation of suspect priority notifiable infectious diseases. There was also a further lack of capacity for timely clinical screening, referral, diagnosis, notification, treatment and containment of suspected cases (17;18;24). Ng'etich et al.,2021 (18) mentions the lack of ownership and consideration of laboratory activities and budgets in national health plans as another important policy issue.

The linkage and management of heterogenous data, incomplete integration, and quality and complexity of data are major challenges for system integration (16). Underuse of other available data sources (civil registration, demographic surveillance sites, research outputs, meteorological data etc.) for planning national disease control programmes was also noted (17).

The slow adoption of technologies, as well as complex and expensive installation of systems, were also issues (16). Poor network, technological capacity (18), and inadequate infrastructure (computers, databases, data mining systems and analytical software) for web-based reporting (16-18;22) were commonly reported.

There was also the lack of clear guidelines including IDS technical guidelines, as well as lack of availability of job aids such as standardized case definitions (SCDs), and various reporting and management tools at health facilities (17;18;23-25). The lack of equipment and laboratory reagents, limited storage (17;19) and transport facilities were particularly issues at the periphery (17;19;23;24).

There were also possible enablers identified for more efficient and effective functioning of IDS systems. Increasing the number of staff trained on disease surveillance, and having a designated focal person increased the adequacy of reporting and reduced workload (18;23). Other enablers included incorporating surveillance activities into job descriptions, as well as training conducted through initial pre-service curricula, induction and on the job training at both the community and district level. Supervisory visits, sensitization meetings, and continued training on correct form filling and reports compilation also helped. Increased awareness of the benefits of supervision and efforts to enhance supervision, together with strict adherence to planned surveillance schedules that prioritized surveillance and supervisory visits were also useful enablers (18).

Other enablers reported by Ng'etich et al.,2021 (18) were the use of electronic reporting systems, mobile-SMS based reporting and use of mobile technologies, technical support, network boosters, and health information systems strengthening. Health facilities that displayed visual aids for IDS functions were more likely to report surveillance data. Posters and the provision of guidelines, as well as properly designed operational plans, and health policy reviews were also useful (18). In Nigeria, a post-basic training intervention was significantly associated with improved reporting practices as a result of the availability of forms and recognition of health workers' reporting efforts. Mremi et al.,2021 (17) also reported improvement of the IDS system through the introduction and use of eIDSR (electronic IDSR) that utilized SMS for reporting weekly epidemiologic data, and implementation of standard surveillance, laboratory and response guidelines. The strengthening of laboratory networks, and quality assurance of dengue diagnosis, were reported to help (20).

Table 4. Overview of reviews and primary studies reporting challenges to and enablers of IDS systems

Author Year	Country/ Region	Governance	System/ structure	Financing	Core functions	Resourcing requirement
Reviews						
George et al.,2020(16)	Worldwide		C/E	C	C	C
Mremi et al.,2021(17)	Sub-Saharan Africa		E		C/E	C/E
Ng'etich et al.,2021 (18)	Africa		E	C	C/E	C/E
Phalkey et al.,2013(19)	LMIC	C	C	C	C	C
Pilot et al.,2019 (20)	India	C	C/E	C	C	E
Sahal et al.,2009(21)	Worldwide		E			
Wendt et al.,2013(22)	Worldwide		C/E		C/E	C
Wolfe et al.,2021(23)	Africa		C/E	C	C	C/E
Primary studies						
Abuzerr et al.,2021(27)	Palestine	C	C	C	C	C
Ibrahim et al.,2020 (24)	Nigeria		C		C	C
Kebede et al.,2010 (28)	Africa		C		C	C
Omondi et al.,2020 (25)	Kenya					C
Saleh et	Tanzania			C		C

al.,2021(26)						

C: challenges; E: enablers

5.5. Quality Assessment

5.5.1. Quality of included reviews

See Appendix 10. Most of the included reviews had a clear objective and/or research questions, described the inclusion and exclusion criteria, reported the funding received for the review, and based their conclusions on the review results. Three (19;20;23) of the eight reviews reported duplicate study selection and data extraction. Half of the reviews (16;18;20;23) referred to a published protocol and half (18;20-22) provided an adequate description of the characteristics of included studies. The other half did not describe the study design of included studies, the methods they used, nor their potential conflicts of interest or funding. All reviews reported search terms and/or a search strategy, but none provided a list of individually excluded studies with justifications for their respective exclusion. Only two (16;18) of the eight reviews reported having conducted a quality assessment of the included studies. We judged that three of the reviews had an overall *low quality* (16;18;23), and the others an overall *critically low* quality.

5.5.2. Quality of included primary studies

See Appendix 11. Three of the five included primary studies were mixed methods studies (24;26;28), one was a qualitative study (27), and one a quantitative study (25). For two of the studies (25;27), 80% of the quality criteria were met, while for two other studies none of the criteria were met. For mixed methods studies, the overall score cannot be more than the weakest score of a component. For the two studies that had an overall quality rating of 0%, the mixed methods component was rated as 0%. A detailed description of how the quality assessment criteria were met is provided below.

5.5.2.1. Mixed methods studies

For one of the studies (28), we found one of the screening questions to be unclear, and therefore, in accordance with the MMAT guidance (15) was judged to be of poor quality and no further assessment was carried out of the remaining quality items.

For the other two studies (24;26), we judged the research questions to be clear, and the qualitative approach and data collection methods to be appropriate. However, there was insufficient information in both studies that made it difficult to judge whether the different study components adhered to the quality criteria of each tradition of the methods involved. In addition, it was unclear whether the findings were adequately derived from the qualitative data, and whether the interpretation of results was sufficiently substantiated by data. Major observations and conclusions without specific frequencies reported from interviews in both studies (24;26) made it difficult to judge whether there was coherence between the qualitative data sources, collection, analysis and interpretation.

As for the quantitative data, the methods (i.e., sampling strategy, measurements, statistical analysis) were appropriate, and the risk of non-response was low. It was however unclear whether the sample was representative: in one study (24) the recruitment focus was on places close to the state capitals, and in the other (26) mainly public facilities were included, and no sample size calculation was performed.

Neither study (24;26) provided an adequate rationale for using a mixed methods design to address the research question. It was also not clear whether the different components of the studies were effectively integrated to answer the research question, and whether the outputs of the integration were adequately interpreted.

5.5.2.2. Qualitative studies

For the one qualitative study (27), it was unclear whether the interpretations were adequately substantiated by data, while the other quality items were judged to be adequate.

5.5.2.3. Quantitative studies

As for the one quantitative study (25), we judged the methods (i.e., sampling strategy, measurements, statistical analysis) to be appropriate, and the risk of non-response to be low. It was however unclear whether the sample was representative since only government-sponsored health facilities were include

6. DISCUSSION

6.1. Summary of Main Results

We identified eight reviews and five primary studies eligible for inclusion in this scoping review that covered the conceptualization and operationalization of current IDS systems. Five of the reviews were narrative systematic mixed studies reviews, two were literature reviews, and one was a scoping review. The included primary studies constituted a mix of qualitative, quantitative, and mixed methods studies. Only two of the eight reviews had assessed the quality of included studies. The included reviews, which were published between 2009 and 2021, were heterogenous in terms of aims, scope, search terms, and search cut-offs. Most articles focused on IDS systems in the WHO African Region, human sector disease surveillance, and communicable diseases. We judged the quality of the included body of evidence to be low to critically low.

6.1.1. RQ1: How IDS is defined and has evolved over the course of the COVID-19 pandemic

The scope of IDS in the included articles ranged from human sector surveillance only, to an integrated One Health system, which may be further extended to include the entire government surveillance system. Only one of the included articles provided a definition of IDS, while the other articles provided various descriptions of the intent, aims, scope, or goal of IDS, as a strategy, framework, platform, health unit, or means to improve surveillance, while highlighting different aspects of the system as important (e.g., useability of data, use of single infrastructure, coverage). This diversity of interpretation of IDS suggests a lack of a common definition for IDS, nor articulated understanding of the nature of IDS or of the parts that constitute the system.

Various descriptions of the concept of 'integration' were provided in the included articles. It was described in some articles as involving organizational structure, processes and personnel (16;17;21;26). Other studies described that it may differ in terms of the degree of integration (17), the stage of the surveillance process when it occurs (27), and in the type of data (25), databases (16), or sectors (22) that are integrated. However, it was typically not explicit in the included articles what type of integration was assessed in the IDS systems under study.

We identified no articles that reported on the evolution of IDS systems triggered by the COVID-19 pandemic (e.g., on accelerated integration of genomic surveillance as advocated by the WHO (30)). However, any additions or changes to the IDS system brought on by the recent pandemic may not yet have been evaluated. Similarly, as the pandemic is recent, work on this aspect may have yet to make it into academic publications.

6.1.2. RQ2: The key features and pre-requisites of effective IDS systems

Whilst there was no common definition of IDS, there were some features and prerequisites of effective IDS systems that were alluded to in the included articles. These were mostly related to the adequacy of core functions (e.g., improved data quality and timeliness), resources required (human resources, laboratory capacity, data/IT infrastructure, SOPs etc.), and the importance of digitization and electronic reporting, strong coordination and communication. The role of NPHIs or equivalent agencies within the IDS system structure was not discussed in the included articles. It was also not clear whether all had a functioning public health agency in place. A couple of articles mentioned good leadership, both at the central and peripheral levels, as well as the involvement of all health facilities, as important factors for good governance. None of the included articles discussed governance structures and charters (i.e., they did not clearly define the respective roles, responsibilities and authority of the entities constituting the IDS system), nor did they discuss laws or regulations that could support system integration and facilitate data sharing. What was required in terms of financing was not discussed in depth in the included articles, which only briefly mentioned the need for adequate and sustainable financing of IDS systems.

6.1.3. RQ3: The identified challenges, and enablers/opportunities to IDS development

Comparably more challenges to IDS-implementation were identified in the included articles than enablers, opportunities or successes. The provision of core functions (data quality, reporting, analysis and feedback) and resourcing (human resources, laboratory capacity, IT infrastructure etc.) were described as overall inadequate, in particular at the local health facility and district level. For some of the core functions such as investigation, response, epidemic preparedness and evaluation, there was limited information, e.g., the monitoring and evaluation of the IDS system, regular analysis of reporting indicators and review of data quality, as well as consideration as to how they impact response activities were not discussed in the included articles. Financing was only briefly described as either inadequate, lacking or non-sustainable when touched upon. Governance was also, when mentioned described as poor, but not further elaborated on. From statements on the progress and status of IDS made in the included articles, it is evident that while there are countries that have reported various improvements in processes over time (e.g. using or merging the IDS system with existing vertical systems, increased staff training and supervision, designated focal person, surveillance activities incorporated into job descriptions, feedback mechanisms, electronic/mobile reporting adoption, technical support, network boosters, and health information systems strengthening, visual aids, provision of guidelines and properly designed operational plans, and health policy reviews etc.), the functioning of current IDS systems is typically still suboptimal in many countries.

Coherence with the conceptual framework and proposed core principles for IDS

We discuss below the findings of the scoping review in relation to our conceptual framework and the five core principles for IDS systems as proposed by Morgan et al. (5), which to some extents were reflected by what was highlighted as priorities for IDS in the literature. Population-based data and integration of non-healthcare data sources (e.g., CRVS data) in IDS, was touched upon but only to describe the problem of non-use of this type of data for disease control purposes. The need for digitized reporting at all levels of the IDS system (including at the health facility level) was highlighted as a priority in many of the included articles. A more detailed discussion of related issues such as unique health identifiers, privacy issues, and web access, was typically lacking, as was any discussion of data transparency and automatic reporting to NPHIs or equivalent agencies (and WHO). Financing was only briefly mentioned as inadequate and non-sustainable in the included articles, which also did not discuss the sources for funding or the ownership of the IDS systems.

Governance and role of legislation

The importance of effective governance (e.g., good leadership at both central and peripheral level, government commitment, regulation and coordination etc..) for a well-functioning IDS-system was only briefly touched upon in the included articles (19;20;24;27;28). One of the reviews (20) reported challenges to IDS development related to national laws, i.e. low reporting completeness as national laws in India do not enforce notifiable disease reporting. None of the articles however, discussed other potential impact national laws and regulations may have on IDS development, e.g., in hampering or facilitating sharing of data across databases, sectors or between countries (31), nor did they discuss governance structure or charter (i.e., they did not clearly define the respective roles, responsibilities and authority of the entities constituting the IDS system).

Public health infrastructure and the role of NPHIs?

A few of the included articles described the structure of the IDS system under study. None discussed the role of NPHIs, or other public health agencies, within the system (e.g., in central coordination, decision-making including forecasting, modelling, and analytics). This was surprising as one of the key roles of any public health agency is disease surveillance and control (32). Little was mentioned of the criticality of national public health infrastructure. The WHO African Region has the weakest public health infrastructure (33), and healthcare systems in many of these countries have very low functionality (including low physical access to essential health services) (34). It is reasonable to conclude that the overall structure and functioning of a country's healthcare system may affect their prospects for successful implementation of IDS. Similarly, countries experiencing humanitarian crises with a collapsed and/or fragmented

healthcare infrastructure (e.g. Sudan (17), Palestine (27)), undoubtedly would experience more challenges with IDS implementation (17;27).

Population-based data and data integration

According to the core principles for IDS (5), a fully integrated disease surveillance system data should be population-based and include data from civil registration vital statistics and sample registration systems to achieve valid denominators for mortality rates and disease burden, all of which are vital for surveillance activities. However, no article described the inclusion of this non-healthcare data in IDS. The problem with lack of or limited integration of healthcare and non-healthcare data (e.g. CRVS), was also mentioned in one of the reviews (17). In many of the IDS systems under study, the majority of the data were sourced from HMIS systems, which typically only reflects the part of the population who seek conventional healthcare (40% to 87% in Sub-Saharan African countries) (17), while many people (in both Africa and South Asia) rely on services provided by private and/or alternate practitioners. Another related problem was the incompleteness of data due to low reporting into the IDS system from public health facilities (23%-50%), and very low (3.3%) to non-existent reporting from private healthcare facilities (19-21;24). In some countries reporting to the IDS is conducted under the WHO IHR legislative framework, but it was not clear if this was the case in the included articles, and if so, whether it influenced reporting adherence. Regulatory enablers may possibly help improve reporting, if reporting under the IDS system could be mandated by law, and provided the law is enforced.

Digitization and role of technology

Digitization and electronic reporting were another consistent theme across the included articles. Although most included studies highlighted the need for digitization at all levels of the IDS system, for improved quality, and timeliness of data, other factors of importance for digitization (creation of unique health identifiers, privacy protection, and web accessibility) were not discussed to a great extent. One review (19) discussed challenges with duplication of cases in outpatient, inpatient and laboratory registers due to a lack of unique health identifiers. Three reviews (18;19;23) highlighted the problem with poor web access in remote areas negatively affecting reporting. None of the articles discussed privacy protection issues related to digitization.

The possibility of implementing IDS also depends on the context, as highlighted by George et al., (2020) (16), who pointed out the technological disparity between LMICs and HICs. There were higher levels of system integration in North America and Europe due to higher technical development, while the technical adoption in many LMICs was described as slow. This was supported by results from some of the other articles, which indicated that current IDS systems in many African countries, at least in part, still rely on paper-based reporting (in particular at the

health facility level). Dysfunctional technology can also be a barrier, and integration will require consistency in processes and interconnectivity between the different local databases and systems. Therefore, to achieve automated reporting to NPHIs/public health agencies, WHO and other regional bodies, the current IDS systems need the necessary technological infrastructure and to become fully digitized, from the bottom (health facilities) and up (regional, and national level).

Economic considerations

While many of the included articles mentioned the need for adequate, and sustainable funding of IDS, there was no information regarding the sources of funding for the IDS systems under study, i.e., no information on whether they received external donor or domestic funding. Nor was there any mention as to whether an agreed country financial (business) plan was in place to ensure sustainable long-term funding and adequate human resources for the IDS system over time. Likewise, there was no consideration of the cost-benefits of integrating disease surveillance. The actual impact of implementation of IDS on cost-savings (e.g., through economies of scale by reducing duplication and redundancies) were not discussed in the included articles, nor were the effects of IDS on disease control (i.e., on mortality and morbidity), which is the ultimate goal of introducing IDS. These are glaring gaps in the current literature.

There is no à priori assumption about the value of IDS to be accepted as an unquestioned truth. Investment in IDS costs time and money, and whilst IDS has the potential to make surveillance better, it also has the potential to make it worse. For example, alterations to existing siloed disease surveillance system in an attempt to integrate it with other surveillance systems may not result in something better. Similarly, frequent changes to the IDS system were also reported to have negative effects on the functioning of the system (16;19;20).

Laboratory infrastructure

Highlighted in many of the included articles were challenges related to lack of basic laboratory confirmation capacity, while increased pathogen sequencing capacity was not mentioned as a priority. The need for increased laboratory capacity, and functioning laboratory networks, were consistent themes in many of the included articles, while the scaling up of capacities for pathogen sequencing was not mentioned. It appears that in many countries a syndromic approach (with low specificity) is still the basis for decision-making (17), thus highlighting a need for increased basic laboratory confirmation capacity. It should however be noted that while four of the eight reviews were published after the outbreak of the COVID-19 pandemic, only four of the 272 articles included in these reviews were published after December 2019 (the discovery of SARS CoV2), and only one of these articles (with was dengue specific) were

published after June 2021, i.e. when Morgan et al. published the five core principles for IDS.

6.2. Completeness and Applicability of Findings

Most of the included articles focused on IDS implementation in the African region. Only one of the reviews (20) covered IDS programs in Asia (India), and one primary study (27) provided insight on barriers to integrated One Health (OH) systems in the Middle East (Palestine). Few reviews (16;21;22) included results of IDS implementation in high income countries, and those that did focused mainly on issues related to computer system integration.

It should be noted that whilst the majority of included articles focused on the WHO African Region, only around one third (28% to 35%) of the 47 member states in this region were represented in the three reviews published in 2021 (17;18;23), and one published in 2012 (19). These findings suggest that little has changed in terms of the number of peer reviewed publications of IDS assessments produced during the last decade. The lack of capacity for basic operations (implementation) research

(35) in these countries may be one reason for this, and publication bias another, i.e. difficulties with publishing system or program description/implementation studies in peer reviewed journals.

Most of the included articles focused solely on human sector surveillance. No study covered animal disease surveillance only (or environmental or biosecurity surveillance), and a few reviews (16;17;22) focused on the integration of human and animal zoonotic disease surveillance (One Health). While One Health (OH) systems are assumed to have the potential to improve prevention, prediction and control of zoonotic diseases (29), there is currently a lack of evidence from robust evaluations of effectiveness to support this. However, since around 60% of known infectious diseases, and 75% of emerging infectious diseases are zoonoses (36;37), it is reasonable to believe that OH has a significant role to play.

Information on the diseases included in the IDS systems was provided only in three of the included reviews (18;21;23), which covered 34 different diseases (or groups of diseases). Most commonly included was Measles, Cholera, Malaria and Tuberculosis, and while acute respiratory infections (including human influenza, and pneumonia) were included in a handful of articles in the included reviews, COVID-19 was not mentioned. But then, as mentioned earlier, only four of the articles in the included reviews were published after the start of the pandemic.

While the focus of all included articles was on various aspects of IDS, what was actually integrated (e.g., types of surveillance data, databases, organizational structure, processes,

personnel, vertical systems etc.) was typically not described in the included articles. For human sector IDS, data from health facilities (both in- and out-patient data), and from the HMIS system, appeared to constitute the main sources of data. In many countries this was mainly referred to as syndromic data (i.e., not laboratory confirmed data) (17). Pilot et al.,2019 (20) described a three-tier IDS reporting system with data flowing in from nurses (syndromic data), doctors (diagnostic data) and laboratories (laboratory- confirmed data). Data used by the OH systems described by Wendt et al,2015 (22) however, were described as predominantly confirmed diagnostic data from notifiable disease reports, or data collected from hospitals or laboratories, i.e., secondary data collected for other purposes. One primary study (25) combined data from primary health care providers with event data collected by community health workers.

Data from EBS and IBS are both part of the epidemic intelligence and vital for early warning and response systems (38). They, however, may have different monitoring indicators, require different monitoring tools and evaluation frameworks. One example is the EBS framework developed by Africa Centers for Disease Control (Africa CDC) (https://africacdc.org/download/africa-cdc-event-based- surveillance-framework/). It should be noted that the articles included in this review typically did not discriminate between data originating from EBS or IBS systems, nor did they detail pre-requisites or challenges specific to these different types of surveillance, and infrequently described the tools or frameworks used for monitoring or evaluation. Providing an overview of existing monitoring and evaluation frameworks was not within the scope of our review, but this could potentially be the topic of another review.

There is also a lack of repeat country assessments that might have shed some light on how IDS has evolved over time. However, from general statements on the progress and status of IDS made in many of the included articles, this suggests that there have been some improvements in processes over time, but the functioning of current IDS systems is still suboptimal. It was also not fully apparent from the review as to how IDS was used by stakeholders to effect change and inform disease control responses. For example, the reviews lacked granularity to demonstrate how IDS outputs informed risk assessments and disease control priorities. Neither was the communication element adequately explored, e.g., how well and how far data was communicated to practitioners, policymakers but also the public. It was also not clear how well information on public health actions taken was communicated back to the level of data collection (i.e., to health facilities or districts).

There were other potential key factors not identified or discussed in the included reviews and primary studies. For example, the IDS system was considered very much in isolation to other external factors, such as the potential impact of donor funding of specific disease control programs on other programs which was not mentioned. Much of the focus was on

communicable diseases with very little mention of the interface with non-communicable diseases or behavioral risk factors. Indeed, the main perspective for the articles was through a biomedical and technocratic lens that did not explore wider influences on disease surveillance such as human behavior, stigma, etc. It is not clear from the included articles what contextual factors and mechanisms lead to the observed outcomes. Notably, there was a lack of detail to describe the functioning of the IDS system in terms of coordination, communication, leadership, regulation, and accountability across the included reviews. None of the included articles discussed governance structure or charter (i.e., they did not clearly define the respective roles, responsibilities and authority of the entities constituting the IDS system), nor did they discuss laws or regulations that could facilitate system integration and data sharing.

Finally, what has not been possible to ascertain from the review is the criticality of the various components. The component domains as outlined in our conceptual framework intuitively are all desirable if not vital, but it has not been possible to determine the relative influence of each. Which domain holds greater influence and impact on the functioning and effectiveness of an IDS system? Is there a hierarchy of importance? Are there co-dependencies and synergies between the different components? In a similar vein, which components are more important in terms of their effect on outcomes? The ultimate test of any disease surveillance system would surely be its impact on disease control. It is not sufficient to be able to describe disease epidemiology better, i.e., integration on its own should not be the goal, but it is the means to achieve a higher goal. The articles in this review do not answer this question – there were certainly no robust before-after studies, nor any interrupted time series studies that could have provided insights as to the actual effect of IDS on disease control.

6.3. Limitations with Review

Due to the variety and complexity of the studied domain, this scoping review has some limitations. The main search of this review was restricted to articles written in English. Therefore, relevant reviews and primary studies published in other languages were not included. Furthermore, the search was conducted in only two major databases and three selected grey literature sources with a European and North American focus. Reports from Ministries of Health or WHO country offices and country- specific IDS technical guidelines or evaluation reports were excluded. Due to the short timeline of the project, the review was intentionally restricted to include only published reviews. This may have led to the exclusion of relevant reports and articles published after recently conducted reviews. We sought to reduce this potential limitation through additional searches for primary studies as detailed above. In addition, the use of different terms and definitions for integrated disease surveillance systems may have meant some potentially relevant studies were missed, in particular from countries not from the WHO African Region.

This review is mainly focused on evidence summaries. Therefore, the scoping results depended on the specific aims and quality of the reported outcomes within the reviews and primary studies. However, much heterogeneity of the included studies in terms of both aims and quality was observed. Some studies lacked detailed description and representativeness of their main outcomes. This led to incomplete synthesis of some elements of this review due to missing information such as the implementation level (local, district, national), the addressed sector (public, private), and the status of integration for human, animal and environmental disease surveillance.

We have adopted a deductive approach using the predefined conceptual framework to help organize our findings. This process risks discarding or marginalizing other emergent themes that may have been captured with a more inductive approach. To avoid reporting bias of included studies, the discussions and conclusions were reviewed for consistency with the collected findings. Due to low-quality reporting, this step was elusive in many studies. The overall low to critically low quality of the included reviews and primary studies with limited representativeness needs to be considered in further interpretations and generalization of the results. Additionally, publication bias may have influenced what articles were published as there is typically solid external support for the implementation and evaluation of IDS. However, no adjustments for this potential bias were made.

All reviews (and the majority of the primary studies) included some results based on subjective responses, which potentially may have been influenced by social desirability bias among study participants (39). In one review (18) 93% of study results were generated mainly from subjective

responses, but for most reviews it was not possible to determine the contribution of qualitative research to the overall results since information on study design and methods for data collection were inadequately described. We cannot therefore be completely confident of the accuracy of included evidence.

The included reviews picked up heterogeneous studies due to their different aims, search criteria and search cut-offs, which may have led to different results being reported. For example, in one review from 2009 (21) the majority of included studies had been conducted around the time (1998) when the IDS strategy was adopted by the WHO African region, i.e. during a period of initial/partial implementation. Two other reviews only included studies published after 2010/2012, i.e., after the publication of the revised IDSR technical guidelines (18;23), and thus did not include any results from the early implementation phases. A couple of reviews (16;20;22) included studies published before the IDS strategy was adopted, which may have generated some irrelevant data for our scoping review.

Further, the fact that around 30% of primary studies included in the reviews were published between 1992 to 2003, i.e., either before the adoption of the IDS strategy, or in the early phases of adoption in most countries, suggest that one third of included studies may not be suitable for assessing the current situation of IDS.

A problem with our scoping review that is specific to overviews of reviews is the overlap in terms of included primary studies across reviews (40). It is described by Lunny et al.,2021 as a problem of precision related to sampling. If the same primary study is included in more than one review this gives undue weight to this study, which may impact both a statistical synthesis, but also a narrative description of the results (40). The overlap across the reviews included in our scoping review ranged from around 0% for reviews with very different scope (20;22), for which little or no overlap was expected, and up to 43.3% overlap between Mremi et al.,2021 (17) and Ng'etich et al.,2021 (18). The quality of the Ng'etich et al.,2021 review was slightly better, although the Mremi et al.,2021 review included more studies. Both reviews included unique primary studies but had slightly different aims. Therefore, keeping one and excluding the other was not a viable option to address the overlap. We have instead used a matrix to visualize the overlap, which may be of help when interpreting the results of this scoping review. There is at present no standardized methodological approach to manage the problem of overlap when conducting overviews of reviews (40).

Finally, as we intimated at the start, the focus of this review has been on the surveillance aspect of IDSR. The ultimate value of any disease surveillance system is its impact on population health outcomes through the response instigated as a result of surveillance outputs. We have not studied the interface between surveillance outputs and disease control responses, nor of the consequent health outcomes. This is a limitation of this review, and a research gap that warrants

further research.

6.4. Implications for Practice, Policy and Research

6.4.1. Implications for policy and practice

The findings from the reviews to varying degrees support the conceptual framework proposed for IDS and affirm the need for good governance structure and charter, implementation of a functional system and structure for disease surveillance, and adequate resourcing (including human resource capacity for disease intelligence). However, the low to critically low quality of the included body of evidence prevents us from drawing any strong recommendations for practice or policy.

Nevertheless, there were some factors that were consistently reported across the included articles as important for a well-functioning IDS system and are therefore worth mentioning. These include the need for ample staffing with appropriate skill mix and training; improved laboratory capacity, digitization and digitized reporting for improved data quality and timeliness; as well as various components needed to deliver the core surveillance functions such as standardized case definitions, protocols and guidance. These factors are likely to be some of the key building blocks for IDS systems.

As noted above, there is no universal definition of IDS, and the various interpretations in part may reflect differing national priorities. Indeed, the degree of integration in each and every country is likely to vary, as well as the stage of the surveillance process when it occurs, and the type of data that is integrated. In addition, what is important for one system may not be a priority for another system. Consequently, national needs and priorities need to be considered, and, as Sahal et al.,2009 argue, a balance should be sought for a flexible surveillance system (21).

There are also the questions as to how much integration is optimal in terms of cost, effectiveness and resources, what should be integrated, how integration should be done and what key factors should be considered when integrating systems (16). The 1998 IDS strategy advocated that all surveillance activities should be integrated, such as the transportation of specimens, training of health personnel on surveillance and supervisory support to health facilities and districts (3). However, over-integration can lead to health workers being overworked with too many responsibilities, limited shared resources being over-stretched, and some units and programs not benefiting from the integration. George et al,2020 advised that the process of integration needs to be fully understood and its impact assessed through systematic evaluations using empirical data (16). This recommendation makes sense and future planned and ongoing integration efforts should be evaluated in order to maximize the benefits of IDS, minimize any

adverse effects, and to learn lessons on how best to operationalize it in different settings.

6.4.2. Implications for research

Stakeholders need to know that the IDS system meet their expectations (35), and therefore, in order to ensure continued funding, it is of utmost importance to be able to demonstrate to funders (e.g., Ministry of Finance or donors) the measurable benefits of IDS such as cost savings and lives saved through the investments in IDS. There is a need for adequate and robust evaluations of the effectiveness of current IDS systems, using measurable elements, and an assessment of the fitness for purpose and application of IDS (e.g. MERLA (41)).

Countries should be encouraged to conduct a review and evaluation of their IDS systems, identify gaps and resource needs, and report the key lessons learned in peer-reviewed academic publications that add to the evidence-based, and that may benefit other countries. All new IDS efforts should at least have a basic operations research (OR) capacity in place (a.k.a. implementation research capacity), so that discrete operational elements can be tested and either adopted, adapted, or discarded if they are not working. OR requires time and money but is critical to ensuring that what is undertaken is actually made to work (35).

The reporting into the IDS system was typically poor in the articles that provided this information. Since in some countries reporting is conducted under the WHO IHR framework, but not in others, it may be of interest to further explore the impact of this legal framework on reporting adherence. Other potential areas for research, role of funding sources and research into monitoring tools and assessment frameworks.

The quality of reviews (and primary studies) included in this review were generally poor and were not well suited to answering the key questions above. It may be useful for a future high-quality systematic review to be conducted, perhaps using a realist synthesis approach to study the contextual factors and mechanisms that influence the implementation and outcomes of IDS in countries. There may also be value in examining specifically case studies of IDS systems that work to find out what makes them work, i.e., a closer examination of success stories.

Although an attempt was made to identify studies or reviews that described changes made to IDS during the COVID-19 pandemic, no articles could be found. Future research should be conducted to describe the experiences with IDS during the COVID-19 pandemic as well as changes made to systems in response to COVID-19 to understand how the IDS system functions in pandemic settings. More research is also needed into how the IDS system is funded and the sustainability of the funding, as well as the presence of national IDS policies and plans on IDS implementation and delivery.

6.5. Conclusion

The existing evidence on the conceptualization and operationalization of IDS is fragmented, incomplete, and the included quality of evidence poor. The focus has mostly been on the African region, with little or no information on the level of IDS adoption in the rest of the world.

There is at present no agreed definition of IDS, nor any articulated and shared understanding of what constitutes an effective IDS system. Before country adoption of IDS and technical implementation, there should be a common definition and shared agreement on what IDS entails, as this is required for standardized operationalization, and would enable comparative evaluations and system improvement to take place.

From the results of this scoping review, seen through the lens of the conceptual framework and Morgan's 5 core principles for IDS, it appears that while there has been some progress in IDS in many countries, much is still wanting on all levels of the IDS system. The findings from the reviews to varying degrees support the conceptual framework proposed for IDS and affirm the need for good governance structure and charter, implementation of a functional system and structure for disease surveillance, and adequate resourcing. Indeed, before additional investment is made in countries without IDS, a financial (business) plan should be in place to ensure sustainable funding and adequate human resources for IDS in the long run.

Our review identified an important knowledge gap, which is the lack of robust evaluations of the effects of IDS on cost savings and disease control. One solution to this knowledge gap may be to encourage countries to conduct a review and evaluation of their IDS systems, identify gaps and resource needs, and report the key lessons learned in peer-reviewed academic publications, which add to the evidence-base. The sharing of such insights may be helpful to other countries on a similar IDS implementation journey. However, an articulated and shared understanding of the nature of IDS(R) is necessary to draw better comparisons between countries and evaluate the specific status of the implementation. For that purpose, a common definition is needed for standardized technical implementation.

Ultimately future evaluations should be conducted using an agreed definition of IDS, using robust study designs (and following reporting standards), and a common evaluation framework, (e.g., MERLA) for improved comparability across studies.

TIMELINE OF REVIEW

The timeline of the review is indicated in Table 1.

Table 1. Indicative timeline of the review

Proposed tasks	Indicative timeline
Develop review protocol ▪ Conduct preliminary search ▪ Develop search strategy ▪ Develop data extraction frameworks	19/04/2022- 02/05/2022
Literature search ▪ Medline and Embase for reviews ▪ Primary studies from included systematic reviews for RQ1 ▪ Websites of WHO, USCDC, MSF	02/05/2022- 13/05/2022
Screening of identified literature	14/05/2022- 25/05/2022
Data extraction	26/05/2022- 10/06/2022
Synthesis and report writing	10/06/2022- 30/06/2022

The first full draft was produced on the 21 July 2022.

6.6. Differences between Protocol and Review

We had planned to search Medline and Embase for primary studies published during the last 3 years. However, due to the time-constraints of this review we limited our search to the Epistemonikos database for primary studies on IDS, to identify those not included in any of the eligible reviews.

We had also planned to screen primary studies included in eligible reviews to retrieve a definition of IDS (RQ-1) if this was not provided in the review per se. This was however not done due to the limited time available. Nor did we search the reference lists of included reviews, due to the same reason.

Since the main search did not identify any reviews concerned with changes to IDS during the COVID- 19 pandemic (RQ-1), we conducted an additional search for primary studies in Medline and Embase (10 June 2022) on this topic, which was not described in the protocol.

We initially had not planned to do a formal quality assessment, but in the end decided to use a set of standard criteria that would work on any type of (narrative) review, and to use the MMAT tool to assess the quality of primary studies.

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Conflicts of interest: All authors declare there is no conflict of interest

6.7. Contributions of Authors

- Search strategy development, and conducting the Medline and Embase searches: CDB
- Screening and study selection: CDB, GMF, and GB (main search), GMF and GB (Epistemonikos search), GMF and NHA (additional Medline and Embase search), SB and GMF (grey literature)
- Data extraction: GMF, JB, JR, and NHA (main search), GMF and SB (Epistemonikos search), GMF and NHA (additional search), additional data extraction on funding and COI (GMF)
- Production of matrix of studies included in reviews: NHA, and JR
- Development of quality assessment criteria for reviews: GMF
- Development of criteria for overall quality assessment (reviews): JB, and GMF
- Quality assessment: GMF, JB, JR, NAH (reviews); GMF, SB, and NHA (primary studies)
- Production of narrative summaries: AL (reviews), GMF (RQ-3, and quality of included primary studies), JB(RQ-1), JR (RQ-2), SB (primary studies)
- Production of tables and figures: AL (characteristics of reviews), GF (PRISMA flow chart, characteristics of primary studies, funding and COI, quality assessment tables, list of abbreviations, glossary, table of excluded studies)
- Arbitration: AL
- Responsible for drafting of the review: GMF (GMF, AL, JB, and SB contributed to the discussion)
- Workstream lead: GMF
- All authors read and approved the final version

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8. APPENDICES

8.1. Appendix 1. Glossary

Term	Definition
Active surveillance	The collection of case study information as a continuous pre-organized process
Civil registration and vital statistics systems (CRVS)	A system that is used to record statistics on vital events, such as births, deaths, marriages, divorces and fetal deaths
COVID-19	Coronavirus disease, is an infectious disease caused by the SARS-CoV-2 virus
Community-based surveillance	The systematic detection and reporting of events of public health significance within a community, by community members
Convergent integration	The merging of technology with business processes, knowledge, and human performance
Coordination	The organization of the different elements of a complex body or activity to enable them to work together effectively
Disease specific/Vertical surveillance	Surveillance that is focused on a particular pathogen/disease
Epidemic intelligence	The systematic collection and collation of information from a variety of sources, which is then validated and analyzed
Evaluation	The use of specific study designs to periodically assess the relevance, effectiveness, and the impact of a surveillance system
Event-based surveillance	The organized collection, monitoring, assessment and interpretation of mainly unstructured ad hoc information regarding health events or risks, which may represent an acute risk to health.
Focal person	A person authorized by a member organization to commit the member or with decision-making powers on behalf of the member
Governance charter	The written policy document that clearly defines the respective roles, responsibilities and authorities of the President, State Council members (individually and collectively) and the Chief Executive

	Officer in setting the direction, management and control of the Association
Horizontal surveillance	Surveillance that focuses on high-risk populations
Indicator-based surveillance	Surveillance that involves reports of specific diseases from health care providers to public health officials
Integrated Disease Surveillance and Response	Strategy adopted by countries in the WHO African Region for implementing comprehensive public health surveillance and response systems for priority diseases, conditions and events at all levels of the health systems
Integration	To form, coordinate, or blend into a functioning or unified whole
Interconnectivity	The state or quality of being interconnected (e.g., across data systems); the sharing of external devices or simply transferring files while the basic applications, functionality and uses all remain fairly specific with respect to their technologies and users with little or no integration at the function levels
Interoperability	The ability of computer systems or software to exchange and make use of information; is the ability of the system or its component to work with another while exploring the capabilities of both without special effort from the users
MERLA	The intentional application of results-focused monitoring, evaluation, and research to inform continuous learning and adaptation for improved program effectiveness, impact, and evidence-based policy decisions

Monitoring	The routine collection and analysis of indicators to measure how well a surveillance system is achieving its objectives
Notifiable disease	Any disease that is required by law to be reported to government authorities
One Health	An approach calling for "the collaborative efforts of multiple disciplines working locally, nationally, and globally, to attain optimal health for people, animals and our environment", as defined by the One Health Initiative Task Force
Operations Research	An analytical method of problem-solving and decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis.
Participatory health informatics	A multidisciplinary field that uses information technology as provided through the web, smartphones, or wearables to increase participation of individuals in their care process and to enable them in self-care and shared decision-making
Passive surveillance	Defined as unsolicited reports of adverse events that are sent to a central database or health authority
Public health surveillance	Defined as the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice
Sample registration systems (SRS)	A large-scale demographic survey for providing reliable annual estimates of Infant mortality rate, birth rate, death rate and other fertility and mortality indicators at the national and sub-national levels
Semantic consistency	This is directed towards the implementation of database management systems and sophisticated management reporting systems such as HealthMap and FAO EMPRES-i. The emphasis is on providing access to data and minimizing the potential for errors in human interpretation through the creation of standard data definitions and formats
Sentinel surveillance	This is the monitoring of rate of occurrence of specific diseases/conditions through a voluntary network of doctors, laboratories and public health departments with a view to assess the stability or change in health levels of a population

Standardization	The process of making something conform to a standard
Streamlining	This is making (an organization or system) more efficient and effective by employing faster or simpler working methods
Syndromic surveillance	The gathering of information about patients' symptoms (e.g., cough, fever, or shortness of breath) during the early phases of illness

8.2. Appendix 2. Search Strategies (Main Search)

The main search was conducted using keywords combined with the Boolean operators (AND, OR). Both the MESH (Medical Subject Headings) terms and free text phrases. For example, MESH terms like 'Sentinel Surveillance'; 'Population Surveillance'; 'Integrated Disease Surveillance', 'IDS' and Integrated Disease Surveillance and Response', 'IDSR', 'IDS/IDSR implementation', 'Integrated Advanced Information Management Systems'; AND 'Communicable Diseases' [prevention and control]; 'Communicable Diseases, Emerging' [prevention and control]; 'Communicable Disease Control'; 'Disease Outbreaks' [prevention and control]; 'Disease Eradication'; 'Infection Control' AND 'Scoping Review'; 'Rapid Review'; 'Review'; 'Systematic Review'; 'Literature Review'; 'Meta-analysis' were used in various combinations. We did not set any country-, region- or geographic-specific search terms to ensure not to exclude any countries. All the terms were searched in abstracts, keywords, subject headings, titles and text words.

Integrated Disease Surveillance (IDS) final search strategies 12/05/2022

Database: Ovid MEDLINE(R) ALL <1946 to May 11,2022>

1 exp Public Health Surveillance/ (5165)

2 exp Population Surveillance/ (73981)

3 exp Sentinel Surveillance/ (6817)

4 ((sentinel or population or "public health") adj surveillance).ti,kw,kf. (2432)

5 Integrated Disease Surveillance.tw,kw,kf. (211) 6 IDS.tw,kw,kf. (4203)

7 "Integrated Disease Surveillance and Response".tw,kw,kf. (118)

8 IDSR.tw,kw,kf. (97)

9 exp Integrated Advanced Information Management Systems/ (290)

10 exp One Health/ (723)

11 one health.ti,kw,kf. (2957) 12 or/1-11 (82637)

13 exp Communicable Disease Control/ (391960)

14 exp Disease Eradication/ (3917)

15 exp Infection Control/ (69046)

16 exp Communicable Diseases/pc [Prevention & Control] (80607)

17 exp Communicable Diseases, Emerging/pc [Prevention & Control] (1625)

18 exp Disease Outbreaks/pc [Prevention & Control] (30952)

19 exp Pandemics/pc [Prevention & Control] (13579)

20 exp Epidemics/pc [Prevention & Control] (15317)

21 ((disease or infection or pandemic or epidemic) adj (control or prevention or surveillance)).ti,kw,kf. (28651)

22 or/13-21 (499388)

23 exp "Review"/ (2989750)

24 exp "Systematic Review"/ (195874)

25 exp "Review Literature as Topic"/ (19824)

26 (review* or meta* or overview*).ti,kw,kf. (1848783)

27 or/23-26 (4338799)

28 12 and 22 and 27 (1588)

29 12 and 22 (12790)

30 limit 29 to "reviews (best balance of sensitivity and specificity)" (1584)

31 28 or 30 (1741)

32 limit 31 to yr="1998 -Current" (1544)

33 limit 32 to english language (1358)

Database: Embase <1974 to 2022 May 11>

1 exp public health surveillance/ (365)

2 exp population surveillance/ (108)

3 exp sentinel surveillance/ (2713)

4 epidemiological surveillance/ (616)

5 exp disease surveillance/ (37433)

6 ((sentinel or population or "public health") adj surveillance).ti,kw,kf. (3099)

7 Integrated Disease Surveillance.tw,kw,kf. (273) 8 IDS.tw,kw,kf. (6612)

8 "Integrated Disease Surveillance and Response".tw,kw,kf. (142)

9 IDSR.tw,kw,kf. (125)

10 Integrated Advanced Information Management System*.tw,kw,kf. (38)

11 exp One Health/ (1513)

12 one health.ti,kw,kf. (3048)

13 or/1-13 (53131)

15 exp communicable disease control/ (146077)

16 exp disease eradication/ (3454)

17 exp infection control/ (116673)

18 exp communicable disease/pc [Prevention] (1288)

19 exp pandemic/pc [Prevention] (4876)

20 exp epidemic/pc [Prevention] (8377)

21 ((disease or infection or pandemic or epidemic) adj (control or prevention or surveillance)).ti,kw,kf. (32628)

22 or/15-21 (180454)

23 exp "review"/ (2922773)

24 exp "systematic review"/ (344281)

25 exp "systematic review (topic)"/ (28852)

26 (review* or meta* or overview*).ti,kw,kf. (2112708)

27 or/23-26 (4468050)

28 14 and 22 and 27 (1346)

29 14 and 22 (7479)

30 limit 29 to "reviews (best balance of sensitivity and specificity)" (1382)

31 28 or 30 (1493)

32 limit 31 to yr="1998 -Current" (1488)

33 limit 32 to english language (1434)

34 limit 33 to conference abstract (7)

35 33 not 34 (1427)

8.3. Appendix 3. List of Excluded Studies (N=63)

Author, year (reference)	Reason for exclusion
Abe 2020 (42)	Not a review and not about IDS.
Abedisi 2021(43)	Do not answer any of our review questions.
Aiello 2020 (44)	Do not mention IDS (only describes different digital surveillance systems)
Alders 2020(45)	Irrelevant, not about IDS.
Allaranga 2012(46)	Describes transmission of two diseases, and general surveillance but not IDS.
Alotabi 2017 (47)	Discusses the need for integration of Hajji surveillance.
Aral 2002 (48)	Not a review and not about IDS.
Archer 2020(49)	Focus on integrated surveillance of two diseases only.
Babalie 2015 (50)	Concerned with performance assessment frameworks, and not with IDS.
Bamou 2021 (51)	Focus on mosquito borne diseases in Cameroon, and not on IDS.
Banerjee 2021 (52)	Focus on Fungi and One Health aspects.
Bardach 2019 (53)	Focus on Aedes aegypti control and not on IDS.
Braks 2011 (54)	Focus on vector borne disease surveillance, and not on IDS.
Bruce 2016 (55)	Not about IDS.
Caprioli 2014 (56)	Focus on surveillance and monitoring of STEC infections, and not on IDS.
Caroll 2014 (57)	About visualization tools only.
CDC 2000	Old report from Uganda. Other more recent reports included.
Charles-Smith 2015 (58)	Not about IDS but about integration of social media into disease surveillance in general.
Chiolero 2020 (59)	Irrelevant.

Choi 2016 (60)	About web-based surveillance, and integration (do not mention IDS).
Dato 2021 (61)	About detection/surveillance of infectious disease, but do not mention IDS.
Fall 2019 (2)	Included in one of the eligible reviews.
Fawzy 2019 (62)	Focus is on rift valley fever only, do not mention IDS (integrated OneHealth approach)
Ford 2015 (63)	Describes Integrated food-chain surveillance, but do not mention IDS.
Fournet 2018 (64)	Vector management only, and no mention of IDS
Gabarron 2021(65)	Describes barriers to the use of PHI, but not in the context of IDS
Garg 2020 (66)	Not a primary study. Viewpoint only.
George 2021 (67)	Describes mainly data sources for animal health surveillance, but do not mention IDS.
Halliday 2012 (68)	Animal surveillance and integration, but not in the context of IDS
Hashimoto 2012 (69)	Chaga disease specific, and do not mention IDS.
Halton 2013(70)	Community based interventions (incl. surveillance) Do not mention integration or IDS.
Houe 2020(71)	Outlines different data sources in Denmark and suggests fit-for-purpose data integration.
Huff 2017 (72)	About bio-surveillance, do not mention IDS.
Ibrahim 2020(73)	Describes different types of surveillance for COVID19, but do not mention IDS.
Ighozo 2022(74)	Not a proper primary study. Environmental scan.
Jima 2017 (75)	Not a review. Malaria surveillance in the context of IDS. Included in the Wolfe review from 2021.
Jourdan 2019 (76)	About harmonization of entomological surveillance, and do not mention IDS.
Juin 2017(77)	Irrelevant.
Kaushal 2020(78)	Not a primary study. Commentary.
Kumar 2021 (79)	Discusses the need of a one health approach in India.
Lukwago 2013(80)	Not a review. Primary study Included in the review by Mremi et al.
Maazou 2021(81)	Focus on CBS, but not in the context of IDS.

Mandja 2019 (82)	About the use of on IDS score to ensure usability of data.
Mariner 2011 (83)	Not about IDS.
NeXtwork 2021(84)	No data of relevance for our research questions.
Ngwa 2016 (85)	Included in the review by Ng'etich from 2021.
Nomani 2021(86)	Not a primary study.
Nyasuly 2021(87)	Rabies specific, and do not mention IDS.
Phalkey 2017(88)	Concerns the involvement of private practitioners in routine disease data notification
Radanliev 2020(89)	Not about IDS.
Ratnayake 2020 (90)	Mainly about CBS and not about IDS.
Rohan 2022 (91)	Not about IDS and COVID19, but Lassa Fever.
Ruiz 2018 (92)	Disease specific and no mentioning of IDS,
Rweyemamu 2013 (93)	Not a review.
Sambala 2019 (94)	Protocol only, which does not mention IDS.
Sharma 2010 (95)	Not a review. Describes the role of IT in surveillance.
Tangerman 2017(96)	About integrated AFP surveillance, but not within the IDS context.
Tshitenge 2022 (97)	No data of relevance for our research questions.
Velasco 2014 (98)	Not about IDS.
Weinberg 2005 (99)	Not a review, and not about IDS.
WHO 2019	WHO country report. Regional strategy.
Zana 2007 (100)	Manual only.
Zhao 2021 (101)	About ethical issues of using artificial intelligence.

8.4. Appendix 4. Characteristics of Included Reviews (N=8)

Author, year	Review type	Aim of review	Scope	Human/ Animal health	Region/Countries	Inclusion criteria	Exclusion criteria
George et al., 2020 (16)	Systematic narrative review	To identify and categorize mechanisms in which existing human and animal health surveillance systems have been integrated, assess the contribution of integrated systems in strengthening relevant surveillance attributes, and key aspects to consider in integration in order to address global health security threats.	Both communicable and non-communicable diseases	Both	Worldwide Africa (13), Asia (11), Australia (5), Europe (25), North America (34), South America (5), International (7), Unknown (1)	Studies had to involve human health surveillance, animal health surveillance, or One Health surveillance systems and interventions and focus on integrated surveillance systems, describe integration designs of the system, or present the effects of the surveillance integration on surveillance systems attributes	Studies with abstracts without full text, not in English or newsletter articles

Mremi et al., 2021 (17)	Systematic narrative review	To analyze the performance of the IDS strategy in Sub- Saharan Africa and how its implementation has embraced advancement in information technology, big data analytics techniques and wealth of data sources, as well as the One Health approach.	Infectious diseases only	Both	Sub-Saharan Africa: Country-specific studies were available for 20 of 47 (42.6%) countries; Africa (6), Tanzania (7), Ghana (4). Nigeria (4), Uganda (4), Zambia (3), Ethiopia (2); Guinea (2), Kenya (2), Côte d'Ivoire, Guinea-Bissau, Senegal, Mali (1); and one each for the others: Democratic Republic of the Congo, Liberia, Madagascar, Malawi, Rwanda, Sierra Leone, Sudan, Tanzania, Ghana Tanzania, Ghana, Uganda, Zimbabwe (1)	Study must involve at least one of the SSA countries, clearly describe the evaluation of the IDS system, focuses on at least one of the IDS functions and/or systems attributes	Studies with abstracts without full text, not in English, reviews and newsletters

Ng'etich et al.,	Systematic narrative review	To review key recommendations resulting from surveillance	Communicable diseases only	Not specified - presume	Africa; 13 countries in the WHO African Region	Published full text articles including unpublished studies and grey literature, either quantitative or	Studies in countries outside Africa, articles published prior to 2010 before countries

2021 (18)		assessment studies to improve implementation of the revitalized IDS system in the African region based on HCWs' perspectives		human health	Nigeria (8), Ghana (6), Zimbabwe (3), South Africa (2), Ethiopia (2), Zambia (2), and one each for the others: Cameroon, Kenya, Tanzania, Madagascar, Uganda, Sudan and Malawi	qualitative studies or both assessing implementation of one or more surveillance functions based on health workers' views through interviews and studies involving records reviews or observations, articles written in English language only	adopted the revised IDS guidelines, articles written in any other language other than English
Phalkey et al., 2012 (19)	Systematic narrative review	To systematically review and document the experiences, lessons learned, and the challenges identified with the implementation of the IDS systems in low- and lower middle-income countries.	Communicable diseases only	Not specified - presume human health	LMICs, 18 countries Burkina Faso, Cape Verde, Eritrea, Ethiopia, Ghana, Guinea Bissau, India, Iraq, Lesotho, Malawi, Mali, Mozambique, Nigeria, South Sudan, Tanzania, The Gambia, Uganda, Zimbabwe) of which 16 from the WHO African region	Full text citations published in English dated 1998 to June 2012 that assessed the lessons learned from the implementation of the WHO IDS strategy in low- or lower middle-income countries, studies that assessed any of the IDS system's core and support functions, as defined by the WHO protocol for the assessment of communicable disease surveillance and response systems or the systems quality attributes as	Abstracts, letters to editors, conference papers, studies concerning upper middle-income or high-income countries and citations dealing with single disease surveillance systems or single diseases addressed within the integrated disease surveillance system.

						identified by the CDC updated guidelines for the assessment of communicable disease surveillance systems	

Pilot et al., 2019 (20)	Systematic scoping review	To identify and critically appraise the organizational, functional, and implementation-related aspects of current dengue surveillance initiatives, contributing towards prospective improvements in timely detection and effective response	Dengue only	Not specified - presume human health	India	Studies written in English, scientific & peer-reviewed articles, focusing on India, published between 1946 and April 2017, addressing national, state, district, rural or municipal Dengue surveillance, entailing a public health surveillance focus	Not fully written in English, grey literature (government reports, project report, etc.), primarily addressing entomological surveillance, primarily addressing sero-epidemiological and virology surveillance, only mentioning public health surveillance in the conclusion/ recommendation sections

Sahal et al., 2009 (21)	Literature review	To compare developing and developed countries in their infectious disease surveillance systems.	Communicable diseases only	Not specified - presume human health	Worldwide (20 developed, 12 developing countries) USA (6); the Netherlands (4); Sweden (2), and one each from Australia, France, Germany, Italy, Norway, and the UK: one each from 11 African countries (Uganda, Tanzania, Ethiopia, Mozambique, Ghana, Mali, Southern Sudan, South Africa, Burkina Faso), and one from Taiwan	Publications found on the assessment of CDSS that were published in English between 1981 and 2007	Not specified
Wendt et al., 2013 (22)	Literature review	To summarize surveillance initiatives which integrate information from humans and animals on zoonotic diseases	Communicable diseases only	Both human and animal health	Worldwide Global (9); USA (3, of which one specific to Illinois, and one to North Carolina), Canada (3, of which one specific to British Columbia); Australia (1); Asia, Africa, East Europe, former Soviet Union, Western South America (1); Europe, China,	Included systems which were developed with the intention of preventing or controlling zoonotic diseases; which pursue a cross-sectoral cooperation between the human and animal health communities; which share health information in an information system; which integrate monitoring and	Temporary data collections for epidemiological research, usually clinical trials and biobanks, storing information on humans and animals.

					Turkey, Iran and South Africa (1); Central Asia, Caucasus (1), and Asia Pacific (1)	surveillance data from different sources with different characteristics	

Wolfe et al., 2021 (23)	Systematic narrative review	To systematically review and document the peer-reviewed lessons learned and challenges identified surrounding the implementation of IDS in the WHO African region and facilitate the identification of common barriers and areas for future research and prioritization.	Communicable diseases only	Not specified - presume human health	Africa; 17 countries Nigeria (10), Ghana (7), Uganda (5), Liberia (4), the Democratic Republic of Congo (3), Ethiopia (3), Kenya (3), Sierra Leone (2), Zimbabwe (2), and one study each from Angola, Botswana, Cameroon, Madagascar, Malawi, Tanzania, Togo, and Zambia.	Peer-reviewed, full-text articles that discussed the use of IDS strategies and its implementation, assessment of IDS implementation or strategies, or articles discussing surveillance of diseases covered in the IDS framework, only articles focusing on countries in the WHO African region	Results published only as abstracts or presented in conferences without full accompanying full-text publications, previous systematic reviews of IDS implementation, articles that discussed diseases covered in the IDS framework but did not relate their assessment or findings back to the IDS strategy

Cont. Characteristics of included reviews

Author, year	No. & name of databases searched	Search terms	Search period	Grey literature included?	Language	Number and type of papers	Quality assessment done?	Themes
George et al.,2020 (16)	5 - PubMed, HINARI, Web of Science, Science Direct, advanced Google search	Surveillance, monitor, animal health, human health, public health, One Health, integrate, system	1900-2018	No	English only	102 quantitative, qualitative and mixed methods	Yesa	Integration, implementation
Mremi et al.,2021 (17)	3 - HINARI, PubMed, advanced Google Scholar	Integrated Disease Surveillance and Response, Integrated Disease Surveillance, Health Management Information Systems, District Health Information System and Sub-Saharan Africa or individual member country	1998-2020	Google search, WHOLIS, CDC, ACDC	English only	45 (study type not stated)	No	Performance, implementation, technology

Ng'etich et al.,2021 (18)	3 - PubMed, Web of Science, CINAHL	Surveillance, public health surveillance, integrated disease surveillance and response, evaluation, assessment, health worker, healthcare personnel, Africa, Sub Saharan Africa	2010-2019	World Health Organization Library and Information Networks for Knowledge (WHOLIS)	English only	30 assessment studies / quantitative, qualitative and mixed methods	Yesb	Performance, implementation
Phalkey et al.,2012 (19)	2 - Web of Knowledge, PubMed	Programme Evaluation, Project Evaluation, Health Care Evaluation Mechanisms, Evaluation/Assessment Studies as Topic, Self-Evaluation Programmes, Evaluation Studies, Health Services Research, Process Assessment, State Health Plans, Costs and Cost Analysis, Task Performance and Analysis, Systems Analysis, Benchmarking, Lessons learned, Communicable Diseases, Communicable Diseases, Emerging, Communicable Disease Control, Disease Outbreaks, Sentinel Surveillance, Population Surveillance, Epidemiology, Disease Eradication, Infection Control,	1998-2012	WHOLIS, Centers for Disease Control (CDC), other grey literature	English only	33 assessment studies	No	Implementation, Performance

		Integrated Disease Surveillance and Response, Integrated Advanced Information Management Systems, Information Systems, Hospital Information Systems						

Pilot et al.,2019 (20)	4 - Medline, Web of Sciences, Global Health, Indian Journals.	India, dengue, severe dengue, dengue virus, DENV, dengue fever, DF, dengue haemorrhagic fever, DHF, dengue shock syndrome, DSS, acute fever, acute undifferentiated fever, population surveillance, sentinel and syndromic surveillance, disease notification, infection, disease control	1946, 1973- 2017	No	Not specified - presume English only	18	No	Implementation
Sahal et al.,2009 (21)	1 – Pubmed	Surveillance, evaluation, communicable, diseases, infectious, assessment, system	1981-2007	WHOLIS, CDC	English only	32	No	Performance
Wendt et al.,2013 (22)	2 - Web of Science, Medline	Integrat*, link*, comb*, shar*, surveillance, data*, information*, infectious disease*', zoono*, human* NEAR animal*, cross-sectoral, cross-species, 'one health', 'one medicine'	1945-2012	WHO, FAO, OIE, EFSA, CDC, & other grey literature	English only	20	No	Integration
Wolfe et al.,2021 (23)	2 - Web of Science, PubMed	Integrated Disease Surveillance and Response, IDS, IDS Implementation, or IDS Evaluation, and the French equivalents	2012-2019	No	English and French	47	No	Implementation, Performance

a. QualSyst Tool for qualitative and quantitative data; b. Quality assessed using Dearholt and Dang's Johns Hopkins Nursing Evidence Appraisal Tool

8.5. Appendix 5. Matrix of Overlap of Primary Studies

Author	Year	Wolfe 2021	Mremi 2021	Ng'etich 2021	Pilot 2019	Wendt 2013	Phalkey 2012	Sahal 2009	George 2020
No. of included studies		47	45	30	18	20	33	32	102
Wolfe et al.	2021		✓						
Mboera et al.	2021		✓						
Ibrahim et al.	2020		✓						
Collins et al.	2020		✓						
Fall et al.	2019	✓	✓						
Frimpong- Mansoh et al.	2019	✓							
Masiira et al.	2019	✓	✓	✓					
Nagbe et al.	2019	✓	✓						
Nagbe et al.	2019	✓							
Nakiire et al.	2019	✓	✓						
Njuguna et al.	2019	✓	✓						
Mandja et al.	2019		✓						
Alemu et al.	2019		✓						
Hemingway-Foday et al.	2019		✓						
Kooma et al.	2019		✓						
Hutchison et al.	2019								✓
Curran et al.	2018	✓							

Jinadu et al.	2018	✓	✓	✓					
Joseph Wu et al.	2018	✓							
Motlaleng et al.	2018	✓							
Randriamiarana et al.	2018	✓	✓	✓					✓
Toda et al.	2018	✓							
Uchenna et al.	2018	✓							
Wu et al.	2018		✓	✓					
Kihembo et al.	2018		✓						
Haakonde et al.	2018		✓	✓					
Dairo et al.	2018			✓					
Suwanbamrung et al.	2018								✓
Wu et al.	2018								✓
Turnidge et al.	2018								✓
Anwar et al.	2018								✓
Albiger et al.	2018								✓
Botto et al.	2018								✓
Acharya et al.	2018								✓
Sofeu et al.	2018								✓
Wang et al.	2018								✓

Herve et al.	2018								✓
Wang et al.	2018								✓
Mavragani et al.	2018								✓
Liang et al.	2018								✓
Lin et al.	2018								✓
Davidson et al.	2018								✓
Ashbaugh et al.	2017	✓							
Hamblion et al.	2017	✓							
Jephcott et al.	2017	✓							
Lakew et al.	2017	✓		✓					
Mandyata et al.	2017	✓	✓	✓					
Muchena et al.	2017	✓							
Mutsigiri- Murewanhema et al.	2017	✓							
Nass et al.	2017	✓							
Nsubuga et al.	2017	✓							
Wassilak et al.	2017	✓							
Cáceres et al.	2017		✓						
Mboera et al.	2017		✓	✓					
Benson et al.	2017			✓					
Adjei et al.	2017			✓					
Pilot et al.	2017				✓				
Andres et al.	2017								✓

Martins et al.	2017								✓
Saha et al.	2017								✓
Pineros et al.	2017								✓
Karp et al.	2017								✓
Brenas et al.	2017								✓
Spreco et al.	2017								✓
Velati et al.	2017								✓
Adokiya et al.	2016	✓		✓					
Adokiya and Awoonor- Williams	2016	✓		✓					
Benedetti et al.	2016	✓							
Mwatondo et al.	2016	✓	✓	✓					
Mwengee et al.	2016	✓	✓						
Ngwa et al.	2016	✓		✓					✓
Poy et al.	2016	✓							
Wesseh et al.	2016	✓							
Begashaw and Tesfaye	2016		✓	✓					
Benson et al.	2016			✓					
Baghdadi	2016			✓					
Mairosi et al.	2016			✓					
Iwu et al.	2016			✓					
Ameh et al.	2016			✓					

Daude and Mazumdar	2016				✓				
Maas et al.	2016								✓
Muellner et al.	2016								✓
Chapman et al.	2016								✓
Cantarino et al.	2016								✓
Mukhi et al.	2016								✓
Onyebujo et al.	2016								✓
Adokiya et al.	2015	✓	✓	✓					
Adokiya et al.	2015		✓	✓					
Issah et al.	2015	✓	✓	✓					
Lar et al.	2015	✓		✓					
Nguku et al.	2015	✓							
Motilewa et al.	2015		✓						
Tsitsi et al.	2015			✓					
Toan et al.	2015				✓				
Bagcchi	2015				✓				
Chandran and Azeez	2015				✓				
Telle et al.	2015				✓				
Stark et al.	2015								✓
Rossi et al.	2015								✓
Adokiya et al.	2015								✓
Lafond et al.	2014	✓							

Mbondji et al.	2014	✓							
Tambo et al.	2014		✓						
Nnebue et al.	2014		✓	✓					
Thierry et al.	2014		✓						
Maponga et al.	2014			✓					
Gupta and Ballani	2014				✓				
Shepard et al.	2014				✓				
Sharma et al.	2014				✓				
Iyer et al.	2014				✓				
Schwind et al.	2014								✓
Bellini et al.	2014								✓
Vincent et al.	2014								✓
Cassini et al.	2014								✓
Barboza et al.	2014								✓
Lober et al.	2014								✓
Lwin et al.	2014								✓
Borchert et al.	2013	✓							
Fatiregun et al.	2013	✓							
Kasolo et al.	2013	✓	✓						
Kebede et al.	2013	✓							
Lukwago et al.	2013	✓							

Nnebue et al.	2013	✓		✓					
Abubakar et al.	2013			✓					
Gupta and Reddy	2013				✓				
Rizi et al.	2013								✓
Kshirsagar et al.	2013								✓
Napoli et al.	2013								✓
Hulebak et al.	2013								✓
Barboza et al.	2013								✓
Al-Samarrai et al.	2013								✓
Phalkey et al.	2013								✓
Turbelin et al.	2013								✓
Lee et al.	2013								✓
Nnebue et al.	2012	✓							
Jima et al.	2012	✓							
Pascoe et al.	2012		✓						
Lukwago et al.	2012		✓				✓		✓
Chakravarti et al.	2012				✓				
Sivagnaname et al.	2012				✓				
Burke et al.	2012					✓			
Galanis et al.	2012					✓			
Markiewicz et al.	2012								✓
Paterson et al.	2012								✓

Teodoro et al.	2012								✓
Karimuribo et al.	2012								✓
Samoff et al.	2012								✓
Kool et al.	2012								✓
Klompas et al.	2012								✓
Wahl et al.	2012								✓
Wolkin et al.	2012								✓
John et al.	2011				✓				
Halasa et al.	2011				✓				
Perez et al.	2011					✓			
Coutinho Calado Domingues et al.	2011					✓			
Wadsworth et al.	2011					✓			
Mantero and Belyaeva	2011					✓			
Pond et al.	2011						✓		
Toutant et al.	2011								✓
Adamson et al.	2011								✓
Kebede et al.	2011								✓
Denecke et al.	2011								✓
Dobbins et al.	2011								✓
Mariner et al.	2011								✓
Sanchez-Vazquez et al.	2011								✓

Heisey-Grove et al.	2011								✓
Lewis et al.	2011								✓
Sahal et al.	2010		✓						
Wamala et al.	2010		✓						
Sow et al.	2010		✓				✓		
Nsubuga et al.	2010		✓				✓		✓
Kloeze et al.	2010					✓			
Potenziani	2010					✓			
Sathyanarayana	2010						✓		
Abubakar	2010						✓		
Abubakar et al.	2010						✓		
Dairo et al.	2010						✓		
MOH Nigeria	2010						✓		
Taboy et al.	2010								✓
Somda et al.	2010								✓
Chini et al.	2010								✓
Somda et al.	2010								✓
McCormick et al.	2010								✓
Mukhi et al.	2010								✓
Michelozzi et al.	2010								✓
Prowse et al.	2009					✓			
Ahmed et al.	2009					✓			

United States Government Accountability Office (GAO)	2009					✓			
Keller et al.	2009					✓			
Keller et al.	2009					✓			
Somda et al.	2009						✓		
Touch et al.	2009								✓
Beatty et al.	2008					✓			
Collier et al.	2008					✓			
Freifeld et al.	2008					✓			✓
AlJawadi and AlNeami	2008						✓		
Wartenberg et al.	2008								✓
Weibel et al.	2008								✓
Gao et al.	2008								✓
Klompas et al.	2008								✓
Reinhardt et al.	2008								✓
Perry et al.	2007		✓						
Rumisha et al.	2007		✓				✓		
Bhargava and Chatterjee	2007				✓				
Wahl and Burdakov	2007					✓			
Weber et al.	2007							✓	
Mukhi et al.	2007								✓

Reis et al.	2007								✓
Giannopoulou et al.	2007								✓
Franco et al.	2006		✓				✓		
Victor et al.	2006				✓				
FAO et al.	2006					✓			
MOH Malawi	2006						✓		
MOH Mozambique	2006						✓		
Van Hest et al.	2006							✓	
De Greeff et al.	2006							✓	
WHO	2006							✓	
Shuai et al.	2006								✓
Faensen et al.	2006								✓
Morris et al.	2006								✓
Wolkin et al.	2006								✓
Grannis et al.	2006								✓
MOH Ethiopia	2005						✓		
Quality Health Partners and Ghana Health Service	2005						✓		
Gueye et al.	2005						✓		
Mboera et al.	2005						✓		
Alfred	2005						✓		
Lam et al.	2005							✓	

Wang et al.	2005								✓
Gosselin et al.	2005								✓
Mghamba et al.	2004		✓				✓		
John et al.	2004				✓				
Yu and Madoff	2004					✓			
MOH Eritrea	2004						✓		
MOH Lesotho	2004						✓		
MOH Uganda	2004						✓		
Jajosky and Groseclose	2004							✓	
Klein and Bosman	2004							✓	
Jansson et al.	2004							✓	
Miller et al.	2004							✓	
Harpaz	2004							✓	
Sopwith et al.	2004								✓
Ruiz et al.	2004								✓
Support for Analysis and Research in Africa (SARA)	2003						✓		
Franco et al.	2003						✓		
CDC	2003						✓		
WHO et al.	2003						✓		
Jansson et al.	2003							✓	
Pillaye and Clarke	2003							✓	
Nardone et al.	2003							✓	
Tan et al.	2003							✓	

Reis et al.	2003								✓
Tsui et al.	2003								✓
Nsubuga et al.	2002		✓						
Doyle et al.	2002							✓	
CDC	2002							✓	
Mboera et al.	2001		✓						
Aavitsland et al.	2001							✓	
Krause et al.	2001							✓	
WHO	2001							✓	
King et al.	2001								✓
Polley et al.	2000					✓			
Atti et al.	2000							✓	
Jara et al.	2000							✓	
CDC	2000							✓	
Effler et al.	1999							✓	
Reintjes et al.	1999							✓	
Hashimoto et al.	1998							✓	
Nsubuga et al.	1998							✓	
Vatapolous et al.	1997								✓
Fleming et al.	1996								✓
Ackman et al.	1992							✓	

8.6. Appendix 6. Characteristics of Included Primary Studies (N=5)

Author Year	Country	Aims	Study design	Methods for data collection	Sampling method	Case diseases mentioned in study	Data collection period	Sample size	Adoption of IDS (year)
Abuzerr et al.,2021 (27)	Palestine	To explore barriers to implementing an integrated One Health surveillance system in Palestine.	Qualitative study	Semi-structured KIIs	Purposeful sampling	NA	April 2020 to August 2020	7 KIs	NA
Ibrahim et al.,2020 (24)	Nigeria	To identify and address gaps in the IDS implementation to strengthen the system.	Cross-sectional mixed methods	Survey (using standard IDS assessment tools), Checklist for assessing implementation tools and resources, and questionnaire for interviewing respondents on their capacities to implement IDS.	Not specified (presumably convenience sampling1)	NA	2017	34 respondents from 6 health facilities and 6 local government areas	2001 Note: Only 606 (23%) of 2,598 health facilities in the three states were involved in IDS

Kebede et al.,2010 (28)	African region	To examine the epidemic preparedness and response (EPR) activities to disease outbreaks at the national and regional levels since the launch of the IDS strategy in 1998.	Mixed methods (review of reports, literature and expert discussion	Documents and reports, meetings and discussions (and a literature review)2	Not specified	Multiple diseases3	2003-2007	NA	NA
Omondi et al.,2020 (25)	Kenya	To assess the uptake of IDS health data and utilization at community level health systems in the six sub counties within Nairobi County of Kenya	Cross-sectional quantitative study	Questionnaire	Stratified sampling and simple random sampling methods (85% response rate)	NA	NA	315 respondents	NA

Saleh et al.,2021 (26)	Tanzania	To assess the performance of the core and support functions of the Zanzibar IDS system to determine its capacity for early detection of and response to infectious disease outbreaks	Cross-sectional mixed-methods study	Document review, observations and KIIs	Stratified random sampling, and simple random sampling4	Multiple diseases5	November and December 2017	45 health facility in-charges or designated IDS staff (one/facility), 10 DSOs (one/district) and 2 staff from the HMIS units (one/unit)	2010
DSO: district surveillance officer; FGD: Focus Group Discussion; HMIS: Epidemiology and Health Management Information System; IDS: Integrated Disease Surveillance; KII: Key Informant Interview; NA: Not Available; DHIMS2: District Health Information Management System II; PHCU; Primary Health Care Unit; PHCC: Primary Health Care Centre; WHO: World Health Organization; 1. Three states worst affected by the humanitarian crisis, selection of 2 LGAs from each state and closest to the state (capitals, and one health facility closest to the LGA headquarters, based on the premise that in these areas the system should be most functional; 2. Documents and reports obtained from WHO/AFRO, WHO inter-country team, WHO Country Offices and partners; Meetings and discussions with WHO/IDSR focal people and partners involved in EPR and a literature review on epidemic outbreaks and response interventions in the African region 3. Cholera, Dysentery, Meningococcal meningitis, Malaria, Measles, Hemorrhagic Fever, Yellow Fever etc.4. Health facilities were sampled across the archipelago, with representation of all strata including administrative areas (districts), rural and urban settings, as well as public and private facilities. Public and private health facilities were selected by stratified random sampling using each of the 10 districts as strata. In each district, PHCUs were selected using simple random sampling while all PHCCs and non- specialized hospitals were included, as were each District Health Management Team (DHMT) and the Epidemiology and HMIS units at the central Ministry of health; 5. Malaria, cholera, bloody diarrhea, diarrhea, measles, yellow fever, dengue, viral hemorrhagic fevers, chikungunya, plague, rabies, human influenza etc.								

8.7. Appendix 7. Results for RQ-1 (Reviews)

Author Year	RQ-1: How is IDS defined and described in the literature and how has this evolved over the course of the COVID-19 pandemic*?
George et al., 2020 (16)	In health surveillance, system integration has been defined as the sum of all surveillance activities which add up to the broader surveillance system. Integration in health surveillance systems may include merging of health records database with surveillance system, sharing of databases with heterogeneous data to form common indicators or merging of surveillance activities and processes.
Mremi et al., 2021 (17)	No definition of IDS provided. The intent with the IDS strategy was to create and implement a comprehensive, integrated, action-oriented, district-focused public health surveillance for African countries
Ng'etich et al., 2021 (18)	No definition of IDS provided. IDS system described as a framework providing a platform to improve national public health surveillance and response capacities and aims to strengthen the public health system at community, health facility, district, and national levels to ensure timely detection, confirmation and response to public health threats to alleviate illness, disability and mortality.
Phalkey et al., 2012 (19)	IDS defined as 'a combination of active and passive systems using a single infrastructure that gathers information about multiple diseases or behaviors of interest' (Nsubuga et al.,2006).
Pilot et al., 2019 (20)	No definition of IDS provided. The aims with the IDSP system were described as follows "to improve overall surveillance procedures and to specifically enhance laboratory networking and quality assurance, as well as to review case definitions and facilitate the integration of inefficiently and vertically operating disease control programs"
Sahal et al., 2009 (21)	No definition of IDS provided. The sum of all surveillance activities that add up to the national surveillance system. An integrated approach envisages all surveillance activities in a country as a common public service, which carries out many functions using similar structures, processes and personnel
Wendt et al., 2013 (22)	No definition or description of IDS provided. Nor for One Health.
Wolfe et al., 2021 (23)	The goal of the IDS strategy is to develop sufficient surveillance and response capacities at each level of the national health system to produce a flexible priority disease surveillance system.

8.8. Appendix 8. Results for RQ-2 (Reviews)

Author year	Governance (Leadership, accountability, regulation and enforcement)	System/structure (NIPHs role, population based, digitized, sectorial integration)	Financing (Adequate sustainable domestic financing)	Core functions (Detect, report, analyze, investigate/confirm, respond, feedback, evaluate, preparedness)	Resourcing requirements (Human resources, laboratory capacity, data, IT, other (e.g., SOPs and GLs))
George et al., 2020 (16)	NA	Integrated human and animal disease sector surveillance system fulfilling four mechanisms for successful integration: Interconnectivity, Interoperability, Semantic consistency, and Convergent integration; Organizational structures of paramount importance in strengthening intra- and inter-institutional collaboration and communication regarding surveillance. The organizational structure should be able to accommodate both vertical and horizontal flows of information and be flexible enough to absorb challenges that may arise from the increased inter-dependence of the	Mentions that adequate financing is required	NA	Human resources: capacity building and training of users; Laboratory capacity: adequate diagnostic tools; Data: Merging of health records database with surveillance system, sharing of databases with heterogeneous data to form common indicators or merging of surveillance activities and processes; IT: adequate technology, and infrastructure. For successful implementation and operation of surveillance systems integration, technology innovation and strengthening of data management systems are needed to link and manage large amounts of heterogeneous data; Other: Clear SOPs and terms, and political will.

		system components			
Mremi et al., 2021 (17)	nil	Strong coordination and communication, a clear organizational structure, adequate resources, and reliable data sources. An effective epidemic intelligence should contain both indicator-based and event-based surveillance. To adopt a OneHealth approach, there is a need to define the characteristics of OH surveillance and identify the appropriate mechanisms for inter-sectoral and multi-disciplinary collaboration.	Nil	Detect: Use of informal and formal data sources; Report: Coordination of case definition reporting protocols across programmes; Analyze: Applying modern technologies such as artificial intelligence and machine learning enables analyze of significant volume of data to assess the status and forecast future outbreaks; Preparedness: Information on prior risks is crucial in setting robust outbreak management and response plans (e.g., mapping of exposure patterns and the burden of infectious diseases).	Human resources: recruit adequate staff who are well trained and motivated as well as the need for periodic support supervision of the surveillance activities; Laboratory capacity: Countries should support the efforts to strengthen laboratory capacities for the detection of a wide range of pathogens in relation to the IDS priority diseases. Laboratory networking should be encouraged and should involve both national, regional and research reference laboratories; Data: incorporating other sources such as mortality data from demographic surveys, environmental data, vital statistics and civil

					registration, antimicrobial resistance, systematic surveys, meteorological data and research data; *IT*: Establishment of national platforms for infectious disease epidemics early warning systems and develop action plans for their operationalization, including resource mobilization and engagement with key stakeholders.
Ng'etich et al., 2021 (18)	nil	Electronic-based system adoption for reporting within health facilities would minimize costs, and mobile phone technology utilization. Revival of community-based surveillance. Syndromic surveillance approaches using mobile phone technologies.	Integrated and sustained funding towards training required. Funds allocation in the health sector budget to support IDS required.	Detect: Prompt specimen collection and improved specimen handling recommended; Report: Improvement of surveillance reporting recommended (8/30 studies). Improved reporting quality and adequate provision of reporting forms required (sub-themes). Improved surveillance documentation required (lacked active case searches written reports). Identification of correct reporting channels; Analyze: Increased data analysis required (3/30); Confirmation/investigation: Strengthening of case confirmation capacities recommended (4/30 studies); Respond: Utilization of up-to-	Human resources: Need for sufficient human resources, and enhanced training of health personnel (18/30); Laboratory capacity: Enhanced provision of laboratory facilities and equipment. Reliable diagnostic results on notifiable diseases; Data: Plans for scaling up data entry; IT: Health facilities and district levels to be equipped with computers (improved infrastructure). Stable internet connectivity. Functional communication equipment; Other: Adequate provision of reporting forms and available IDS reporting tools. Formulate and distribute protocols for specimen handling. Simplifying training materials

				date information; Feedback: Improved feedback needed (6/30) Enhanced feedback from higher to lower levels needed	to ease understanding of the system. Materials, equipment and functional transport facilities required. Strengthening capacity for data analysis and availing tallying sheets, register books and reporting forms. Data management tools availability to be complemented by functionality to ease surveillance data entry and analysis. Further research efforts to assess the effect of health worker training on surveillance system performance
Phalkey et al., 2013 (19)	importance of leadership at central and peripheral levels	Co-ordination of IDS with other sectors and surveillance components of other national vertical programmes are the main determinants of its successful integration	NA		NA

Pilot et al., 2019 (20)	NA	Increased (dengue) awareness and a better understanding of its manifestation needs to be established within health care networks, as well as the whole public	NA	Better collection, collation, compilation and validation of timely data	Data: Exploration of routine health data and additional data sources for disease surveillance; Other: Surveillance networks involving all agencies (NVBDCP, NSPCD, IDSP) need to be further strengthened (dengue). Surveillance needs to be addressed with a systems approach; generating reliable information and valid data on dengue is the obvious first step
Sahal et al., 2009 (21)	NA	Use of electronic reporting systems might improve the timeliness of surveillance data mainly in developed countries where the systems are well established. Successful CDSS depends on effective two-directional information flow between clinicians at the periphery and communicable diseases control units, decentralization, and political support in Ethiopia.	NA	Evaluate: The surveillance system must be evaluated on a routine basis.	IT: Modern technology for efficient data collection, analysis, and interpretation must be used

Wendt et al., 2013 (22)	Nil	Cross-sectoral structures, trust and good communication networks are required	Nil	*Detect*: Timeliness of data collected; *Report*: Standardized format, completeness and comparability of data reported; Evaluate: Accuracy and transparency of data collected (good meta-data when secondary data are used)	*Data*: Fit for purpose and good quality data; *IT*: IT systems that can connect and report between each other
Wolfe et al., 2021 (23)	Nil	Investment in e-IDSR. Potential of digital technology & some urgent solutions	nil	Nil	Laboratory capacity: Improved lab capacity.

8.9. Appendix 9. Results for RQ-3 (Reviews)

8.9.1. Challenges with IDS implementation (RQ3a)

RQ-3 a: Challenges with IDS	Governance (Leadership, accountability, regulation and enforcement)	System/structure (NPHIs role, population based, digitized, sectorial integration)	Financing (Adequate sustainable domestic financing)	Core functions (Detect, report, analyze, respond, feedback, evaluate, preparedness)	Resourcing requirements (Human resources, laboratory capacity, data, IT, Other (e.g., SOPs and GLs))
George et al., 2020 (16)	NA	Incomplete system integration.	A major challenge	Report: Different reporting policies, and heterogenous data.	Human resources: Lack of compliance with SOPs, limited knowledge of terms of reference, surveillance procedures, and case definitions; Laboratory capacity: Limited; Data: Linkage and management of heterogenous data, and incomplete integration. Quality and complexity of data; IT: Slow adoption of technologies, complex and expensive installation of systems, poor data management systems.

Mremi et al., 2021(17)	NA	NA	NA	Detect: Weaknesses in case identification and recording at PHC. This is associated with limited skills among HCWs (lack of training and refresher courses), patient load vs human resource availability, low motivation and inadequate HMIS-related resources; Report: Use of paper-based reporting likely to lead to severe limitations in transmission of data to higher level due to inefficient report review and approval processes, manual routing of reports; Analyze: Poor data management and analysis skills. Routine data analysis insufficient. Core IDS data is weak (incomplete and inconsistent) and inaccurately reflects data from PHC (HMIS data only reflect population seeking care from HCFs). Data from HMIS rarely assessed for quality and rarely analyzed and used for decision-making	Human resources: Shortage of skilled personnel with an understanding of the use of surveillance data in planning; Laboratory capacity: Laboratories are ill-equipped to provide confirmation of suspect priority notifiable infectious diseases. Lack of capacity for timely clinical screening, referral, diagnosis, notification, treatment and containment of suspected cases. PHCs reliant on syndromic approach (with low specificity); Data: Other data sources are present (civil registration, demographic surveillance sites, research outputs, meteorological data etc.) however are not used for planning national disease control programmes; IT: inadequate infrastructure (computers, databases, data mining systems and analytical software); Other: Lack of clear guidelines, lack of recording and reporting forms, lack of warehouses. Health facilities lack copies of IDS Technical Guidelines for standard case definitions
Ng'etich et al., 2021(18)	NA	NA	Lack of financial aid	Detect: Health workers more aware of case definitions for common diseases, and limited focus on other disease of public health importance (such as neglected tropical diseases); Report: Poor data quality. Paper-based reporting increased data errors. Uncertainties exist of the most appropriate reporting channels.	Human resources: Lack of health workers designated to manage disease surveillance data, High turnover of trained health workers Training limited to regional and national levels. Irregular and partial supervision undertaken at regional and district levels; lack of supervision at district level. Most supervisory reviews focused on immunizable diseases, TB and

				Limited knowledge on correct forms to be used as well as specific dates for report submissions (Inconsistencies in weekly and monthly reporting timelines). Lack of active case search written reports (regional surveillance offices) Unavailability of information on disease notification; *Analyze:* Limited capacity and low evidence of proper data analysis. Limited use of outcomes from surveillance performance analysis; *Respond*: Limited generation of reliable health information. Surveillance data generated for onward reporting and not utilized at source; Feedback: Inadequate feedback that demotivate health workers. Feedback often neglects peripheral levels; *Evaluate*: Ministries of Health and WHO Regional Office for Africa to undertake periodic surveillance assessment studies.	HIV/AIDS; *Laboratory capacity*: Limited lab supplies and low knowledge on specimen handling. Lack of ownership and consideration of lab undertakings and budgets in national health plans; *IT*: Poor network, technological and infrastructural capacity; *Other*: Unavailability of notification forms, reporting and management tools, e.g., IDS technical guidelines and appropriate protocols unavailable in health facilities

Phalkey et al., 2013 (19)	Lack of coordination, regulation	Lack of integration (vertical disease surveillance strategies), exclusion of NCDs, weak infrastructures at the district level. Most efforts have been focused on technical aspects (data processing equipment, logistics and lab structures). Poor private sector participation.	Non-sustainable financial resources	Detect: Low use of SDCs. Syndromic surveillance was limited and data capture from communities was often poor; Report: Mostly paper-based reporting. Poor data management. Frequent changes in reporting formats were challenges faced by most evolving systems; Analyze: Poor analytical skills; Confirm/investigate: Weak diagnostic capabilities at facilities in confirming diseases, particularly at the peripheral level; Respond: Poor use of data for decision-making; Feedback: Erratic feedback; Preparedness: Poor preparedness. Inactive teams and poor coordination of activities; Detect: Low use of SDCs. Syndromic surveillance was limited and data capture from communities was often poor; Report: Mostly paper-based reporting. Poor data management. Frequent changes in reporting formats were challenges faced by most evolving systems; Analyze: Poor analytical skills; Confirm/investigate: Weak diagnostic capabilities at facilities in confirming diseases, particularly at the peripheral level; Respond: Poor use of data for decision-making; Feedback: Erratic feedback; Preparedness: Poor preparedness. Inactive teams and poor coordination of	Human resources: Inadequate training and turnover of peripheral staff, inadequate lab technicians, inadequate supervision from the next level; Laboratory capacity: weak, and lack of functional networks; Other: Lack of equipment and reagents, unavailability of job aids (case definitions/ reporting formats), poor availability of communication & transport systems particularly at the periphery and limited storage and transport facilities.

				activities.	

Pilot et al., 2019 (20)	National law is generally not enforcing the reporting notifiable diseases (currently operating public health act of 1897, and revision pending)	Poor integration and cooperation between National Vector Borne Disease Control Programme (NVBDCP) and IDSP resulting in fragmented reporting. This leads to inefficiencies, duplication and potential waste of valuable resources. Poor or no involvement of the private sector. Limited reporting units and missing integration with other programmes (including with health care structure)	Strong reliance on 'out of pocket' expenditure	Report: Underreporting, inconsistencies, irregularities and inaccurate data	Other: Overall performance impacted by frequent changes in programme's functioning, reporting formats and procedures
Sahal et al.,2009 (21)	NA	NA	NA	NA	NA

Wendt et al.,2013 (22)	NA	Challenges from disparate data when attempting One Health integrated surveillance (e.g., different documentation conventions limiting integration)	NA	Report: disparate data (data reported in different formats, with different quality, challenge the IDS system not only at country, but at regional and global levels; time consuming and costly to map different terminologies and translate different formats; Evaluate: ability to evaluate data for accuracy, measuring completeness of data reporting (number of cases reported & number of missing variables)	Data: mostly secondary data that have been collected for another purpose; IT: missing infrastructure for web-based reporting
Wolfe et al.,2021 (23)	Accountability (ToR, procedures for reporting, documentation)	Parallel data collection system causing reporting burdens for staff; lack of coordination	Unsustainable financial resources	Report: Issues with data reporting (accuracy, incomplete data, delay in reporting, under or over-reporting) Feedback: erratic	Human resources: Lack of trained staff; high turnover of peripheral staff; inadequate training and supervision from the next level. Laboratory capability: weak laboratory capacity, and lack of lab networks Others: unavailability of job aids (e.g., case definitions, reporting forms); poor availability of communication and transport facilities

8.9.2. Enablers/opportunities for successful IDS (RQ3b)

RQ-3 b: Enablers /Opportunities with IDS implementation	Governance (Leadership, Accountability, Regulation and enforcement)	System/structure (NPHIs role, Population based, Digitized, Sectorial integration)	Financing (Adequate sustainable domestic financing)	Core functions (Detect, report, confirm/investigate, analyze, respond, feedback evaluate, preparedness)	Resourcing requirements (Human resources, laboratory capacity, data, IT, and other (e.g., SOPs, and GLs))
George et al.,2020 (16)	NA	NA	NA	NA	IT: System integration have the potential to improve data quality, and timeliness of data
Mremi et al.,2021 (17)	NA	Integration of the surveillance functions of the categorical (or vertical) disease control programmes. CBS has the potential to strengthen the early detection and reporting capabilities for several suspect priority diseases	NA	Detect:NA; Report: Improved completeness and timeliness of data (but still sub-optimal); Analyze: Some countries analyze and use routine HMIS data at sub-national levels; Investigate/confirm: NA; Respond: increased national level review and use of surveillance data for the response (but still sub optimal); Feedback: Feedback mechanisms for sharing national surveillance data; Evaluate: NA; Preparedness: NA	Human resources: Training conducted at sub-national (district) level; Other: Introduction and use of eIDSR (electronic IDSR) using short message services for reporting weekly epi data. Implementation of standard surveillance, laboratory and response guidelines. Development of generic data analysis template.

		and events. OH surveillance is strongly encouraged at all levels to efficiently manage and coordinate health events involving humans, animals and their environments			

Ng'etich et al.,2021 (18)	NA	NA	NA	Detect: NA; Report: Weekly reporting forms increase disease surveillance reports. Clarity on the proper reporting channels and reporting dates. An efficient reward system for reporting. Effective reports documentation on public health actions or decisions following data collected from surveillance systems; Analyze: Analyze surveillance data and closely monitor surveillance performance indicators at regional levels. Routine data analysis centered on surveillance system performance monitoring and improved data accuracy. Scaling up data entry; Investigate/confirm: NA; Respond: NA; Feedback: Adequate and prompt feedback required; Evaluate: NA; Preparedness: NA	Human resources: Increased number of staff trained on disease surveillance, designated surveillance focal person and reduced workload. Surveillance activities in line with job description. Training to be conducted through initial pre-service curriculum, induction and on the job training (supervisory visits and sensitization meetings) at both community and district level. Continued health worker training on correct form filling and reports compilation. Increased awareness on supervision benefits and efforts to enhance supervision. Strict adherence to planned surveillance schedules (prioritized surveillance and supervisory visits); IT: Electronic reporting system, mobile-SMS based reporting and use of mobile technologies, technical support, and network boosters; Other: Health information systems strengthening. Health facilities displaying visual aids for IDS functions were more likely to report surveillance data. Posters and guidelines to be provided, as well as properly designed operational plans. Health policy reviews.

Phalkey et al., 2013 (19)	NA	NA	NA	NA	NA
Pilot et al.,2019 (20)	District malaria officers (from NVBDCP) urged to actively share their reports, as well as closely cooperate with IDSP authorities in an aim to streamline procedures and reduce inefficiencies	Incorporating System for early warning based on emergency data (SEED) data into IDSP have a potential to identify outbreaks of dengue earlier infrastructure of IDSP. Promising infrastructure especially for achieving integration of vertically and inefficiently operating programs	NA	Detect: IDSP's three-tiered system has the potential of capturing cases (detection) that might never reach the lab or hospital, and thereby enhancing sensitivity	Laboratory networks: One study suggests that IDSP has contributed to strengthening laboratory networks, quality assurance of dengue diagnosis; Data: Enabling open access to IDSP data would potentially facilitate stakeholder involvement, especially from the public and the private sector; Other: One study suggests that IDS has contributed to reviews of case definitions.
Sahal et al.,2009 (21)	NA	Use of electronic reporting systems might improve the	NA	NA	NA

		timeliness of surveillance data mainly in developed countries where the systems are well developed			

Wendt et al.,2013 (22)	NA	Enables the use of a combination of existing information instead of a segregated sector approach which may help to assess the magnitude and the spread of zoonotic agents better and to improve the understanding of health risks at the human- animal interface	NA	Preparedness: A One Health approach to IDS can offer more effective and efficient preparedness and response systems by detecting disease in animals first, syndromic surveillance instead of only diagnostic data.	NA

Wolfe et al.,2021 (23)	NA	Use or merge with existing system (e.g., influenza surveillance with IDS) to reduce redundancy & improve the effectiveness	NA	Data management/Analysis: Evidence of improved data management after baseline IDS assessment with improved analysis at health facility and district level (Uganda), and regular calculating and monitoring of AFP and measles surveillance indicators in several health district (Ethiopia) Feedback/info: Release of epi bulletins from the national level (Uganda)	Human resources: Designated focal person increased adequate reporting (e.g., Kenya)

8.10. Appendix 10. Results RQ-1-3: Included Primary Studies (N=5)

Author Year	RQ-1	RQ-2 Features and pre-requisites of effective IDS systems					RQ-3 Challenges and enablers/opportunities to IDS development				
	Definition of IDS	RQ-2 Governance	RQ-2 System/ structure	RQ-2 Finances	RQ-2 Core functions	RQ-2 Resourcing requirements	RQ-3 Governance	RQ-3 System/ structure	RQ-3 Finances	RQ-3 Core functions	RQ-3 Resourcing requirements
Abuzerr et al., 2021 (27)	No definition. Incorporation of COVID-19 surveillance into the existing open DHIS2 system is mentioned.	'Better governance and leadership				Improved understanding of the transmission and effective control (including OH approach) of zoonotic disease.	Lack of policy coherence; Poor governance and leadership		Limited financial resources		Lack of One Health training programmes

Ibrahim et al., 2020 (24)	No definition. IDS is described as "a framework implemented to improve the usability of surveillance and laboratory data and improve detection and response to the primary causes of morbidity and mortality in African countries". IDS also guides, monitors and assesses the impact of interventions;	Involvement of all health facilities in IDS will produce more reliable data				Harmonization of the multiple health facilities registers; Training for clinicians (e.g., on confirmation of disease using laboratory test by the relevant agency of government); Production and distribution of all reporting tools to all levels of implementation; Chain of adequately trained staff who are adequately supported; Adequate		Limited participation of health facilities in IDS and		Poor documentation of patients' data in the facility registers; Lack of laboratory results for most of the diseases treated at the health facilities	Limited capacities of personnel to identify, report IDS priority diseases, analyze and interpret IDS data for decision-making and for supportive supervision (limited training); Inadequate reporting tools; Lack of transportation facilities

	provides a framework for identifying major public health problems in a community; and serves as a planning guide.					infrastructure (e.g., computers and printers) for reporting, and training					

Kebede et al., 2010 (28)	No definition, The goal of the IDS strategy is to "implement a coordinated and integrated approach to data collection, analysis, interpretation, use and distribution of surveillance information on priority communicable diseases to assist in public health	Enhanced advocacy	Organizational structures and international initiatives critical for the strengthening of the capacity of countries in EPR		Intervention decisions, including timely and appropriate responses to epidemics"	Collaboration and resource mobilization for improving the database of outbreak reports specific to time, place and risk factors; Commitments of governments to implement IDS; Support of partners and the establishment of various EPR.	Poor coordination of epidemic detection and response; Weak public health systems; The spatial and temporal variability of the various epidemics also present a challenge; Achievements in surveillance and weekly reporting of epidemic-prone diseases, laboratory confirmation of etiologic agents, communication of			Lack of complete reporting	Lack of trained personnel; Lack of adequate laboratory services

							epidemic outbreaks and collaboration with national, regional and international institutions for strengthening preparedness and response to disease.				
Omondi et al.,2020 (25)	No definition. IDS is described as "a unit of the healthcare that makes surveillance and laboratory data more usable in improving detection and prevention of illnesses and disease outbreaks"				Timely Dissemination of IDS Data	CHW training on IDS ; Availability of IDS System Tools				Lack of timely IDS data as hindrance to uptake	Lack of training on using disease surveillance data; Lack of tools for disease surveillance in facilities

Saleh et al.,2021 (26)	No definition. IDS is described as "a means towards strengthening epidemiologic surveillance and response in the African region"	-	-	Allocation of adequate resources required.	(Case detection, registration and confirmation, reporting, data analysis, epidemic preparedness and response, and provision of feedback.)	If all health facilities receive appropriate and sufficient equipment, technical and logistic support, there is an opportunity to extend the electronic DHIS2 currently available at district level to peripheral levels	-	-	-	Overall weak and unsatisfactory core functions: Detection and Confirmation: infrequent use of SCDs for diagnosis and weak laboratory facilities Data analysis: inadequate at all levels Reporting: paper based leading to overburdening of staff Feedback: irregular oral and non-existent written feedback	Support functions overall inadequate especially at facility-level; Inadequate human and material resources Weak laboratory capacity Lack of motivation for IDS implementation; Financial constraints

National level											Lack of electronic system/ database for infectious disease reporting; Inadequate financial resources for conducting regular supervision visits and training; Lack of back-up system for data security
Regional level										Delay of reports from health facilities	Lack of electronic system for infectious

										particularly privately owned	disease reporting; Inadequate resources including fund for conducting supervision visits; Low staff knowledge on IDS strategy particularly at health facilities; Poor communication system for reporting suspected outbreaks; Unreliable internet service; Lack of incentives for IDS reporting leading to low staff motivation

Facility level										Filling paper-based surveillance forms time consuming; Late report collection by DSOs	High staff workload; Absence of airtime vouchers for submitting weekly cell phone-texted data; Lack of regular trainings or capacity building on disease surveillance and IDS reporting tools; Inadequate supervision and feedback from higher levels; Lack of designated personnel responsible for IDS at the hospital level

CHW: community health worker; DHIMS2: District Health Information Management System II FGD: Focus Group Discussion; IDS: Integrated Disease Surveillance; KII: Key Informant Interview; NA: Not Available; UER: Upper East Region; WHO: World Health Organization.

8.11. Appendix 11. Quality of Included Reviews (N=8)

Author Year	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	Over-all quality
George et al., 2020 (16)	Yes	Yes	Yes	Yes	No	Yes	No	Partly yes[a]	Yes	Yes	No	Yes	Yes	Low
Mremi et al., 2021 (17)	Yes	No	Yes	Yes	Partly yes[b]	Yes	No	Partly yes[a]	No	Yes	No	No	No[c]	Critically low
Ng'etich et al., 2021 (18)	Yes	Yes	Yes	Yes	Partly yes[b]	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Low
Phalkey et al., 2021 (19)	Yes	No	Yes	Yes	Yes	Yes	No	Partly yes[a]	No	Yes	No	Yes	Yes	Critically low
Pilot et al., 2019 (20)	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Critically low
Sahal et al., 2021 (21)	No	No	No	No	No	No	No	Yes	No	?	No	Yes	Yes	Critically low
Wendt et al., 2013 (22)	Yes	No	No	Yes	No	Yes	No	Yes	No	?	No	Yes	Yes	Critically low
Wolfe et al., 2021	Yes	Yes	Yes	Yes	Yes	Yes	No	Partly yes[a]	No	Yes	No	Yes	Yes	Low

(23)														

Justifications for 'partly yes':

a. Some study characteristics reported, but no information on study design (or methods) of included studies

b. Duplicate data extraction, but not duplicate study selection

c. Recommendations given in discussion based on other reviews, and not on the included studies

Quality assessment criteria and critical criteria* for determining overall quality (No. 2, 6, 7, 9, and 12)

1. Clear objective and/or research questions
2. Refers to a published review protocol*
3. Use of reporting standards (e.g., PRISMA)
4. Inclusion and exclusion criteria (e.g., study design criteria)
5. Duplicate, independent screening and data extraction (or for part of the citations)
6. Adequate search (at least 2 databases, and reports a search strategy and/or search terms)*
7. Provides a list of excluded individual studies with justification for exclusion*
8. Description of the main characteristics of included studies
9. Quality assessment of included studies by two authors independently*
10. Sources of funding for the review reported, and there are no conflicts of interest.
11. Provides information on the funding and potential conflict of interest of individual included studies.
12. Discusses possible biases, or limitations with the review*
13. Conclusions based on main results

Table. AMSTAR Rating overall confidence in the results of a review (Shea et al.,2017)

High	Moderate	Low	Critically low
No or one non-critical weakness	*More than one non-critical weakness**	*One critical flaw with or without non-critical weaknesses*	*More than one critical flaw with or without non-critical weaknesses*
The review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest	The review has more than one weakness but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review	The review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest	The review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies

*Multiple non-critical weaknesses may diminish confidence in the review, and it may be appropriate to move the overall appraisal down from moderate to low confidence

8.12. Appendix 12. Quality of Included Primary Studies (N=5)

Author, Year	Screening question		Qualitative					Quantitative descriptive					Mixed methods					Overall Quality Rating
	1	2	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Abuzerr et al., 2022 (27)	yes	yes	yes	yes	yes	Can't tell	yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	80%
Ibrahim et al., 2020 (24)	yes	yes	yes	yes	Can't tell	Can't tell	Can't tell	yes	no	yes	yes	yes	no	Can't tell	Can't tell	no	no	0%
Kebede et al., 2010 (28)	yes	Can't tell	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Omondi et al., 2020 (25)	yes	yes	NA	NA	NA	NA	NA	yes	no	yes	yes	yes	NA	NA	NA	NA	NA	80%
Saleh et al., 2021 (26)	yes	yes	yes	yes	Can't tell	Can't tell	Can't tell	yes	no	yes	yes	yes	no	Can't tell	Can't tell	no	no	0%

NA: Not Applicable '

*Overall quality scoring was not conducted as we could not progress past the screening questions

a. Screening questions:

1. Are there clear research questions?
2. Do the collected data allow to address the research questions?

b. Qualitative

1. Is the qualitative approach appropriate to answer the research question?

2. Are the qualitative data collection methods adequate to address the research question?
3. Are the findings adequately derived from the data?
4. Is the interpretation of results sufficiently substantiated by data?
5. Is there coherence between qualitative data sources, collection, analysis and interpretation?

c. Quantitative descriptive

1. Is the sampling strategy relevant to addressing the research question?
2. Is the sample representative of the target population?
3. Are the measurements appropriate?
4. Is the risk of nonresponse bias low?
5. Is statistical analysis appropriate to answer the research question?

d. Mixed methods

1. Is there an adequate rationale for using a mixed methods design to address the research question?
2. Are the different components of the study effectively integrated to answer the research question?
3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

$Calculation of an overall quality scorea using the MMAT				
5*****	4****	3***	2**	1*
100% of criteria met	80% of criteria met	60% of criteria met	40% of criteria met	20% of criteria met

Based on the 5 criteria per domain the overall score can be presented using descriptors (e.g., stars) or percentages (%). For mixed methods studies, since all three domains are rated (and there are 15 instead of 5 criteria), the overall score will be the score of the weakest component.