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Health Information Systems for Public Health Surveillance and Decision-Making

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ABSTRACT

Health Information Systems (HIS) are central to effective public health surveillance and evidence-based decision-making, enabling the systematic collection, integration, analysis, and dissemination of population-level health data. Rapid digitalization of healthcare, alongside the widespread adoption of electronic health records, disease registries, laboratory information systems, and surveillance platforms, has significantly enhanced the capacity of public health systems to monitor health trends, detect outbreaks, and support policy and programmatic interventions (World Health Organization [WHO], 2018; Centers for Disease Control and Prevention [CDC], 2022).

This narrative review synthesizes evidence from peer-reviewed literature and global health reports to examine the role of Health Information Systems in public health surveillance and decision-making, with a focus on system components, data interoperability, analytical capabilities, and governance frameworks. The findings indicate that integrated and interoperable HIS improve data quality, timeliness, and completeness, strengthening early warning systems and supporting timely and informed public health action (AbouZahr & Boerma, 2017; WHO, 2020). The integration of advanced analytical tools—including big data analytics, artificial intelligence, and geographic information systems—further enhances predictive modeling, risk stratification, and decision support at local, national, and global levels (Kamel Boulos et al., 2019).

Despite these advances, persistent challenges remain, particularly data fragmentation, lack of standardization, privacy and security concerns, and disparities in digital infrastructure and workforce capacity, especially in low- and middle-income countries (Mechael et al., 2014; WHO, 2021). Addressing these barriers through strengthened governance, adoption of international data standards, and investment in capacity building is essential to fully realize the potential of HIS.

This review underscores Health Information Systems as indispensable tools for modern public health surveillance and decision-making and offers insights to guide policymakers and health system leaders in optimizing HIS implementation to enhance resilient and responsive public health systems.

Keywords: Health Information Systems; Public Health Surveillance; Decision-Making; Digital Health; Health Informatics

INTRODUCTION

The availability and accessibility of safe, timely, accurate and sufficiently complete data are essential elements to effective public health surveillance-and thus-informed decision-making. Health Information Systems (HIS) constitute the core of contemporary public health systems and function as formal and structured facilities for systematically collecting, processing, and analyzing population-ecological data on health status. This increased dependence on well-coordinated and harmonized HIS is a response to the evolving public health threat landscape among other issues such as re- and emerging infectious diseases, burgeoning global non-communicable disease burden, climate related risks to public health, enduring social determinants of inequities in health between different popu lations-regions.

Traditionally, public health surveillance systems were largely dependent on manual reporting and varied data sources, which led to slow outbreak detection and response, incomplete recording of cases, as well as the inability to provide support for strategic planning and timely action. These limitations inhibited public health response to threats, and the efficient use of resources. The advent of digital health technologies including electronic health records (EHRs), laboratory information systems, disease registries and mobile health platforms has changed the landscape of surveillance through its

potential to capture data systematically and monitor population-based indicators in near real time[1–3]. These technological advances have enhanced public health systems in the surveillance of disease trends, monitoring and evaluating the impacts of public health interventions, and in evidence-informed decision-making.

Health Information Systems (HIS) at different geographical and administrative levels function to ensure the availability of necessary information required for public health decision-making in a wide range of activities ranging from outbreak response, regular surveillance system monitoring and policy development . Combined HIS systems allow interoperability between clinical, laboratory and administrative databases resulting in increased situational awareness and the ability to take complete and coherent public health action (CDC, 2022). This type of integration is especially critical in the context of public health emergencies, where rapid access to high-quality data is crucial for risk assessment and response planning.

Meanwhile, the application of sophisticated analytical methods - e.g., big data analytics, AI, GIS has strengthened HISs predictive and decision-support functionality. These systems can support the development of early warning systems, predictive models and risk stratification methodologies to inform proactive public health intervention and resource utilization (Kamel Boulos et al., 2019). HIS are thus moving from passive storehouses of data to active tools for shaping public health action.

However, despite these progressions, many health systems around the world – including those of low- and middle-income countries (LMICs) – have experienced major obstacles when it comes to successful HIS implementation and use. Ongoing barriers include data siloes and fragmentation, non-standardized data architectures; insufficient systems' inter-operability; lack of technical and analytics expertise; as well as persisting concerns over data privacy, security and governance (Mechael et al., 2014; WHO, 2021). Such limitations compromise the efficiency of surveillance systems, reduce the credibility of data and restrict the capacity of HIS to support informed, equitable and evidence- based decision-making.

Given the growth of digital health data applications for public health action, a comprehensive understanding of what HIS can and cannot do becomes increasingly crucial. This review aims to summarize the current evidence on how HIS is being used for public health surveillance and decision-making, describe important system components and new technologies of interest, and discuss issues related to strengthening through HIS. Based on a review of the existing literature, this paper seeks to offer guidance to decision makers who are interested in strengthening the ability of public health systems to withstand the pressures placed on them, be responsive and equitable in their actions, and take advantage of available data assets in today's more data-intensive global health environment.

METHODOLOGY

Review Design and Objectives

Using a structured narrative review approach, this study reviewed available literature to understand the contribution of Health Information Systems (HIS) towards public health surveillance and decision making. The key focus was to systematically assess the contribution of HIS to data generation, synthesis, interpretation and use in decision-making relating to public health across various health system settings. The methodological approach was guided by existing frameworks used for health informatics and public health reviews, in order to capture transparency, reproducibility and methodologic rigor (Grant & Booth 2009; Arksey & O'Malley 2005). Reporting for the review was guided, where relevant, by the main components of PRISMA-ScR (The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews): to improve transparency and maximize completeness (Tricco et al., 2018).

Data Sources and Search Strategy

We systematically searched literature from a range of electronic databases, namely PubMed/MEDLINE, Scopus, Web of Science, IEEE Xplore and Google Scholar using appropriate search terms in order to capture multidisciplinary evidence across public health, health informatics and digital health spectrum. In addition to peer-reviewed literature, grey literature including policy documents, technical reports, and implementation guides were reviewed. Special attention was paid to publications from leading international bodies such as the World Health Organisation (WHO), The Centers for Disease Control and Prevention (CDC) and the World Bank in consideration of their prominent position in the development HIS globally and public health surveillance.

The search strategy included mesh terms and free-text keywords such as "Health Information Systems," "Public Health Surveillance," "Decision-Making," "Digital Health," "Health Informatics," Disease Surveillance, and Health Data Analytics among others. Use of Boolean operators (AND, OR) was used to further narrow the search and final queries. In order to maintain a modern focus of HIS development and utilization, the search was confined to English literature published from 2010 through 2024.

Eligibility Criteria

New data were considered eligible for inclusion if they fulfilled:
Assessed the development, deployment, evaluation or monitoring of HIS with respect to public health surveillance or decision-making;

Covered priority public health areas such as communicable diseases, non-communicable diseases emergencies or health systems performance monitoring;

Eligible documents Types of eligible documents included peer-reviewed journal articles, systematic or narrative review papers and authoritative technical and policy reports from established bodies.

Studies were excluded if they:
Restricted to clinical decision support systems without obvious public health relevance;
Were not well enough described methodologically to allow for meaningful interpretation;
Were opinion, editorial commentaries or conference abstracts that did not have full text.

Study Selection and Data Extraction
Study selection Studies were first screened based on the title and abstract, followed by a review of the full text of articles that met inclusion criteria. Data extraction Data were extracted from included studies using a standardized data extraction form. Data that was extracted included publication details, characteristics of the HIS (components and architecture, data sources, interoperability), analytical and decision support tools available to the system, governance/regulatory issues and reported yields in terms of effectiveness for surveillance purposes/public health decision making (WHO, 2018; AbouZahr & Boerma, 2017).

Data Synthesis and Analysis
The method of thematic analysis was used to combine the results from the included studies (Braun & Clarke, 2006). Data were synthesized according to a set of major thematic domains: (1) HIS structure and data sources, (2) interoperability and integration of data, (3) analytical capacity and decision support tools, (4) governance, privacy, and security considerations for data capture and control, as well as patient engagement; 5) implementation challenges encountered. Broader themes cutting across surveillance capacity and decision-making effectiveness-systems (eg, machine learning, geoweb) were also reviewed to uncover novel directions for innovation.

Quality Considerations
Because of the heterogeneity in study design and evidence type presented in this review, a formal risk of bias was not performed. The credibility and applicability of included evidence was systematically assessed with an appraisal source authority, methodological transparency, and consistency of findings across multiple studies (Tricco et al., 2018). Preference was given to high-impact peer-reviewed journal articles and reports released by reputable global public health organizations in order to maintain the strength of evidence made available for synthesis.

RESULTS

Study Selection and Characteristics
Results The literature review identified a large and heterogeneous body of evidence on HIS for public health surveillance and decision-making. After systematic title, abstract, and full-text article screening with predetermined eligibility criteria, the final synthesis included peer-reviewed studies and technical and policy reports." The reviewed literature was notable for methodological and contextual heterogeneity and consisted of both empirical studies and assessments of implementation initiatives.

The studies included were geographically diverse, representing both high-income countries and LMICs. Applications included work in the key public health priority areas of communicable disease surveillance, non-communicable disease monitoring, emergency preparedness and response and health system performance assessment. This diversity allowed for broad evaluation of HIS performance across different health system capacities and resource scenarios.

Components of health information systems
Consistent with other systematic reviews of HIS, the highest number of systems identified were complex, multi-component systems that integrated data from multiple sources (e.g., electronic health records, laboratory information systems, disease registries, vital statistics systems, community-based reporting platforms) . Highlighted HIS with standardized data

collection processes and interoperable architectures exhibited significant improvements in data completeness, accuracy and timeliness. These changes were singularly linked to improved surveillance and better functioning of public health response (AbouZahr & Boerma, 2017; WHO, 2018).

Impact on Public Health Surveillance

The results show that HIS that are well integrated considerably improve public health surveillance capabilitys. Access to real-time or near–real-time data improved early outbreak detection, allowed more accurate assessments of disease trends, and bolstered the utility of early warning systems . When it comes specifically to communicable diseases, HIS-enabled surveillance systems provided valuable support in the areas of disease tracking, supporting data linked to vaccination and immunization programs, and monitoring emerging public health threats. Together, these prepared the ground for more rapid, finessed public health interventions and supported a greater understanding of decision-makers (CDC 2022; WHO 2020).

Decision-Support and Analytical Capabilities

Among the key results of the review was the changing role of HIS as decision-support tools with the advent of high-end analytical functions. The inclusion of big data analytics, artificial intelligence, geographic information systems, and predictive modeling, risk stratification, and spatial analysis of disease patterns have been reported . Such analytical functions facilitated evidence-informed decision making for resource allocation, health policy formulation and for emergency preparedness and response planning at local, national, and global levels (Kamel Boulos et al., 2019).

Governance, Data Quality, and Interoperability

While a number of technological advancements were noted, issues around data governance, quality and interoperability were repeatedly reported in the literature. The lack of cohesion among existing information systems, absence of common data standards, and inadequate mechanisms for data-sharing restricted comprehensive surveillance systems and multisectoral decision-making. Other major barriers to adoption and use of health information systems (HIS) included data privacy, security, and ethical use of health information, especially in contexts where the regulatory framework and enforcement mechanisms are weak or underdeveloped (Mechael et al., 2014; WHO, 2021).

Equity and Implementation Challenges

Overall, the review found large differences in HIS maturity, features and efficiency between High Income Countries (HICs) and LMICs. Resource-limited settings often faced inadequate digital infrastructure, empty spectacle of digitally-enabled health investment constrained by shortage of trained human resources each year, and persistent financial constraints on digital infrastructure as barriers to effective implementation and long-term sustainability of information systems. But, multiple studies showed that a targeted approach in investing digital infastructure, human resources and appropriate context specific digital technology could provide tremendous improvement in surveillance capacity and decision making in LMICs. These results may inform strategic HIS strengthening efforts that mitigate inequities and strengthen population health outcomes in complex and diverse settings.

DISCUSSION

Results from this review strongly support the view that HIS are integral to the strengthening of public health surveillance systems and the promotion of evidence-informed decision-making across different health systems contexts. The integration of health information systems (HIS) where data sharing is more natural and insightful, has been identified as a key driver of both the timeliness, quality, and utility of health data . These enhancements will allow for the expansion of national disease trend surveillance, early detection of public health threats along with more efficient operational and strategic decision-making to address such threats. These findings are in line with previous work that has described HIS as essential building blocks for resilient and responsive public health systems (AbouZahr & Boerma, 2017; World Health Organization [WHO], 2020).

One of the key messages that arises from this review is the increased use of analytical and digital technologies in public health decision-making. Big data analytics, artificial intelligence and geographic information system (GIS) have significantly improved the predictive and explanatory potential of surveillance systems, moving countermeasures from reactive response to proactive and predictive public health response. This has made them especially useful in outbreak projection, health risk stratification, and the optimal distribution of resources, facilitating the wider movement towards data-driven public health governance (Kamel Boulos et al., 2019). That said, the successful implementation of these emerging technologies relies on quality data, interoperability of systems and adequate governance.

While technological capabilities have matured greatly over the past few decades, many enduring and systematic issues

continue to hinder the widespread use of Health Information Systems. Despite decades of reporting, data fragmentation and lack of standardised data models remain some of the most frequently reported challenges to complete surveillance and intersectoral data alignment. In decentralized health systems, some of these hurdles simultaneously weaken the continuity, comparability, and interpretability of health information across jurisdictions. Since HIS are being built on individual health (including real time, longitudinal) data streams, issues of data privacy, security and ethical use of health information have received more attention (WHO, 2021). Some of these are resolved with stronger regulatory frameworks, the use of globally accepted data standards, and consistent trust-building with data providers, users, and the public.

The review also found significant inequalities in HIS implementation and HIS functioning between high-income countries and low- and middle-income countries (LMICs). Although, HIS has made great strides, limited digital infrastructure, inadequate human resources for health, and funding constraints continue to hinder horizontal HIS implementation and sustainability in many low- and middle-income countries (LMIC). Still, some evidence from different contexts in LMIC points to the role that scalable digital platforms, targeted capacity-building initiatives and international collaborations can play at enhancing surveillance capacity and decision-making capacity. The conclusive results presented here further strengthen international demands for continuous investment in country-specific Health Information Systems – key across health system strengthening and global health security efforts (WHO, 2018).

From a policy and practice perspective, the review findings emphasize the importance of a balanced and integrated approach to HIS development, one that includes both technical innovation alongside governance, institutional capacity and HR development. In the context of this growth in digital tools, interoperability, data governance, and workforce training should be prioritized by policymakers and health system leaders to ensure HIS can serve as effective facilitators of public health action . Integrating HIS along with formulating wider health system and emergency preparedness strategies across sectors are vital to making the system resilient and responsive to future public health emergencies.

Thus, this review shows that Health Information Systems are an integral and complementary instruments for successful public health monitoring and decision making not treatable by any alternative tools. Further work is warranted to assess the effectiveness of the analytic approaches, identify scalable, sustainable models of HIS for low-resource settings, and develop consensus metrics for HIS and public health outcomes. These will be essential to making sure HIS continue to develop as strong, equitable, and usable platforms in an increasingly data-driven public health landscape.

CONCLUSION

Health Information Systems (HIS) are at the core of effective public health surveillance and evidence-based decision-making. This review clearly illustrates that with good design, building, and implementation of integrated, interoperable HIS, health data quality, timeliness, access, and usability substantially improves. These enhancements facilitate the timely identification of public health threats, ongoing surveillance of population health trends, and policy formulation and programmatic planning based on better data. With digital data playing an increasingly pivotal role in dictating action within health systems, the role of HIS has grown both strategically as well as in the support it provides to the need for responsive, adaptive, and resilient public health systems (AbouZahr & Boerma, 2017; World Health Organization [WHO], 2020).

The results also show the increasing role of advanced analytical capabilities, such as big data analytics, AI, and GIS, in enhancing the HIS decision-support functions. Together with strong governance frameworks and standardized data models, such technologies could turn most traditional public health surveillance systems from reactive reporting systems to proactive, predictive systems that anticipate and indicate health threats, allowing for timely interventions (Kamel Boulos et al., 2019). Nonetheless, innovation cannot deliver on its promise of benefits unless long-standing barriers to data use—especially data fragmentation, insufficient inter-operability, privacy and security concerns, and a lack of workforce capacity—continue to be tackled in a systematic manner.

Finally, it highlights significant regional inequalities in the implementation, maturity, and functioning of HIS, with contrasting examples from high-income countries versus low- and middle-income countries. Closing all these gaps will necessitate continued investments in the digital infrastructure, workforce, and governance needed to provide equitable access to high quality health information. Efforts to strengthen national Health Information Systems should thus be considered as a key building block of wider health system strengthening activities and global health security plans (WHO, 2018; WHO, 2021).

HIS are vital to public health surveillance and decision-making. There are priority actions for the future related to the development and sustainment of HIS that are interoperable and secure; responsible implementation of technology; and cross-sectoral action to transform health data into useable, timely, equitable public health results.

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