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Role of Health Informatics in Public Health Surveillance and Response

Mohammed Javeedullah[1*]

[1]New England College 98 Bridge Street, Henniker, NH 03242

[1]JMohammed3_GPS@nec.edu

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Corresponding Author

Mohammed Javeedullah
JMohammed3_GPS@nec.edu

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ABSTRACT

Health informatics functions as a vital resource which improves the quality of public health monitoring together with response activities. Health informatics combines EHRs with mHealth and GIS alongside AI to assist rapid disease recognition and create data-based choices that produce effective public health intervention programs. The research evaluates the significance of informatics systems for disease outbreak tracking alongside their capacity to share information in real-time and develop forecasting capabilities. Successful surveillance systems demand the ability to bring together various health data and make them work together seamlessly. The global health response receives ongoing broader strength from digital health infrastructure improvements despite data fragmentation and technological gaps. Modern public health strategies need health informatics since it helps organizations act proactively and collaborate better in managing current health threats while boosting population health results.

INTRODUCTION

Health informatics establishes a connection between healthcare activities and information technology together with data science methods to enhance medical care through better results and service delivery. The framework enables staff to collect data and analyze it to enhance clinical decision-

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making then boost medical treatment quality while improving operational health system effectiveness [1]. Public health depends heavily on health informatics to detect health threats because this field serves as an essential tool for monitoring important health-related events.

Public health surveillance involves the consistent collection and analysis of health information followed by interpretation of population health conditions and outbreak detection purposes and public health intervention guidance. Health informatics plays an essential role in determining the evolving nature of disease transmission and human behaviors and environmental elements that impact health status [2]. Surveillance data guides policymakers through decision-making and enables allocation of resources and promotes intervention creation which improves population health. The core elements of effective surveillance systems need excellent data systems combined with accurate reporting and fast response capabilities and this is exactly where health informatics ensures success [3].

Public health surveillance and response adopted health informatics to modernize its practices and create improved abilities to detect and manage health threats more efficiently and precisely and quickly. The health monitoring process uses modern technologies like electronic health records (EHRs) and mobile applications as well as geographic information systems (GIS) and real-time data analytics tools for surveillance functions [4]. The systems provide public health authorities with machinery to monitor disease outbreaks through better trend forecasting ability so they can efficiently deploy resources.

Health informatics serves a purpose that extends past data gathering activities when conducting surveillance. Health informatics achieves data integration across various sectors of health services while preserving system interoperability to establish continuous dialogue among government health officials. The evaluation of big datasets through machine learning techniques and artificial intelligence algorithms helps public health authorities discover concealed patterns and generate predictive information for better proactive decision making [5].

The extensive opportunities provided by health informatics to boost public health surveillance encounter various technical obstacles which must be resolved. Three main obstacles that restrict the full adoption of health informatics in public health include data privacy challenges combined with connectivity difficulties between differently advanced IT systems and variable technological capabilities of public health regions [6]. Health informatics for public health demonstrates promising prospects because cutting-edge technology and well-formed policies will contribute to better surveillance systems.

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HEALTH INFORMATICS: AN OVERVIEW

The field of health informatics uses technology together with data to develop methods which advance healthcare delivery quality and develops improved patient experiences while optimizing healthcare management. Through the unification of healthcare practice with information technology and data science it enables optimal solutions regarding health data storage as well as retrieval and utilization [7]. Health informatics operates as a framework that works to strengthen clinical choices and optimize healthcare operational efficiency and guarantee complete population access to beneficial healthcare services.

Health informatics consists of three fundamental elements which include electronic data management and collection for healthcare use followed by data analysis for clinical and administrative choices along with data applications for better healthcare delivery and public health results [8]. Health informatics includes medical informatics along with nursing informatics and pharmacy informatics and public health informatics as its various disciplines. Each specialty field under health informatics targets a different healthcare domain to enhance practice outcomes by using informatics knowledge [9].

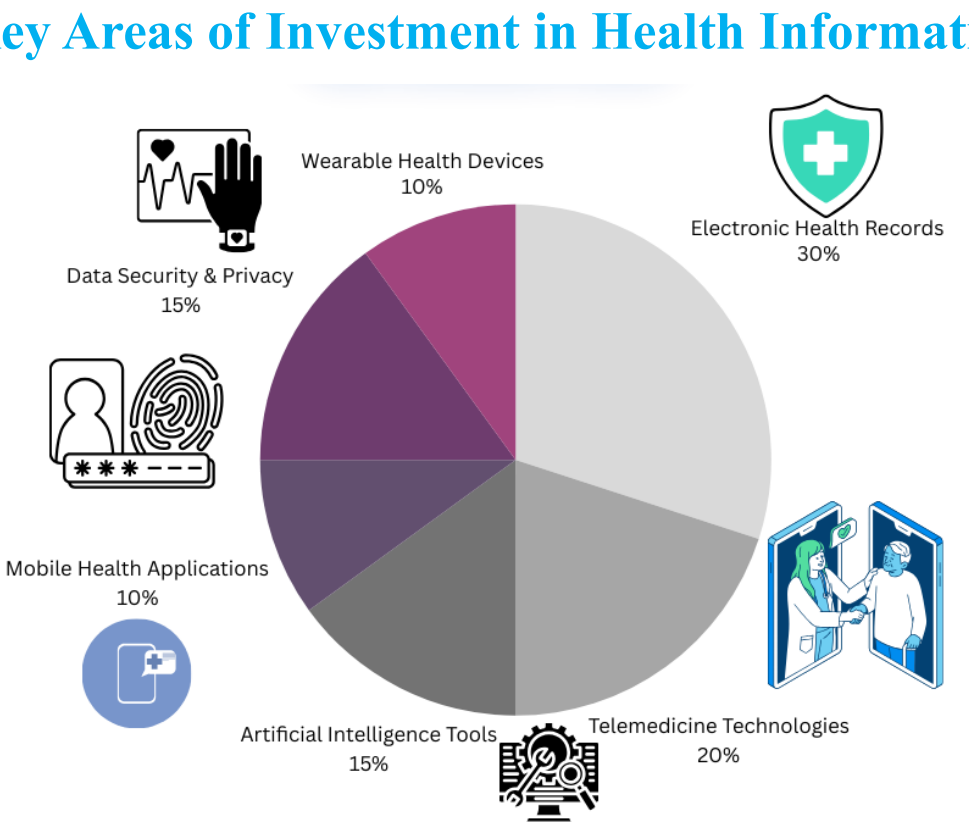

Figure: 1 showing key areas of investment in health informatics

Electronic Health Records (EHRs) represent the primary core element of health informatics practice.

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The digital system called EHRs acts as an alternative to paper charts while maintaining a complete collection of patient details including clinical histories plus diagnoses together with all medications and test outcome information along with treatment strategies. EHRs enhance patient care operations and establish immediate medical data accessibility for healthcare providers. Coordinated care operations depend on this accessibility particularly when various pharmacists treat one patient at a time [10].

Health information exchange (HIE) represents an essential health informatics technology that enables safe information sharing between different healthcare providers and healthcare institutions. Health information exchanges help maintain care continuity and eliminate redundant testing while optimizing communication among various healthcare groups to generate positive patient results [11]. Public health informatics depends heavily on health informatics to gather and interpret data then distribute findings for developing public health policies and intervention plans. Through information systems public health informatics establishes tracking methods for disease spread and health trend analysis while predicting how risks affect group populations. Health professionals can enact prompt interventions toward new health problems through data-based methods addressing infectious diseases along with environmental hazards and persistent medical issues [12].

Health informatics greatly depends on clinical decision support systems (CDSS) which serve as a vital functional element. Medical staff benefits from these analytic systems to produce clinical decisions that combine established guidelines together with individual patient records and information [13]. The implementation of CDSS helps healthcare providers lower their mistakes while providing more precise medical diagnoses and delivering best practice medical treatments to patients. The utilization of technology in health informatics allows multiple disciplines to improve healthcare by enhancing both its quality along with efficiency and accessibility. Advanced data management tools and systems which health informatics implements enable worldwide improvement of clinical practices and public health surveillance and health outcomes [14].

HEALTH SURVEILLANCE FOR THE PUBLIC SECTOR OPERATES THROUGH ESSENTIAL FRAMEWORKS

The continuous system of collecting and analyzing health-related data accompanies interpretation and distribution of this information for public health action efforts. The discipline performs essential functions toward recognizing new health threats by monitoring disease patterns and supporting decisions which lead to new interventions and policy implementations [15]. Public health surveillance functions as a method to stop disease outbreaks while regulating infectious disease transmission while monitoring chronic disease patterns with the purpose of enhancing population health outcomes.

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Public health surveillance depends primarily on data collection as one of its fundamental principles [16]. The sources of surveillance data stem from hospitals alongside healthcare providers and laboratories as well as vital statistics documents such as birth and death records and population survey information. Statistical data from multiple sources go through aggregation processes before analysis which enables tracking of disease levels together with risk factors and health indicators. The reliability of surveillance analysis depends heavily on proper data acquisition which allows immediate responses to health threats [17].

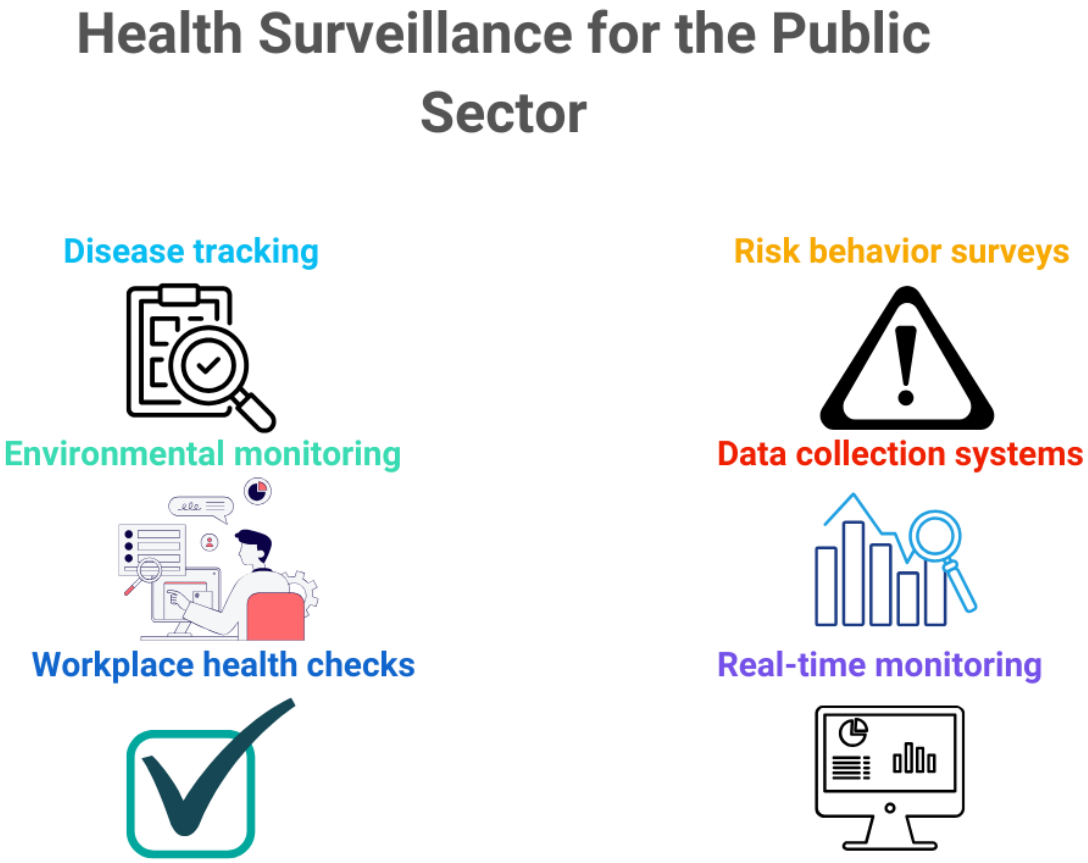

Figure: 2 showing health surveillance for public sector

Disease monitoring consists of continuous observation of particular health conditions and diseases as they develop over time. Real-time monitoring is available for urgent situations though some disease surveillance needs periodic checks established by the nature of the observed disease. The surveillance systems concentrate on infectious diseases throughout their operations to track infections like tuberculosis and influenza alongside non-communicable diseases (NCDs) including diabetes cancer as well as cardiovascular problems [18]. Public health surveillance employs different frameworks that direct process activities from data acquisition through information analysis into appropriate action responses. The public health surveillance system defined by Centers for Disease Control and

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Prevention (CDC) utilizes these sequential steps for its operations [19].

Collecting relevant data from healthcare facilities, laboratories, and public health reports. The analysis of gathered data allows personnel to find patterns alongside trends and statistical abnormalities we will need to confront suspected public health hazards. The evaluation phase interprets collected data for public health meaning and purpose. The distribution of surveillance data goes to stakeholders who include health professionals and policymakers together with the public [20].

The World Health Organization introduced the Global Health Surveillance Framework that promotes international cooperative efforts through unified surveillance network systems between countries. It focuses on enhancing national health systems to share data in a timely manner while building capabilities of healthcare infrastructure to discover and manage health threats [21].

The collecting of data through direct administration by health officials occurs through their contact with healthcare providers and laboratories. Public health authorities receive and record data that reports to them through passive means with limited intervention required. Health conditions data is collected through the structured system of Sentinel Surveillance which runs through designated healthcare providers and institutions. Public health surveillance operates as an essential public health practice which enables monitoring and reaction to health emergencies. The system depends on established mechanisms to acquire and analyze information before sharing findings with specific needs in disease control and health improvement efforts in place [22].

TECHNOLOGIES POWERING PUBLIC HEALTH SURVEILLANCE

Technologies have transformed the entire process of public health surveillance by changing how health data gets collected and analyzed along with its use for public health planning. Public health systems of today use multiple technological platforms to enhance precision in data reporting which leads to elevated operational speed as well as swift responses to developing health risks. The technology spectrum includes EHRs as well as advanced AI systems and mobile health applications and GIS systems [23]. Through collaboration these technological systems have strengthened worldwide capabilities to detect illnesses and execute monitoring programs and responses.

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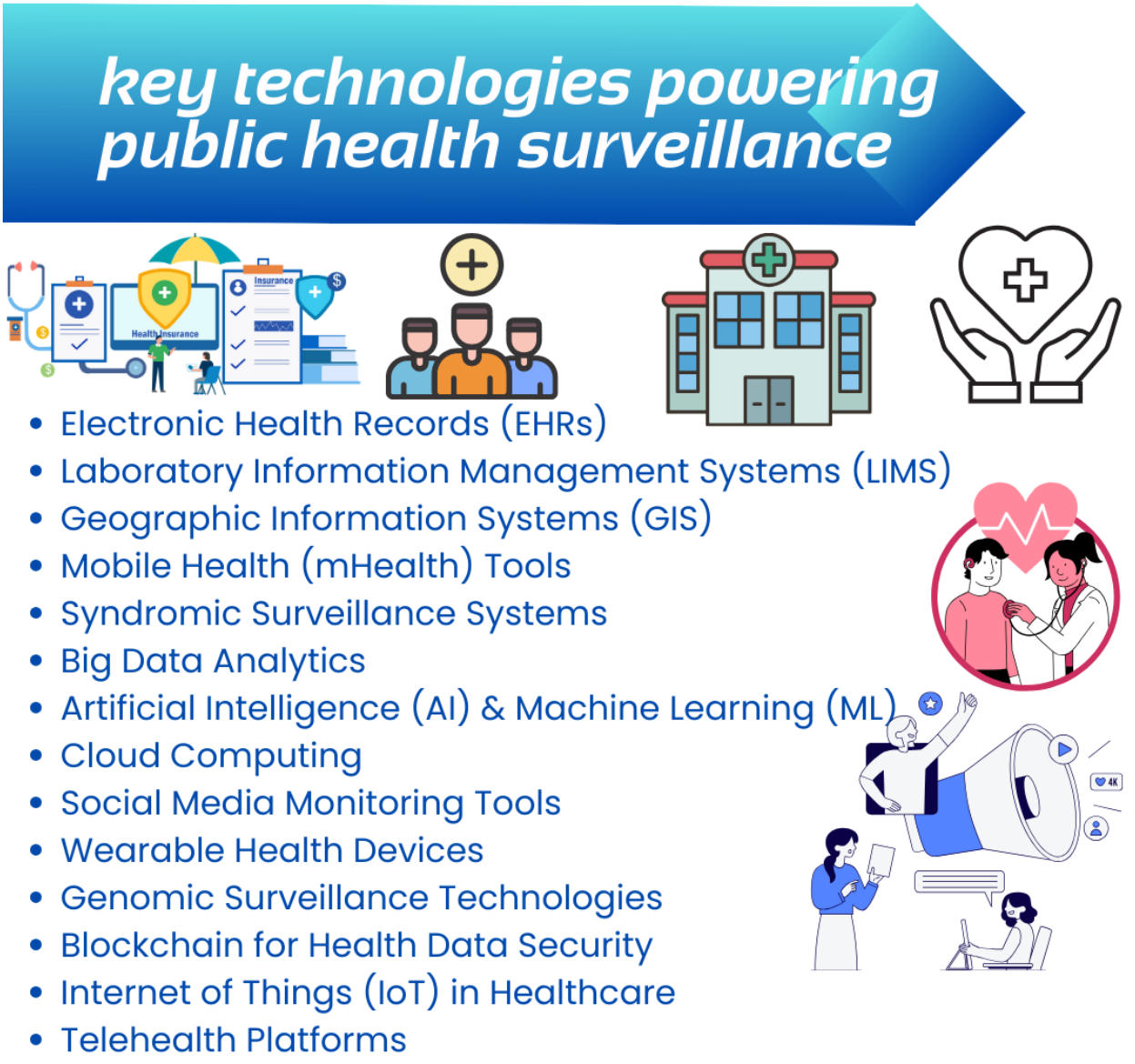

Figure: 3 showing key technologies powering public health surveillance

Electronic Health Records (EHRs) represent a leading and vital technology being used for modern public health surveillance operations. EHRs represent digital versions of patients' paper documentation which includes full healthcare information such as medical records with diagnosis histories together with prescriptions and treatment protocols and test results. Healthcare providers use EHRs to send and receive information instantly with public health agencies which shortens the time needed to identify diseases and outbreaks [24]. These data collection systems allow healthcare providers to combine patient information across various levels that enables them to detect patterns needed for identifying upcoming public health dangers. EHRs enable the assessment of disease patterns while they help healthcare providers monitor ongoing medical conditions and facilitate on-time delivery of medical interventions [25].

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The second component in healthcare data sharing is health information exchange (HIE) platforms that permit providers to exchange patient information between various healthcare systems and institutions. HIEs create more effective public health surveillance through their ability to permit authorities access to all patient records accumulated across multiple data systems [26]. Public health authorities need the ability of diverse health systems to interact mutually because this interoperability enables surveillance data to be processed more quickly and accurately. Mobile health (mHealth) technologies have delivered essential surveillance tools to public health practitioners primarily in resource-constrained environments. These technologies give individuals the power to track their health status and symptoms while submitting their data to both medical staff and authorities [27]. The collection capacity of these technologies enables the receipt of live information about disease occurrences alongside observations of health practices and environmental settings for improved public health threat management.

Mobile applications function as widely accepted systems to monitor the transmission of influenza alongside COVID-19. The combination of symptom checkers and contact tracing and location tracking features in mHealth technology enables public healthcare teams to identify possible health outbreaks more rapidly and administer improved interventions. Such systems enable local community members to submit healthcare reports in regions without enough healthcare infrastructure [28]. The public health surveillance receives important support from Geographic Information Systems (GIS). GIS allows public health professionals to conduct spatial health data assessments and create visual pictures that present statistical indicators and disease outbreak distributions alongside environmental influences [29].

The application of disease data over environmental and demographic information using GIS generates patterns about disease transmission and environmental risks along with healthcare service availability. A large number of infectious diseases including cholera, malaria and the recent COVID-19 have used GIS mapping to identify geographic patterns which allow public health officials to create better resource allocation and intervention strategies [30].

Public health surveillance now heavily depends on advanced artificial intelligence (AI) and machine learning (ML) algorithms for their progressively important functions. The capabilities of these technologies enable them to process extensive health information while revealing unnoticed relationships which lead to foresighted public health choices [31]. AI operates through disease outbreak prediction by analyzing both health data and social media data and weather data and other similar patterns in information. Through the application of machine learning algorithms health diagnostics can become more precise which helps medical staff find diseases such as cancer or

tuberculosis at an earlier stage when studying medical pictures and test outcomes [32].

Data analytics tools merge and examine information from various sources to establish complete surveillance programs. Health authorities can detect upcoming health risks through data analytics' trending ability across health metrics which helps them make early prevention steps to control outbreak growth. Public health surveillance benefits from wearable health technologies which include fitness trackers along with smart watches and biosensors [33]. These medical devices generate uninterrupted health information which incorporates measurements from heart rate metrics together with physical movement assessments as well as records of sleep behavior and disease-warning signs. Wearable devices implemented within health system frameworks enable live wellness observation along with early disease diagnosis within collective populations which provides critical health information about population health conditions [34].

Health surveillance technologies have brought about remarkable advances in the method by which health threats get identified and tracked through real-time monitoring and response initiatives. Health information systems along with mobile apps and geographic information systems together with Artificial intelligence help public health organizations gather data quickly while providing precise analysis capabilities for faster reactions to developing health crises [35]. The continuous development of technology promises better performance of public health surveillance and better worldwide health outcomes.

HEALTH INFORMATICS IN DISEASE OUTBREAK DETECTION AND RESPONSE

The field of health informatics stands essential for both speedily identifying new diseases outbreaks and executing proper responses to infectious threats. Current globalization requires fast disease outbreak identification and surveillance systems to minimize the impact on public health. Public health authorities use health informatics methods based on advanced technology and analytical systems to detect new outbreaks while tracking their spread effectively and deploy suitable responses with higher speed and efficiency [36].

Disease-related information gets tracked through several sources by health informatics tools including electronic health records (EHRs) and health information exchanges (HIEs) and syndromic surveillance systems. Healthcare technologies provide the ability to detect illness patterns which can recognize nascent outbreak developments [37]. Health surveillance systems can detect sudden symptom increases particularly fever and cough throughout multiple healthcare facilities which signals the possibility of new infectious disease emergence. Health informatics technology proved its strength for identifying infectious diseases and guiding their responses during the COVID-19 pandemic crisis [38]. The combination of real-time data analytics alongside mobile health apps

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enabled monitoring of virus spread and symptom tracking as well as contact tracing activities. GIS technology became essential for COVID-19 spread visualization which allowed health departments to manage their resources and coordinate intervention strategies [39].

The outbreak response capabilities receive major improvements from modern technologies which feature artificial intelligence (AI) and machine learning (ML). Technology platforms based on artificial intelligence and machine learning systems evaluate extensive health records about disease spread using historic pattern data, population statistics, and movement patterns [40]. Public health authorities benefit from predictive models which enable them to preventively decide about travel bans and vaccine delivery and direct preventive measures toward susceptible regions. The fast identification and proper controlling of disease outbreaks depend on health informatics as a crucial system. Through digital tools and data analytics the public health sector receives more efficient and timely intervention strategies which successfully decrease disease transmission while delivering improved health results [41].

DATA INTEGRATION AND INTEROPERABILITY IN PUBLIC HEALTH SURVEILLANCE

Doctors can successfully monitor health conditions through public health surveillance because data integration works to make different systems interoperable. A wide dispersion of public health data exists between multiple platforms that combine facilities such as hospitals and laboratories with departments at the local and national health level [42]. When a seamless integration between healthcare data is not achievable it creates problems for prompt surveillance resources and weakens the overall surveillance quality. Health informatics serves as a fundamental solution to resolve these data problems by promoting efficient data monitoring operations which drive disease tracking responses and improvement of decision processes [43].

Integration of data binds information collected from multiple sources into one complete consolidated database. Public health surveillance requires combining information that emerges from different health systems including electronic health records (EHRs), laboratory databases, and demographic records of government agencies and environmental health records. Such data fusion enables a better understanding of public health patterns to support precise tracking of diseases along with health risk elements and social health influencers [44].

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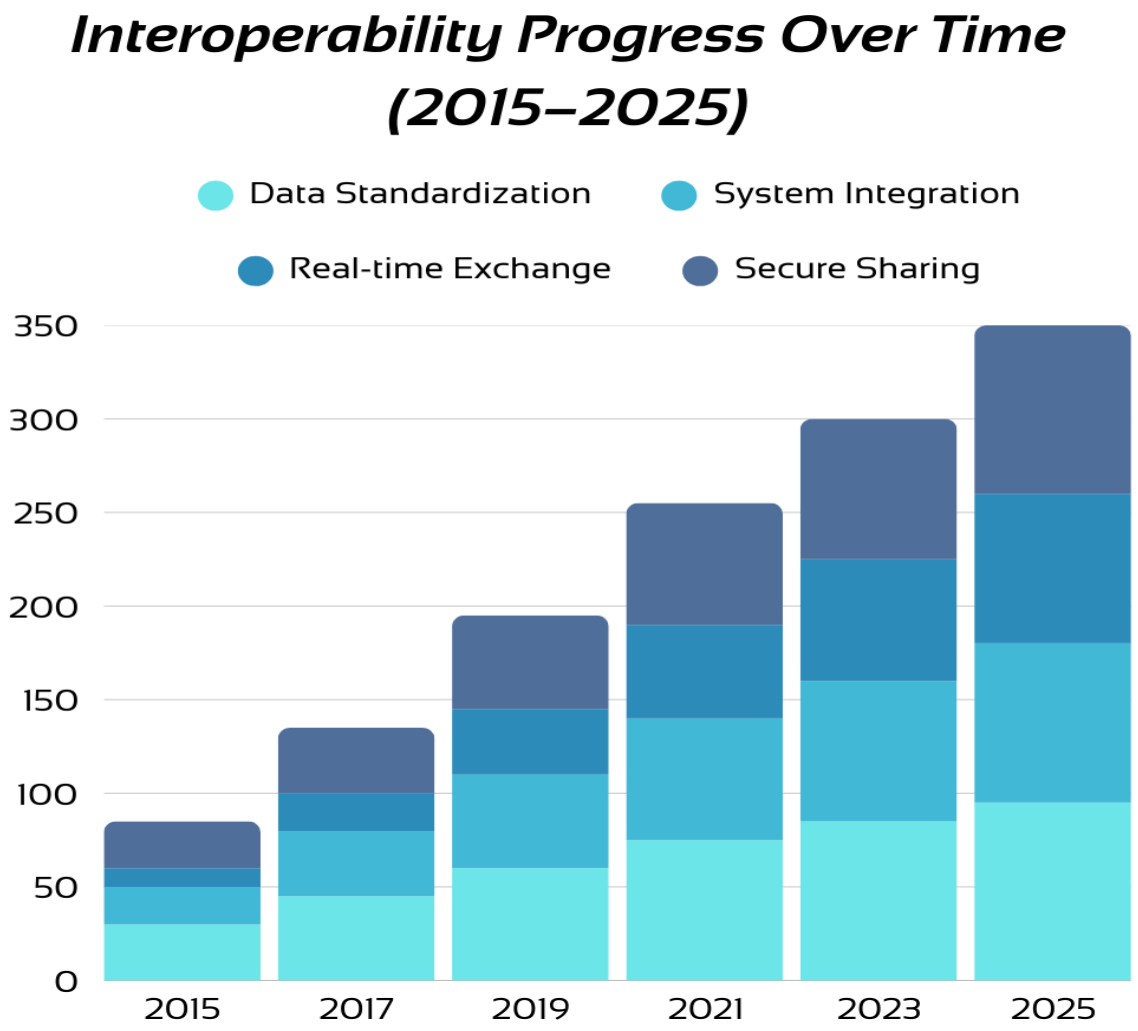

Figure: 4 showing interoperability progress over time

Health providers can detect infectious disease outbreaks quickly by combining information from both medical facilities and testing laboratories. Environmental data integration with health information allows researchers to predict possible effects which weather conditions and air pollution have on the health status of communities. Public health authorities gain broader perspectives of public health challenges because these integrations help them evaluate several potential disease-causing factors [45]. Different health systems together with data sources can exchange information using common security protocols to interact and share data through standard processes. The implementation of interoperability within public health surveillance systems allows different regional areas and healthcare services and countries to efficiently share and unitize their data. The ability to achieve accurate simultaneous data access from multiple sources at proper times remains essential for handling public health epidemics which need comprehensive border-spanning data analysis [46].

Health systems need to follow standard exchange formats and communication rules to reach

interoperability. The exchange and sharing of healthcare data become effortless between systems through the standardized frameworks of HL7, FHIR and ICD due to their consistent data structure. The exchange of health data requires protected protocols since patient confidentiality demands safeguarding sensitive medical data specifically during infectious disease outbursts [47]. Efficient public health surveillance data integration and interoperability remain challenging to accomplish even with the confirmed advantages. Multiple data systems used in healthcare create a significant barrier to information sharing between them [48]. Health systems adopt multiple data formats and individual software platforms which hinders the smooth process of information amalgamation between platforms. Security concerns about personal data privacy along with data protection issues make many organizations reluctant to exchange particularly sensitive healthcare-related information [49].

Technical barriers in regions with limited resources limit the implementation of contemporary health informatics systems which would assist with combining information between different healthcare platforms. A shortage of technological infrastructure together with limited digital skills creates obstacles for achieving successful implementation of surveillance systems in these regions. The world as a whole actively works on solving these issues [50]. The healthcare sector maintains its momentum toward establishing Health Information Exchanges (HIEs) for safe data sharing between healthcare networks. International organizations along with governments work to create standards which ensure borderless data exchange between various types of health systems [51].

The advancement of cloud-based systems along with block chain technology and analytics tools will enhance data integration and interoperability in the future. The described technologies serve to develop adaptable database platforms which ensure security and scalability while enabling immediate data transmission for better identification of worldwide health patterns [52]. Public health surveillance benefits strongly from achieving data integration together with interoperability. Health informatics delivers complete population health information in real time for various healthcare systems when it combines different data sources while achieving data sharing compatibility [53]. Addressing integration issues coupled with interoperability barriers will increase overall public health readiness because it allows interventions to respond quickly to emerging health dangers.

CONCLUSION

Public health surveillance and response systems have experienced a major transformation since health informatics was integrated into their data collection and analysis and response procedures. Digital technologies together with data systems enable public health professionals to gain enhanced population health surveillance capabilities for early disease outbreak detection while allowing them to implement prompt health interventions. Public health decision-making becomes stronger when

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health authorities obtain simultaneously updated and complete health data which results in improved response efficiency.

Health informatics includes several types of tools and practices which include electronic health records (EHRs), mobile health (mHealth) applications and geographic information systems (GIS) along with artificial intelligence (AI)-driven analytics. These technological solutions work collectively to assist disease follow-up and hazard analysis as well as predict epidemics and develop government policies. Their integration provided critical support during critical public health events especially during the COVID-19 pandemic because data-based management strategies proved essential for crisis management.

Public health surveillance operates through informatics systems which depend upon the successful integration and coordinated work of different data sources. The integration of multiple data sources linked through efficient platform communication systems generates an extensive understanding of public health matters. The implementation of health information exchanges with interoperability standards enables secure data sharing processes between local and international communities at various operation levels.

The upcoming technological improvements encounter several ongoing difficulties consisting of data fragmentation issues in addition to privacy-related matters and technology discrepancies and system standardization requirements. The solution to these problems needs ongoing spending for health IT infrastructure and enhanced international governance together with enhanced international collaboration. Low-resource settings need programs to develop local capacity so their populations may benefit from health informatics technologies. As a crucial foundation in current public health monitoring and response operations health informatics surpasses being a supportive tool. The upcoming era of technological advancement will expand health informatics' utility since it will create better chances for population health enhancement through streamlined public health actions which operate faster with more intelligence.

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