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Electronic health records for population health: a critical review of technological opportunities and public health challenges

Lina Handayani, Dini Astutiningsih
Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

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ABSTRACT

Electronic health records (EHRs) have become an important source of health information beyond their original purpose of supporting individual patient care. Their structured clinical data, longitudinal records, and increasing adoption create opportunities for population health monitoring, epidemiological research, disease surveillance, and the evaluation of public health interventions. This review critically examines the technological opportunities offered by EHRs, focusing on data acquisition, secondary data use, information integration, population-level analysis, and clinical-public health collaboration. It also discusses the limitations associated with data quality, interoperability, population coverage, privacy, and institutional readiness. Particular attention is given to the distinction between data collected for clinical purposes and information required for valid population health assessment. The review argues that the value of EHRs for population health depends not merely on the volume of available records but also on their representativeness, completeness, consistency, and appropriate interpretation. Finally, research directions are identified to support more integrated, reliable, and sustainable use of EHR data in public health practice.

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1. INTRODUCTION

Electronic health records (EHRs) have transformed the way healthcare organizations collect, manage, and use clinical information. They provide digital documentation of patient encounters, diagnoses, medications, laboratory results, procedures, and other healthcare activities. Although EHRs were primarily developed to support clinical decision-making and healthcare delivery, their accumulated information also offers opportunities to understand health conditions across populations.

Population health requires information that extends beyond individual clinical encounters. Public health professionals need to identify disease patterns, monitor risk factors, assess health inequalities, and evaluate the effectiveness of preventive interventions. EHRs can contribute to these activities by providing longitudinal clinical information from large groups of patients, potentially reducing the time and cost associated with collecting primary health data.

However, the secondary use of EHR data introduces methodological and organizational challenges. Clinical records are generated to support patient care rather than to provide complete and representative population health measurements. Consequently, the availability of large electronic datasets does not automatically guarantee valid population-level conclusions. This review examines the technological opportunities of EHRs for population health and critically discusses the challenges that influence their effective use.

2. EHR SYSTEMS AND THEIR ROLE IN POPULATION HEALTH

An EHR is a digital information system designed to capture, store, retrieve, and manage patient-related health information across healthcare encounters. Its core functions commonly include clinical documentation, medication management, laboratory result reporting, diagnostic coding, and access to patient histories. The adoption of EHR systems has been influenced by efforts to improve healthcare quality, operational efficiency, and information accessibility, as discussed by Jha *et al.* [1] and Blumenthal [2].

The potential contribution of EHRs extends from individual patient management to population-level information analysis. Aggregated clinical records can support the monitoring of disease prevalence, treatment patterns, preventive care, and healthcare utilization among defined patient groups. Friedman *et al.* [3] emphasized that EHRs could contribute to improving population health, but realizing this potential requires a clear understanding of what the data can support and what additional information infrastructure is needed.

EHR-based population health analysis differs from conventional clinical information management in its objectives and analytical requirements. Clinical systems focus on documenting patient conditions and supporting treatment decisions, whereas population health applications seek to identify patterns across groups and geographic areas. This distinction is important because data that are adequate for individual care may be incomplete or unsuitable for epidemiological interpretation.

3. TECHNOLOGICAL OPPORTUNITIES FOR POPULATION HEALTH

EHRs provide several technological opportunities for improving population health assessment and public health practice. Their ability to store longitudinal clinical information allows researchers and health authorities to examine disease patterns, healthcare utilization, and changes in patient conditions over time. These capabilities can complement traditional surveys, disease registries, and routine reporting systems.

One important application is population health surveillance. EHR data can support the identification of disease cases, monitoring of chronic conditions, and detection of unusual patterns in clinical encounters. Klompas *et al.* [4] discussed the potential of EHR systems for public health surveillance, highlighting their capacity to provide detailed and timely information about large patient populations.

EHRs can also support the identification of individuals and communities requiring preventive interventions. Clinical records may contain information about risk factors, screening history, immunization status, and chronic disease management. When appropriately aggregated and analyzed, these data can help healthcare organizations identify gaps in preventive care and evaluate whether interventions reach their intended populations.

Another opportunity is the use of EHR data for epidemiological research and health service evaluation. Researchers can examine associations between clinical conditions, treatments, and health outcomes using routinely collected information. However, these analyses require careful attention to selection bias, missing information, differences in clinical documentation, and the potential influence of healthcare-seeking behavior.

The integration of EHRs with other information systems can further expand their value. Linking clinical records with laboratory databases, disease registries, health insurance information, and geographic data may provide a more comprehensive understanding of population health. Tomines *et al.* [5] emphasized that electronic health information can support surveillance, disease investigation, decision-making, quality assurance, and public health policy, although significant implementation barriers remain.

4. DATA INTEGRATION AND INTEROPERABILITY

Data integration is essential for transforming distributed clinical records into useful population health information. Healthcare organizations frequently operate independent EHR platforms with different data structures, terminologies, and exchange mechanisms. Without effective integration, information remains fragmented and may be difficult to compare across providers or geographic areas.

Interoperability involves the ability of different information systems to exchange and meaningfully interpret data. Syntactic interoperability concerns compatible data formats and message structures, while semantic interoperability concerns the consistent meaning of exchanged clinical information. Standardized terminologies, coding systems, and exchange protocols are therefore important for combining information from multiple sources.

Health information exchange can facilitate the transfer of clinical information among healthcare providers and public health agencies. It may support the enrichment of disease reports with additional patient information and reduce the need for repeated manual data entry. Dixon *et al.* [6] demonstrated that health information exchange could improve the completeness of selected electronic laboratory reporting fields, although data quality varied across source systems.

Nevertheless, technical connectivity does not guarantee meaningful data integration. Differences in clinical workflows, documentation practices, coding conventions, and institutional policies can affect the consistency of shared information. Effective interoperability therefore requires coordinated technical standards, governance arrangements, and organizational collaboration.

5. DATA QUALITY AND POPULATION REPRESENTATIVENESS

Data quality is a fundamental requirement for reliable population health analysis using EHRs. Clinical records may contain missing demographic information, inconsistent diagnostic codes, duplicated entries, delayed documentation, and variations in clinical terminology. These limitations can influence disease estimates, risk assessments, and comparisons between healthcare organizations.

Weiskopf and Weng [7] identified five important dimensions for assessing EHR data quality: completeness, correctness, concordance, plausibility, and currency. These dimensions provide a useful foundation for determining whether clinical data are suitable for secondary analysis. Weiskopf *et al.* [8] further demonstrated that the definition and measurement of completeness can influence findings derived from EHR datasets.

Population representativeness presents a separate but closely related challenge. EHR data generally describe individuals who receive care from participating healthcare providers rather than the entire population within a geographic area. People with limited healthcare access, infrequent clinical visits, or reliance on nonparticipating facilities may be underrepresented, potentially producing biased population health estimates.

The distinction between clinical data completeness and population coverage must therefore be carefully maintained. A record may contain complete information about a patient encounter while the dataset still excludes substantial segments of the population. Reliable population health research requires an understanding of both the quality of individual records and the characteristics of the population represented by the available data.

6. PRIVACY, SECURITY, AND ETHICAL CONSIDERATIONS

The secondary use of EHR data raises important privacy, security, and ethical concerns. Clinical records contain sensitive information that may reveal diagnoses, treatments, personal characteristics, and other aspects of an individual's life. Integrating these records for population health purposes therefore requires safeguards that protect confidentiality while allowing legitimate public health activities.

Access control, authentication, encryption, audit mechanisms, and appropriate data governance are essential components of secure EHR environments. Fernández-Alemán *et al.* [9] reviewed security and privacy issues in EHR systems and discussed the use of technical and regulatory mechanisms to protect electronic health information. These measures must be accompanied by clear institutional policies defining who can access information and for what purposes.

Privacy protection should also be balanced against the public health value of data sharing. Excessively restrictive access arrangements may limit the availability of information needed for disease surveillance and population health research. Conversely, insufficient controls may undermine public trust and expose individuals to inappropriate disclosure or misuse of sensitive information [10].

7. IMPLEMENTATION AND ORGANIZATIONAL CHALLENGES

The effective use of EHRs for population health requires more than the acquisition of software and computing infrastructure. Healthcare organizations and public health agencies must establish workflows, technical capabilities, trained personnel, and governance arrangements that support secondary data use. Differences in financial resources and institutional readiness can create substantial disparities in implementation capacity.

The adoption of EHRs has also demonstrated that technological implementation does not automatically produce improvements in healthcare quality or operational performance. Jha *et al.* [1] documented variation in EHR adoption among hospitals, while Blumenthal [2] discussed policy initiatives intended to accelerate the transition toward electronic health information systems. These experiences indicate that implementation success depends on organizational change, incentives, workforce preparation, and sustained investment.

Public health agencies may face particular difficulties because their information infrastructure and workforce resources are often different from those of healthcare providers. Tomines *et al.* [5] highlighted the limited funding and capacity available to public health organizations for exploiting electronic health information. Sustainable collaboration between healthcare providers, public health authorities, and technology developers is therefore necessary to ensure that EHR-based population health applications remain operational and useful.

8. COMPARATIVE ANALYSIS AND RESEARCH DIRECTIONS

EHRs offer several advantages for population health, but their capabilities should be assessed in relation to conventional information sources and their inherent limitations. Traditional surveys can collect information from individuals who may not frequently use healthcare services, whereas EHRs provide detailed clinical information from people receiving care. Disease registries offer condition-specific information, while integrated EHR networks may support broader analysis across multiple clinical domains.

Table 1 summarizes the principal opportunities and limitations of EHR-based population health applications. The comparison indicates that EHRs are particularly valuable for longitudinal clinical monitoring and the analysis of healthcare utilization. However, their usefulness for population-level inference depends on data quality, coverage, and integration with complementary information sources.

Table 1. Opportunities and challenges of EHRs for population health

Application	Technological opportunity	Main challenge
Disease surveillance	Timely identification and monitoring of clinical conditions	Incomplete reporting and inconsistent diagnosis coding
Chronic disease monitoring	Longitudinal assessment of treatment and health indicators	Missing follow-up information and fragmented records
Preventive care assessment	Identification of screening and immunization gaps	Incomplete documentation of services received elsewhere
Epidemiological research	Analysis of large-scale clinical datasets	Selection bias and confounding factors
Health service evaluation	Monitoring healthcare utilization and outcomes	Differences in institutional workflows and data definitions
Population risk assessment	Identification of clinical risk patterns	Limited coverage of social and environmental determinants

Future research should prioritize interoperable EHR architectures that support consistent data exchange across healthcare organizations and public health agencies. Data quality assessment should be incorporated into the entire data lifecycle, including collection, validation, integration, and analysis. Researchers should also develop methods to evaluate population coverage and address selection bias when using clinical records for epidemiological studies.

Another important direction is the integration of clinical information with nonclinical determinants of health. EHRs alone may not adequately capture socioeconomic conditions, environmental exposures, health behaviors, and barriers to healthcare access. Combining clinical data with population surveys, geographic information, and other administrative sources may provide a more comprehensive foundation for population health assessment.

9. CONCLUSION

EHRs offer important opportunities to strengthen population health research and public health practice. Their longitudinal clinical information can support disease surveillance, chronic disease monitoring, preventive care assessment, epidemiological research, and health service evaluation. However, the value of these applications depends on effective data integration, reliable data quality, adequate population coverage, and appropriate privacy protection. The review demonstrates that EHRs should not be treated as automatically representative sources of population health information. Their clinical origins, institutional coverage, and documentation practices must be considered when interpreting aggregated data and drawing public health conclusions. Future development should emphasize interoperability, data quality governance, integration with complementary population data, and sustainable collaboration between healthcare and public health organizations.

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