APPLIED PUBLIC HEALTH INFORMATICS: AN EHEALTH DISCIPLINE FOCUSED ON POPULATIONS

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Abstract

The discipline of public health informatics, part of the broader eHealth field, brings methods, knowledge, and theories from computer science and information science to support population health and well-being. This branch of informatics is most often found in governmental public health agencies that focus on population-level activities, including surveillance of disease as well as disease prevention. There are several specialised public health information systems used to prevent or mitigate disease, including syndromic surveillance, electronic laboratory reporting, and population health dashboards. This article defines and describes public health informatics and its role in eHealth. The article further discusses the role of public health information systems and challenges they face for the future. Strengthening public health will require greater investment in interoperability as well as analytics and the workforce. Disease outbreaks like COVID-19, Ebola, and H1N1 demonstrate the need for robust public health informatics applications and methods. Yet there is much work to be done to evolve existing tools and methods to strengthen the public health infrastructure for the next pandemic.

Keywords: public health informatics; public health; registries; data visualization; workforce; information systems

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Introduction

Public health informatics is an applied discipline that brings methods, knowledge, and theories from both computer science and information science to support population health and well-being.[1] Whereas eHealth facilitates the delivery of health care via information and communications technologies,[2] public health informatics supports prevention of disease as well as maintenance of well-being among populations using a variety of information and communications technologies. The two fields complement one another, and they often intersect and overlap, especially in nations where both functions are facilitated by the Ministry of Health.

This publication represents lecture notes from a series of seminars delivered as part of DigiHealth Day – 2020 at the Deggendorf Institute of Technology European Campus Rottal Inn Campus. The notes are designed to help the reader understand the scope of the applied field of public health informatics and how the field contributes to the broader field of eHealth. First, the article reviews key terms and definitions. Then it explores key information systems used in public health practice. Finally, the article considers where the field is heading in the future.

Public Health

Public health is "the science and art of preventing disease, prolonging life and promoting health through the organised efforts of society, organisations, public and private communities, and individuals."[3] Public health focuses on the health and well-being of populations—collections of individuals who reside in communities. Multiple disciplines exist within the field of public health, including epidemiology, biostatistics, social and behavioural science, health policy and management, global health, and environmental health science.

Governmental public health organisations exist at federal, state, and local levels. Whereas federal agencies often coordinate responses to disease outbreaks like the COVID-19 pandemic, state and local agencies are often on the front lines of addressing everyday health challenges such as diabetes, obesity, influenza, and dementia. Public health agencies typically focus on 10 essential services to support the health and well-being of populations in their jurisdiction.

The 10 essential services of public health[4] include:

1. Monitor health status to identify and solve community health problems
2. Diagnose and investigate health problems and health hazards in the community

3. Inform, educate, and empower people about health issues
4. Mobilise community partnerships and action to identify and solve health problems
5. Develop policies and plans that support individual and community health efforts
6. Enforce laws and regulations that protect health and ensure safety
7. Link people to needed personal health services and assure the provision of health care when otherwise unavailable
8. Assure competent public and personal health care workforce
9. Evaluate effectiveness, accessibility, and quality of personal and population-based health services
10. Research for new insights and innovative solutions to health problems

Public Health Informatics

Public health informatics as a field aims to support the business of public health, which is to improve the health and well-being of populations. Information and communications technologies (ICT) can be deployed to collect, store, manage, analyse, use, and exchange data and information by public health organisations.[1] Ideally the data and information managed and used by public health organisations can be used to establish policy or implement programs that improve population health outcomes.

The work that occurs in public health informatics has many natural relationships with the work performed by health systems as well as that of eHealth. The intersection of public health informatics with eHealth and health systems is depicted in Figure 1. A primary area of overlap is immunizations. Health systems desire for populations to be immunized to prevent disease spread. Public health informaticians developed and work to expand the capabilities of immunization information systems to track the delivery of vaccines. eHealth systems include those used in clinics and hospitals that record the delivery of immunizations or order vaccinations from pharmacy systems. Decision support systems apply equally to public health informatics and eHealth systems, which guide decisions made by clinicians or epidemiologists who seek to measure the proportion of the population vaccinated against a disease like polio, rubella, or influenza.

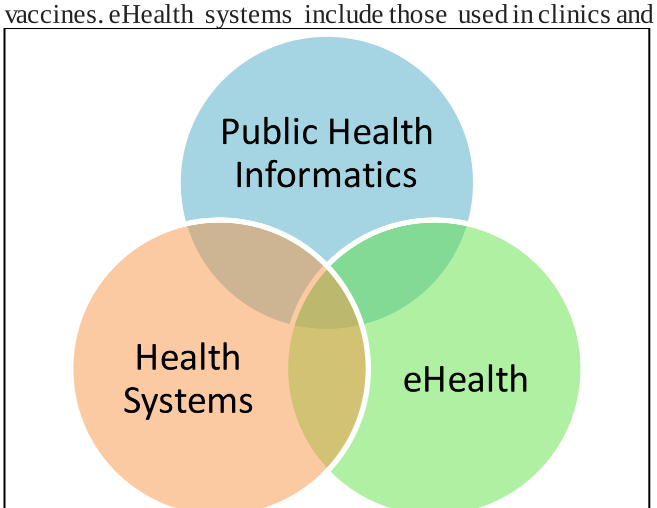

Figure 1. Venn diagram depicting the overlap between public health informatics, health systems, and eHealth.

Competencies and Training in Public Health Informatics

The Applied Public Health Informatics Competency Model, developed by the Public Health Informatics Institute (PHII) in Atlanta, Georgia, is a framework for the knowledge and skills needed for discipline. The framework includes broad categories of informatics principles and strategic thinking; informatics standards and interoperability; project management; knowledge of infrastructure, including hardware, software, and networks; effective communication; evaluation of workflows and technology; data analysis, visualisation, and reporting; and policy and regulations. Combined with core competencies in public health, including epidemiology, biostatistics and social determinants, public health informaticians contribute both to data management, information systems operations, and leveraging information systems to support the core functions in public health organisations.

Informatics is recognised as a core competency for MPH students as defined by the Council on Education in Public Health.[5] More recently, the Council for State and Territorial Epidemiologists (CSTE) identified informatics as a top training priority to support achievement of public health department capacity needs.[6]

There exist a variety of training options in public health informatics. A recent analysis by Joshi[7] revealed there are now more than a dozen graduate level programs in PHI. In addition to graduate programs, PHI courses are now regularly taught to public health students at undergraduate and graduate levels in schools of public health.[8]

Information Systems Used in Public Health

There are dozens of information systems used in public health. Public health clinics, sometimes referred to as "free" clinics, use electronic health record (EHR) and other forms of eHealth systems. Yet there are many different specialised systems used mainly by public health for collecting, storing, managing, analysing, and sharing data relevant for populations. These systems include, but are not limited to, the following:

- Specialised disease registries;
- Electronic laboratory reporting (ELR) systems;
- Syndromic surveillance systems;
- Immunization information systems (IIS); and
- Population health dashboards.

Specialised Disease Registries

Public health organisations routinely capture information on specific, high-priority populations. For example, most public health agencies collect data on genetic disorders diagnosed through newborn baby screening processes (e.g., heel stick blood draw). Staff at the hospital collect the sample from the newborn baby, and the blood is analysed by a laboratory. Results are reported back to the hospital EHR system, and often simultaneously reported to a public health agency. The data are maintained to allow public health to monitor rates of genetic disorders in the population, such as the percentage of babies born with sickle cell disease, a set of inherited red blood cell disorders. Public health organisations collectively refer to these datasets as registries, such as the 'newborn registry'. A registry is formally defined as an organised system that uses observational study methods to collect uniform data to evaluate specified outcomes for a population defined by a particular disease, condition, or exposure, and that serves one or more predetermined scientific, clinical, or policy purposes.[9]

Another example of a public health registry is a comprehensive registry for sexually transmitted infections (STIs).[10] Public health agencies typically receive information from providers and laboratories when an individual tests positive for an STI (e.g., chlamydia, syphilis, HIV). Using an STI registry developed by the Regenstrief Institute, researchers found that STI clinics were more likely to test men and outpatient practices more likely to test women.[11] Yet they also discovered that emergency departments increasingly test a larger proportion of the population and document greater morbidity. This suggested that public health agencies might wish to partner with emergency settings to address rising rates of STIs in the community. Researchers further leveraged the STI registry to examine the validity of using ICD-10 codes to document STI cases[12] and syphilis testing rates among women with a stillbirth delivery.[13]

Electronic Laboratory Reporting (ELR)

Every nation contains laws that require health care providers and/or laboratories to report new cases of diseases such as tuberculosis, malaria, chlamydia, and HIV, to public health. These diseases are collectively referred to as notifiable or communicable diseases, because they are spread rapidly from person to person. While the specific diseases to be reported vary by nation, most necessitate reporting by a laboratory and/or physician who ordered the laboratory test for the disease. Public health agencies use these data to monitor the prevalence of disease as well as reduce the potential for disease spread through investigation and follow up with the individuals who are diagnosed.[14]

The process of reporting data on notifiable diseases from laboratories to public health agencies is referred to as electronic laboratory reporting (ELR). The process of ELR is an excellent example of health information exchange (HIE), an eHealth technique in which syntactic and semantic standards are used to facilitate interoperability between two information systems.[15] In this case, it is the laboratory information system exchanging data with a public health information system referred to as a case management system. The case management system stores data on patients diagnosed with a communicable disease. Public health workers can then add additional details to each case in the system, such as the person's health history as well as potential methods by which they came to be infected.

Syndromic Surveillance Systems

Syndromic surveillance examines electronic pre-diagnostic and diagnostic health-related data to detect, characterise, and monitor events of potential public health importance.[16] A common data source for syndromic surveillance is the emergency department (ED), and primary data elements of interest include chief complaint (brief reason for visiting the emergency department, ideally in the patient's own words) and diagnosis codes (e.g., ICD-10-CM, SNOMED-CT®). These data elements are used to group ED visits into syndromes for a given time period (e.g., daily, weekly) to detect statistically significant clusters in a given geographic area within a given time frame, or to monitor trends.

The term 'syndrome' implies the use of signs and symptoms to identify disease and other events of public health significance. However, as diagnostic coding practices improve and interoperability improves, it is becoming increasingly possible to use greater detail provided by ICD-10-CM codes entered into EHR systems.

The National Syndromic Surveillance Program (NSSP) promotes and advances development of a national strategy for the timely exchange, analysis and visualisation of syndromic data.[17] Syndromic data are used to improve nationwide situational awareness and enhance responsiveness to hazardous events and disease outbreaks. NSSP functions through collaboration with local, state, and federal public health agencies; federal agencies including the U.S. Department of Defense and the U.S. Department of Veterans Affairs; public health partner organisations; and hospitals and health professionals.

Although originally focused on detection of bioterrorism events, i.e., those in which a terrorist unleashes a biological weapon onto a civilian population, syndromic surveillance is not used broadly by local and state health departments. For example, these systems are used to detect cold weather events like carbon monoxide poisonings,[18] influenza,[19,20] and heat related illnesses like heat exhaustion.[21,22] Today syndromic surveillance systems play a key role in monitoring many syndromes, including emerging diseases. In 2020, syndromic surveillance systems were adapted to monitor for the emerging SARS-CoV-2 virus, otherwise known as coronavirus disease 2019 (COVID-19). The NSSP developed an initial COVID-like illness syndrome, which has been implemented in jurisdictions across the U.S.

Immunization Information Systems (IIS)

An immunization information system (IIS), also referred to as an electronic immunization registry (EIR), is an information system that facilitates the monitoring of individual immunization schedules and the storage of individual vaccination histories, and, consequently, helps enhance the performance of immunization programs, in terms of both coverage and efficiency.[23,24] These systems are also sometimes referred to as vaccine registries. The systems capture details on individuals, and then collectively these records are analysed at the population level. Public health agencies use them to examine, for instance, the proportion of children in a city vaccinated against a given disease. These systems can also check the immunization status for an individual child, providing clinical decision support for a clinic that delivers care to the child.

Immunization information systems are deployed across much of the United States[25] as well as most countries around the world. Even developing nations, such as Tanzania and Zambia, have implemented IIS infrastructures that enable analysis of vaccination coverage as well as inventory management of immunizations.[24] A project in Indiana, USA leveraged the state public health agency's IIS to facilitate a clinical decision support project aimed at improving vaccination rates among adolescents against the human papillomavirus.[26-29]

Population Health Dashboards

Visual analytics is a branch of informatics and data science that illustrates data in a meaningful way which connects with the user. Many hospitals and health systems deploy dashboards to convey timely data and information on operations to clinical leaders as well as administrators. Historically public health agencies have not employed dashboards to monitor population data. However, that is rapidly changing.

The COVID-19 pandemic now has public health organisations awash in visual analytics. One of the most famous dashboards to emerge from the current global pandemic is the COVID-19 Dashboard by the Center for Systems Science and Engineering at Johns Hopkins University.[30] The dashboard is a website that routinely updates with new data and information collated from many data sources across the globe. The tool presents information useful to individuals tracking where the disease is currently and where it might be headed next. The dashboard further tracks mortality from COVID-19 and estimates the proportion of individuals who have recovered from the virus.

Many public health agencies now have their own dashboard for COVID-19. Each agency publicly posts information about new cases in its jurisdiction along with mortality data and trends. The dashboards are sought out by news media as well as the public to learn about what is happening in their community or nation. The pandemic highlighted the need for such rapid deployment of information tools in the wake of an epidemic; something public health has not always been able to do in the past. Fortunately, with the advent of eHealth, public health agencies can quickly amass the data needed to populate a dashboard.

An example is the dashboard hosted by the Regenstrief Institute, in coordination with the Indiana State Department of Health, which depicts hospitalisation data along with comorbidities and lengths of stay for individuals impacted by COVID-19.[31] A screenshot of the dashboard is presented in Figure 2. At a glance, visitors to the website can quickly ascertain the rate of hospitalisations among those infected with the SARS-CoV-2 virus. Furthermore, users can determine the rate of recovery from COVID-19, which is approximately 80%. Inpatient mortality is displayed,

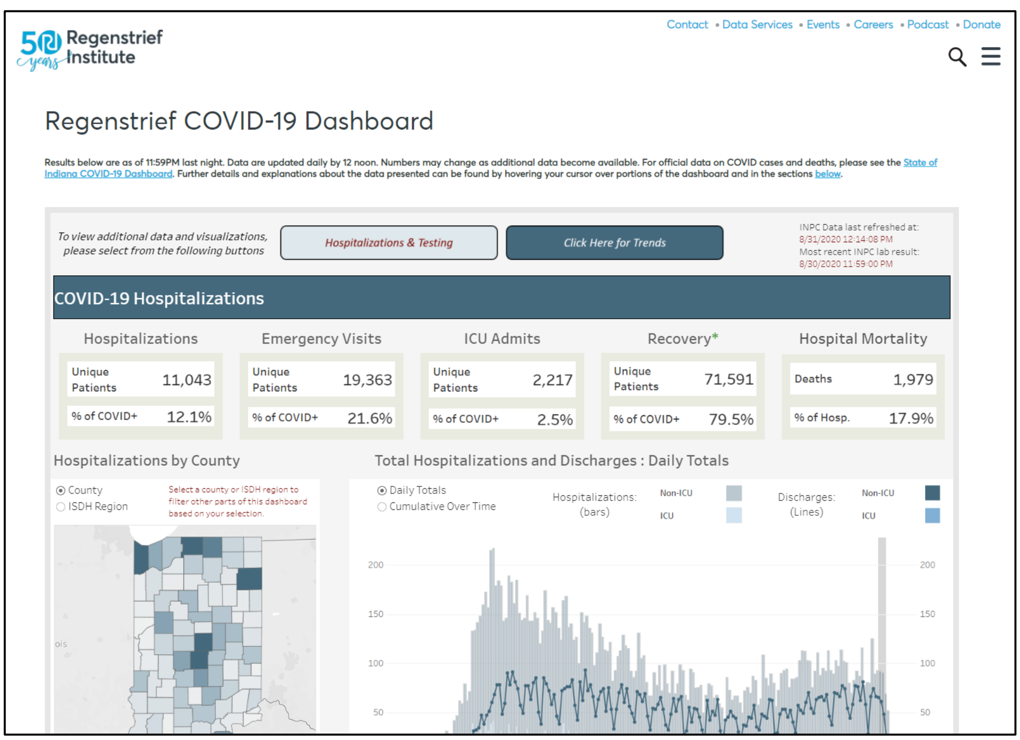

Figure 2 – Screenshot of the Regenstrief Institute dashboard for COVID-19.

suggesting that approximate 1-in-6 individuals hospitalised from COVID-19 does not survive. Although the dashboard appears very much in sync with health care delivery and therefore illustrates eHealth, the purpose and use of the dashboard is to address a population health crisis by a collaborative team of organisations that span health care delivery and public health. More dashboards like this one are needed to not only bring together clinical and public health organisations but also to inform the public about pressing population health crises.

New Directions for Public Health Informatics

Despite many advances since the turn of this century, public health informatics continues to evolve for the future. There are a number of challenges to address and innovations needed to meet the needs of public health in 2020 and beyond.[32] This section of the paper outlines the challenges and innovations for informatics and eHealth researchers to address going forward.

The Public Health 3.0 Framework

In the recent past, the U.S. Department of Health and Human Services proposed a new framework for delivering public health in America, dubbed 'Public Health 3.0'.[33] The framework urges evolution of the public health system with respect to its infrastructure[34] and collaborations needed to achieve a vision where health is incorporated into all aspects of society (e.g., health in all policies).[35,36] Achieving the vision set forth for public health will require additional investment in informatics, including technical infrastructure as well as workforce.

Although health care policy in the U.S. and eHealth strategies in other nations have influenced the adoption of EHR systems in medicine,[37] many public health agencies continue to rely on outdated technology and lack connectivity to providers. For example, local public health departments often utilise fax (facsimile) machines to receive reports of notifiable diseases from providers.[38,39] Transitioning to Public Health 3.0 requires investment in cloud-based infrastructures[40,41] as well as new, interoperable interfaces between medicine, public health, and social service agencies.[15,42] When fully connected, public health will have bi-directional capabilities to receive and send information with partners who can ensure equitable health services for all populations. Furthermore, broader connectivity and use of analytics will enable intelligent epidemiology by public health agencies.[43-45]

In addition to its infrastructure, public health needs upgrades to its workforce. In a recent survey of the public health workforce in America, the Association of State and Territorial Health Officers (ASTHO) found that few health departments employ informaticians.[46] Public Health 3.0 demands we train more public health informatics workers to lead the transformation of the public health system.[47,48] Given the rise in public health informatics educational programs, there is hope for the future. Yet agencies will also need to invest in training opportunities for existing public health staff.

Infodemiology and Social Media Tools

Infodemiology involves the use of Internet-based tools, including social media applications and online news sites, to capture data on health-related symptoms, risks and exposures directly from consumers prior to when individuals present for care.[49,50] For example, a recent study explored the use of Web search behaviors to detect potential clusters of COVID-19.[51] While some studies show a correlation between Internet-based searches or social media posts and future rates of disease in a specific geographic location, infodemiology tools have yet to become part of routine public health practice. Correlations are many times weak, and there are few robust predictive models that could be translated into an early warning system for emerging infections. Going forward, eHealth researchers should work to refine the methods and develop models that better predict future disease trends so that these tools can become part of the public health informatics toolbox.

Open Data Movement

Over the past decade, governments around the world have systematically moved towards open data repositories that bring transparency and liberate data to be used by all citizens. In the U.S., the website data.gov was created following the 2009 Memorandum on Transparency and Open Government from President Obama, and many states like New York have launched their own version of an online repository of datasets created by public agencies.[52] These sites provide citizens as well as researchers access to timely data on individuals who receive public health insurance, trends in disease rates, and the performance of hospitals with respect to standardised quality metrics.

Although datasets are increasingly available, many are not readily usable for analysis. Some of them are simply PDF reports involving scanned tables or charts, and some of them do not have any metadata that can help analysts interpret their meaning.[53] Going forward, public health informatics should lead the charge in establishing better methods for publishing data in open and transparent ways. For example, informaticians should advocate for the use of application programming interfaces (APIs) that better enable reuse of data as opposed to static documents on a portal.[54] Furthermore, informaticians should help curate better datasets along with metadata that can enable broad reuse of health-related datasets for research as well as development of public health interventions and policies. There is hope given the recent creation of popular COVID-19 datasets like those hosted at Johns Hopkins University and the New York Times. Several APIs for COVID-19 were developed quickly and now provide timely data on trends in disease spread as well as mortality to hundreds of websites, epidemiologists, and researchers. Access to these data no doubt is helping to spur collaboration towards mitigation of disease spread and the development of a vaccine. Imagine what we could do to address diabetes, obesity, and HIV if data on those health conditions were similarly available via APIs at-scale across nations.

CONCLUSIONS

Recent epidemics and pandemics like COVID-19, Ebola, and H1N1 have provided informatics an opportunity to showcase how the methods and applications from the broader eHealth field can be applied to solve challenges in public health. There are numerous information systems in use each day to help public health agencies prevent and mitigate disease spread. Yet there are many challenges that, if addressed, would further strengthen the public health infrastructure and help governments be prepared for the next emerging disease. Research and workforce development in public health informatics are needed to prepare for the future while advancing both science and practice.

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